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Biological agents and work-related diseases: results of a literature review, expert survey and analysis of monitoring systems

European Risk Observatory
Literature Review

European Agency for Safety and Health at Work

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Key messages

Exposure to biological agents such as microorganisms can cause adverse health effects in workers. There is a lack of knowledge and awareness of workplace exposures to biological agents and related health problems. This report presents the findings of a scientific literature review, a survey of occupational safety and health (OSH) experts and an evaluation of selected monitoring systems. The aims were to:

- assess existing information on exposure to biological agents and the related health effects;
- identify databases and datasets that provide systematic information on biological agents and risks to workers;
- identify gaps in data and knowledge.

It includes extensive tables that provide information on the typical exposures in the professions most often studied in the literature; workers in these jobs may be exposed to a wide range of infectious agents, some of which can cause serious or even fatal disease.

Occupations at risk

Overall, information on exposure to biological agents and related diseases is scarce. There was a lack of literature on many occupations and sectors; sometimes, the search strategy retrieved only a single publication. This applies for example to the aquaculture sector, border guards and fertiliser workers. A single publication on a link between a biological agent and a work-related disease could signal a bigger underlying issue or a risk that needs to be addressed.

The relatively sparse evidence base makes it difficult to set general priorities in policies for the prevention of work-related diseases from exposure to biological agents in the workplace, although some exceptions do exist.

Links between exposures and diseases are clear for, for example:

- healthcare workers, who are at risk of blood-borne infections;
- forestry workers, who are at risk of tick-borne diseases;
- sex workers, who are prone to sexually transmissible infections.

More research is needed on typical exposures in some professions. Monitoring and prevention efforts should ensure broad coverage of jobs involving potential exposure to biological agents, especially those that involve contact with people, animals, food or plants.

Exposures are normally to several biological agents with different effects, and to complex mixtures such as organic dust. Monitoring of exposures in professions involving unintentional contact with such agents, and where levels of awareness are low, should be improved.

The identification of allergens linked to biological agents' exposure and their differentiation from chemicals agents is the most challenging issue identified in this review — although it is the most-researched issue — as the exact cause of the allergy at the agent level cannot easily be identified. The sectors and occupations where there is a clear risk include the agricultural and fishery sectors, the food industry, the woodworking and metalworking industries, and waste treatment, composting and waste collection. For many occupations, however, the exact agent or substance causing the allergic reaction is not yet known. Occupational asthma in farmers and farmer's lung — hypersensitivity pneumonitis — are the conditions most frequently reported in the literature. More research is needed to identify the causes of allergies and better target prevention, although some exposures have been addressed more in-depth (e.g. with regard to bakery workers).

Emerging risks

Climate change is associated with a wider spread of some diseases (e.g. through mosquitoes and ticks). A wide range of vector-borne diseases is putting workers in many professions at risk. Systematic monitoring and exchange of information between countries are required.

Waste management and composting, which are growing sectors, are associated with exposures to specific allergens. The expected increase in green jobs in the future may result in more workers becoming sensitised to biomass-related allergens.

Changing travelling patterns (e.g. an increase in working abroad) are also influencing the spread of diseases (e.g. recent occurrences of tropical diseases and haemorrhagic fevers). Some diseases, such as tuberculosis, are re-emerging, and this development needs to be monitored; this could be linked to increased migration flows and to changing vaccination patterns and attitudes to vaccination. Prevention efforts to address the risk of infection may also be needed among groups of workers who are in first contact with travellers and migrants (e.g. customs and healthcare workers).

The increased resistance of microorganisms to antibiotics is another emerging risk. This development puts healthcare professionals and agricultural workers at risk. It will be important to control the use of antibiotics and ensure registration and recording of cases.

No system is currently in place in Europe to respond quickly to emerging risks from biological agents; such a system could build on the epidemics alert systems in place in public health systems and a cooperation between both policy areas would be beneficial.

Vulnerable groups

Despite a lack of information specifically on vulnerable groups, the research identified the following groups of workers as at particular risk:

- pregnant and breastfeeding women
- young workers
- maintenance workers and cleaners, who may work in different workplaces and for different employers;
- trainees in healthcare systems, especially in resource-poor countries;
- immunocompromised workers;
- socially vulnerable groups, such as sex workers.

The following actions, among others, are recommended to better protect these groups from the risks posed by biological agents:

- improve knowledge about vulnerable groups, especially among GPs, occupational physicians and OSH actors;
- ensure that research and prevention efforts aim to identify vulnerable groups with reference to the specific circumstances in question;
- improve training programmes for new workers in sectors and jobs involving contact with biological agents;
- reinforce the messages of the Pregnant Workers Directive and Young Workers Directive, including with regard to biological agents;
- ensure that, as far as possible, workplace prevention measures take into account pre-existing medical conditions.

Monitoring systems

Systems for monitoring exposure to biological agents or the resulting diseases vary considerably with respect to:

- what is monitored;

- how frequently it is monitored;
- the level of detail recorded;
- the accessibility of the information.

To enable a better understanding of the real extent of the problem:

- a standard set of key parameters that need to be monitored (at least information on causative agents (exposures), industries/sectors, jobs/occupations, age and gender) should be used;
- the level of detail to be reported should be agreed upon;
- training of physicians who record and notify cases of disease should be improved to prevent under-reporting;
- the information collected should be made available to all stakeholders across countries;
- some core information should be made available in English to encourage sharing among EU Member States.

Information on prevalence or incidence of exposures and diseases is scarce. Research and monitoring should seek to provide such information. This would help in identifying the most common and serious work-related diseases.

To detect new, as opposed to known, occupational health risks, sentinel systems such as those used in public health may be needed.

Measuring exposure

There are particular challenges relating to the measurement of biological agents in workplaces. They are living organisms, affected by changing conditions, and measurements can provide only an indication of exposure.

With regard to measuring exposure in the workplace, the authors make the following recommendations:

- Measurement methods used for infectious diseases and in public health should be made more generally accessible to OSH actors.
- Efforts should be made to improve sharing of information on the measurement of biological agents at work, for example through EU-OSHA's OSHwiki portal.
- The development of new measurement and identification methods should be further stimulated.
- Measurement strategies that cover both biological and chemical substances and provide data on exposure to both in specific occupations and sectors should be designed.
- Respiratory and skin diseases are important groups of diseases caused by biological agents, so there should be a focus on improving methods of measuring the agents that cause them.

Improving prevention through better communication

Greater awareness and improved communication are needed to better prevent work-related health effects caused by biological agents.

Stronger links and more information sharing between the research community, the authorities and OSH experts in workplaces and their networks, including those established across ministries, OSH institutes and occupational medicine or hygiene associations, could help to ensure that all potential exposures are covered in monitoring and prevention.

The research found that it was unclear if outputs from monitoring systems are suitable for informing preventive measures. Better dissemination of information in a suitable format would help to ensure that it was used for this purpose.

General practitioners are in a great position to raise awareness and help in prevention. They should be trained in the particular risks that certain groups face and to be aware of exposure to biological agents at work.

Networks of occupational health experts and physicians should be strengthened, as their involvement seems to be vital for better monitoring and prevention.

Some Member states have made significant efforts to introduce more systematic prevention and better monitoring systems for exposure to biological agents and the resulting diseases. Some national examples are described in the report and can serve as models for other countries.

The EU Biological Agents Directive

Directive 2000/54/EC (the Biological Agents Directive) aims to minimise the health risks arising from biological agents in the workplace. It requires employers to protect workers from harmful effects caused by these agents. It has annexes that list:

- classified biological agents;
- tasks that put workers at risk;
- specific preventive measures for certain tasks, mostly laboratory work.

Awareness should be raised about the obligations set out in the Directive among employers and workers.

National legislation implementing the directive has often used a broader definition of biological agents than is found in the directive itself, and the experiences with the national processes implemented based on the Directive should be shared among countries to improve monitoring and prevention.

The directive could usefully be updated to address the whole range of biological agents and the related health effects identified in research and practice.

Classification systems in use in France and Germany could function as useful tools in planning an update to the directive.

Provisions on information gathering and reporting found in the Chemical Agents Directive could be incorporated into the Biological Agents Directive to encourage more effective risk assessments and preventive measures.

Executive summary

European Agency for Safety and Health at Work (EU-OSHA) research on emerging biological risks and national reviews have highlighted a lack of knowledge and awareness of exposures to biological agents and related health problems, and the lack of a systematic approach to workplace prevention of these risk factors. Consequently, in 2015, EU-OSHA commissioned a project to address these risks in the workplace. The overall objectives of the project were to:

- raise awareness of the issue of exposure to biological agents in professions that are most affected, especially those in which there is unintentional use of biological agents;
- increase the amount of information on health problems related to exposure to biological agents at work;
- support efforts to prioritise and structure the prevention of these work-related health problems.

Exposures to biological agents in the occupational environment are associated with a wide range of health effects, including infectious diseases, acute toxic effects, allergies and cancer. However, there is no systematic approach to estimating workplace exposure to biological agents or recognising the related health problems. A limited number of diseases related to biological agents — some of which are zoonoses — are recognised as occupational diseases. But there is little structured information on emerging issues in new professions such as waste management, wastewater management and composting, or other green jobs[1], or, for example on emerging issues relating to the use of novel construction materials. New industrial activities have emerged in recent years in which exposure to bioaerosols can be significant, for example biotechnology industries producing highly purified enzymes and the detergent and food industries that make use of these enzymes, waste management and recycling technologies, and industrial animal breeding. Hazardous bioaerosols and new biological factors present in organic dust that may induce work-related allergic and immunotoxic diseases among farmers and workers in the agricultural and wood industries have been identified. Respiratory symptoms and lung function impairment are among the most studied effects. Workers suffering from specific diseases within this spectrum have been compensated in some European Union (EU) Member States. Droplet aerosols, which are generated from water, oils, oil-water emulsions and other liquids in various work environments, may contain infectious agents (e.g. *Legionella* spp.) as well as allergic and/or toxic agents. Novel viruses and prions, emerging in various parts of the world may pose a threat to the health and life of healthcare workers, food and agricultural workers, and veterinarians. Other important areas include the interaction of bioaerosols with non-biological agents, and other potential health effects, such as skin and neurological conditions and birth defects. All in all, there is a wide variety of exposures and health problems.

In response to this, the project aimed to provide insights into the problems encountered by workers who are exposed to biological agents, and by their employers. Furthermore, it aimed to provide information on structured approaches to recognising and preventing the effects of biological agents that can support policy-makers, actors in occupational disease recognition and reporting, actors at enterprise level and sectoral organisations.

The project consisted of five tasks that fed into each other:

1 a literature review on specific work-related diseases due to exposure to biological agents and an analysis of selected monitoring systems;
2 structured interviews with experts about their views on policy;
3 focus groups with workplace intermediaries;
4 an expert workshop in which the preliminary findings were presented and discussed;
5 a final report, including analysis, policy options and expert views.

[1] Green jobs cover a wide range of different jobs in different sectors, and involve a diverse workforce. There are many different definitions of the term, such as the ones by the United Nations Environment Programme , the European Commission or Eurostat. But green jobs can be understood as contributing, in some way, to the preservation or restoration of the environment. They can include jobs that help to protect ecosystems and biodiversity, or reduce consumption of energy and raw materials, reduce waste and pollution.

The various tasks were meant to provide an overview of what is known on this topic and how the issues identified are addressed in policy and practice. Together, these tasks were expected to enable an assessment of the discrepancies and similarities between policies and practice in companies, to provide policy options that can be considered by decision-makers to improve the prevention and control of the effects of biological agents in the workplace. This report summarises the first task.

Biological agents

Directive 2000/54/EC of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work defines 'biological agents' as 'microorganisms, including those which have been genetically modified, cell cultures and human endoparasites, which may be able to provoke any infection, allergy or toxicity'. It goes on to define 'microorganism' as 'a microbiological entity, cellular or non-cellular, capable of replication or of transferring genetic material'. For the purpose of this report, however, the following definition has been used: biological agents are microorganisms and other carriers of plant or animal origin that can cause adverse health effects in workers. Only a small subset of microorganisms, known as pathogens, cause disease in humans. Biological agents, in the sense in which the term is used in this report, can be divided into two groups: living (micro)organisms (e.g. bacteria, viruses, fungi, yeasts and prions), that is, the organisms covered by the European definition; and substances or structures that originate from living or dead organisms (e.g. exotoxins, endotoxins, glucans, mycotoxins and allergens).

This definition is broader than that laid down in European legislation.

In the context of the analysis of exposures in this report, it is important to consider that workers are usually exposed not only to one agent but to several at the same time, some of which may interact. In many work situations, workers are also exposed to dust of biological origin, often called organic dust, which usually consists of for instance proteins (or allergens) from the materials they use and (micro)organisms growing in those materials. Health risks related to biological agents occur in all kinds of circumstances and (occupational) environments.


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Legal requirements

Directive 2000/54/EC aims to minimise the health risks arising from biological agents in the workplace. It is a specific directive that complements the general requirements set out in Directive 89/391/EEC, known as the Framework Directive, and specifies requirements with regard to exposures related to biological agents. The directive classifies biological agents into four risk categories, according to their potential to cause disease, the severity of disease and the extent of the possibilities for prevention and treatment. In the lowest category, the agent is unlikely to cause disease in humans and in the highest category the agent causes severe disease for which no effective treatment is available. The directive also lays down obligations for employers to protect workers from harmful effects caused by biological agents and their constituents, and other obligations such as providing information and training, personal protective equipment and health surveillance, recording exposures and diseases, and record-keeping. Furthermore, the directive has an annex that provides a list of classified biological agents, one that defines tasks that put workers at risk and one that defines specific preventive measures for certain tasks, mostly laboratory work.

EU Member States have implemented the directive in their national legislation. As the directive sets minimum standards, Member States have a right to lay down stricter or more detailed requirements. Some of these are referred to and described in this report.

Methods used for gathering information

This report presents the results of a literature review on specific work-related diseases due to biological agents, a questionnaire survey of experts and an evaluation of a selection of monitoring systems of diseases and exposures. These results are synthesised and discussed, and recommendations are made for better monitoring, improved prevention and collaboration across policy fields.

The aim of the review of the scientific literature was to identify and summarise existing reviews of exposure to biological agents at work and adverse health outcomes, identify the most relevant exposures and most exposed workers, and assess studies on monitoring systems, databases and the EU directive on biological agents. An extensive search was carried out in databases containing both official scientific literature and grey literature.

In addition to the literature search, a questionnaire was developed to gather information about data sources that help target prevention of diseases and emerging risks caused by biological agents, as well as about national policy measures, reports, campaigns and case studies of adverse health outcomes. The questionnaire was distributed to the EU-OSHA focal point network, EurWORK (the European Observatory of Working Life), PEROSH (the Partnership for European Research in Safety and Health) and Modernet (Monitoring trends in Occupational Diseases and tracing new and Emerging Risks in a NETwork). Detailed information on the results is provided in the annex to this report.

A third part of the work described in this report involved exploring and comparing national monitoring systems in Denmark, Finland, France, Germany, the Netherlands and the United Kingdom, with a reputable knowledge and infrastructure to deal with exposures to biological agents. This work resulted in an overview of systems for reporting exposures to biological agents and diseases caused by exposures to biological agents, some of which were selected for more in-depth analysis.

Results

The literature search yielded 96 reviews on biological agents and/or their health effects, 4 papers on monitoring systems, 8 papers on databases and 5 papers on the EU directive. The questionnaire elicited responses from 62 participants in 29 European countries and 50 organisations for further analysis.

Occupations at risk

For biological agents not including allergens, the associations between certain occupations and diseases resulting from biological agents are clear. For example, healthcare workers are at risk of blood-borne and other infections, forestry workers are at risk of tick-borne diseases, sex workers are prone to sexually transmissible infections, workers maintaining air-conditioning systems are at risk of legionellosis and those whose work involves the intentional or inadvertent handling of animals, such as agricultural workers, animal breeders, animal carers or handlers, veterinarians and zoo personnel, are at risk of zoonoses, that is, diseases that are transmitted from animal to human.

This report includes extensive tables that provide information on the typical exposures in the professions most often studied in the literature; workers in these jobs may be exposed to a wide range of infectious agents, some of which can cause serious or even fatal disease. However, the extent to which a particular biological agent had been researched and reported in the literature varied considerably. For several occupations, the risk factors were less clear. The literature search indicated that these jobs included aquacultural workers, bone button makers, border guards, fertiliser workers and outdoor game managers.

The identification of allergens and their differentiation from chemicals agents is the most challenging issue identified in this review — although it is the most-researched issue — as the exact cause of the allergy at the agent level cannot easily be identified. In the literature on allergenic agents, a differentiation between chemical agent and biological agent is not normally applied, although there are cases where a link between a substance originating from microorganisms and allergenic effects is elucidated. This is one of the reasons why a broader definition of biological agents was applied and a wider range of possible sources of allergens considered in this review. For many occupations, the exact agent or substance causing the allergic reaction is not yet known. The sectors and occupations where there is a clear risk include the agricultural and fishery sectors, the food industry, the woodworking and metalworking industries, and waste treatment, composting and waste collection. In these areas, the risk often is not limited to one biological agent but relates to a number of different agents and a range of possible triggers, further increasing the risk of disease. Occupational asthma in farmers and farmer's lung — hypersensitivity pneumonitis — are the conditions most frequently reported in the literature. These are followed by allergies triggered by laboratory animals, allergies resulting from working with wood, and allergies due to bacterial or fungal contamination of metalworking fluid in the metalworking industry. Agriculture, food preparation, food management, fishing and aquaculture are associated with allergens originating from plants and animals, as well as co-existing allergenic sources such as bacteria, fungi and insects.

Travelling patterns have changed, and travelling, especially outside Europe, is generally assumed to increase the geographical spread of diseases not commonly encountered in Europe. Moreover, the migration of immigrants and refugees to Europe may also introduce diseases not commonly found in Europe and increase the risk of reintroducing diseases that have been nearly eradicated in Europe, such as tuberculosis. However, literature on the extent of the risks associated with travel and increased migration is scarce.

Other issues also emerge, such as the spread of fungal diseases among professional drivers and the increased occurrence of leptospirosis among agricultural workers, construction workers, dock workers, hunters, maintenance workers, pest control workers, and wastewater and sewage workers.

Emerging risks

The work carried out for this report also identified new and emerging risks, although the validation of the information that was retrieved is not straightforward. Information on the prevalence or incidence of exposure to biological agents and the associated diseases was scarce. Therefore, it was difficult to assess if diseases caused by biological agents were occurring more frequently and if a possible increase in frequency was due to changes in exposure. However, some issues seem to be linked to new developments — such as climate change or environmental legislation leading to changing patterns in waste management — newly occurring microorganisms that have spread to other regions, or better knowledge or better awareness of some issues, and these developments are described in the review.

Waste management and composting are associated with specific allergens and the expected increase in green jobs in the future may result in an increased prevalence of sensitisation to biomass-related allergens.

Re-emerging diseases, such as Q fever, tuberculosis and influenza, were identified among workers in agriculture and healthcare.

Climate change is associated with a wider spread of some diseases and their vectors (e.g. mosquitoes and ticks). A wide range of tick-borne diseases is putting workers in many professions at risk.

Changing travelling patterns and volunteer schemes in developing countries are also influencing the spread and distribution of diseases. Recent occurrences of tropical diseases and haemorrhagic fevers, such as Ebola, or the spread of diseases such as chikungunya and Crimean-Congo fever are just some examples.

The increased resistance of microorganisms to antibiotics was another risk mentioned in the literature and tackled in several Member States; this development puts care professionals as well as workers in the agricultural sector at risk because of intensive breeding and widespread use of antibiotics. Intensive breeding and technological changes in agriculture are also putting workers at risk of being exposed to organic dust, a complex mixture of dust and microorganisms. Workers in other professions, such as waste handlers and compost workers, are also exposed to organic dust.

Vulnerable groups

The review also focused on identifying those groups of workers that are considered vulnerable because of a lack of experience or training or because of physiological vulnerability. The critical doses, and the circumstances of exposure, may be different for these groups. However, for most occupations, no information was available with regard to vulnerable groups.

One group that was often mentioned was maintenance workers and cleaners, who may be particularly at risk when working in different workplaces and for different employers.

Furthermore, trainee nurses and medical trainees who work in the healthcare systems of resource-poor countries are considered to be more vulnerable to contracting occupational infections. As a result of a lack of experience and knowledge, and possibly also the tasks that they are given, it is assumed that trainees and new professionals in all occupations are more often exposed to biological agents and are thus at higher risk of disease.

It can also be assumed that pregnant and breastfeeding women and young workers are at risk, as these groups are identified as at risk in the relevant European directives. It should also be borne in mind that in some of the sectors at risk, such as agriculture, family members who may not be considered workers in the legal sense of the term, as well as seasonal workers, may be at risk.

Another group mentioned in relation to fungal diseases were immunocompromised workers, who may be at risk because of their reduced immunity to infectious agents.

Furthermore, social vulnerability is another issue that should be considered. This issue was mentioned in relation to sex workers, who are also a group that is difficult to reach and for whom prevention of disease depends on the success of wider policies that entail better social protection and support, and protection from violence.

Monitoring systems

A number of monitoring systems were selected from those mentioned by the questionnaire respondents and were further analysed. Descriptions of the systems for monitoring exposure and diseases are provided in this report, together with some data extracted from publicly available sources. The selected systems were from countries with a certain level of knowledge about and policies for tackling biological agents at work. A number of conclusions can be drawn from these analyses, although, from the data that are publicly available, it can be gathered that the systems for monitoring exposure to biological agents or the resulting diseases vary considerably between the five countries analysed. They differ with respect to what is monitored, how frequently it is monitored and to what level of detail. This makes an analysis of occupational diseases at a more general level difficult or even impossible, and it is assumed that the same conclusion would be drawn if the systems were to be compared at the EU level. To ensure a better overview of the exposures and outcomes, and the real extent of the problem, it is recommended that a standard set of key parameters that need to be monitored are used and that the level of detail that should be reported is agreed upon. For more usable information and to improve prevention, it is important to make information available to all stakeholders. Providing at least some core information in English would make sharing among EU Member States easier.

Another issue that emerges from the analysis is that it is unclear if the outputs that the various systems provide on occupational diseases due to biological agents and on exposure to biological agents in the workplace are suitable to inform preventive measures, especially because of the scarcity of data. It would help if the data from the systems in each country were broken down by causative agents (exposures), industries/sectors, jobs/occupations, age and gender, and this information published. This would provide better information that the various stakeholders could use to target preventive measures and would allow comparisons between countries and between industries within countries. Even where the outputs are suitable for informing preventive measures, the extent to which the information is actually used by stakeholders to target prevention is unclear. Usually, the information is provided in annual reports that are distributed among the stakeholders such as the relevant ministry and the labour inspectorate, but in several countries the information that is publicly available is very general and cannot be refined.

Addressing the limitations of the current monitoring systems

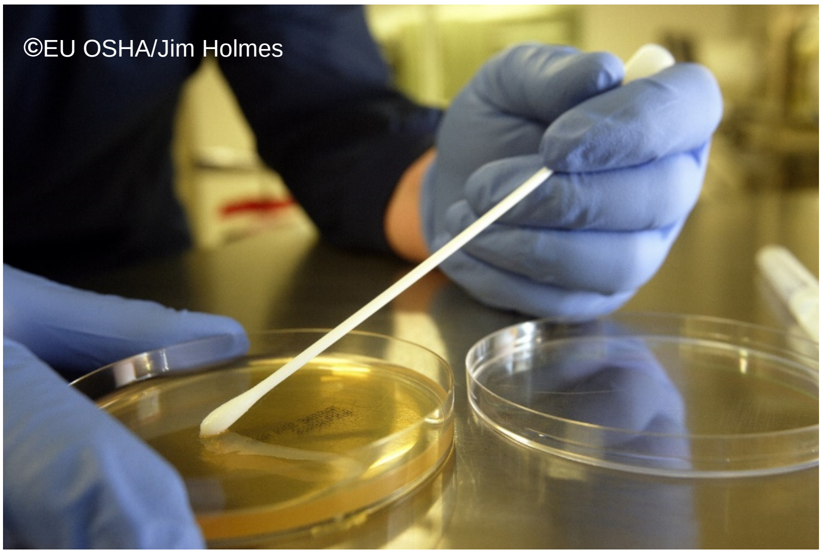
A key purpose of monitoring systems is to inform the design of preventive and control measures. Recognised limitations of current systems that have implications for their suitability for this purpose are the amount and type of information available to stakeholders and the under-reporting of diseases. The latter is possibly linked to under-recognition due to insufficient guidance and training for those registering cases. An obvious solution is therefore to increase the guidance and training given to relevant professionals (e.g. occupational physicians and general practitioners) about how to recognise occupational diseases, including by transferring knowledge between the research community and public health experts. This would help to provide a better overview and would facilitate the collection of information for systems thus addressing the issue of under-reporting.

For the detection of new occupational health risks, instruments other than those used for the monitoring of known occupational diseases may be needed. Information that is routinely collected by public health systems could possibly be used to this end, especially when it is not directly clear to the worker/and or employer that there is a relation between exposure to a biological agent in the work environment and the disease. The choice of instrument is determined by characteristics of the health problems, such as its nature, its seriousness and the strength of the causal link with the possible cause. It may not be possible to detect new occupational health risks using a single method, and several complementary methods are likely to be required.

Information on exposure to biological agents is scarce and monitoring systems do not exist in all countries

Little information is available on exposure to biological agents in the workplace. These exposures are not measured frequently, and only a few systems for monitoring them exist. However, some exposure information can be gathered from disease monitoring systems. The French rnv3p system, for example, provides an extensive thesaurus of exposures, agents and diseases that supports systematic recording of the circumstances, exposures and tasks, and helps identify new or previously unknown health problems at work. It is an adaptation of the European coding categories and follows the pharmacovigilance approach used in public health. Furthermore, there are databases of workplace measurements and other tools, such as the Finnish Job-Exposure Matrix, FINJEM, that provide information on a wide range of issues and regarding some of the most exposed professions identified in this review.

There are particular challenges relating to the measurement of biological agents, as opposed to, for example, chemical substances, at work. Exposure is often dependent on the growth conditions for microorganisms and the availability of water and other substrates. Therefore, a measurement can be regarded only as a snapshot of the concentration in the air. Exposure may also be highly dependent on temperature and may differ depending on the time of year. Usually, measurement methods record concentrations in the air, but exposure to biological agents may also result from contact with contaminated surfaces or instruments and through skin exposure. Currently, quantification of infectious agents is based on cultivation and colony counting. However, this does not capture substances generated by organisms, fragments from dead organisms, or toxic or allergenic compounds. Alternative methods developed to identify these include (electron) microscope counting.



Methodological developments have concentrated on workplace measurements but also on identification of microorganisms that cannot be measured through methods that involve cultivation. Novel measurement methods have been developed to assess exposure to endotoxins in a wide range of workplaces, and also to identify organisms through DNA sequencing or staining. It would be worth considering how this information could be shared across borders to identify emerging issues and to tackle the most widespread health risks through efficient prevention measures. This is one area that the next task in this project will help address, as it will involve interviews with experts in the field. Further development of measurement and analytical methods for biological agents is recommended to enable control or prevention of such exposures.

Classification of biological agents

In relation to monitoring exposure, the categorisation and classification of biological agents is an important issue. The classification systems that are in use in France and Germany can serve as practical examples of harmonisation, and they are referred to in this review. Considering that a recent review of the Biological Agents Directive has found that the lists in the directive should be adapted and updated, they constitute a valuable resource.

Occupational exposure limits

In principle it is possible to derive occupational exposure limits (OELs) for biological agents that have toxic or allergenic effects in the same way as for chemicals. However, the lack of good quantitative data on exposure and the associated effects — that is, the exposure-effect relationship — hampers the derivation of OELs. For infectious biological agents, the deriving an OEL is more difficult owing to a lack of knowledge about exposure and pathogenicity. It is therefore not very likely that OELs for biological agents that result in infectious diseases will be developed in the near future. In the meantime, other preventive measures should be taken.

The EU directive on biological agents

The main focus of the directive as regards more detailed prevention measures is on sectors in which exposure to biological agents is part of the primary process, such as in industrial processes or laboratories, or in situations where workers have regular contact with patients or sick animals. Healthcare and veterinary services are known for the high level of implementation of regulation and control measures. In general, the workers active in these sectors are likely to be better trained and more aware of the risks they are exposed to. In other sectors, where there is inadvertent exposure because exposure is not part of the primary process, the control measures described in the annex to the directive are not easily implemented.

Owing to the significant variation in conditions in workplaces in which biological agents pose a risk to workers, a uniform preventive approach will be difficult to put into practice. Therefore, a directive that takes a generalised approach cannot be expected to cover all possible situations. The classification of biological agents according to level of risk, as prescribed by the directive, would require a risk assessment for each individual biological agent, which is not possible because of the scarcity of data. However, some countries have carried out more systematic assessments of specific exposures or specific occupations and tasks, and it would be beneficial if the information were to be shared between countries, for example in the case of the assessments described in the technical rules on biological agents in Germany or the German GESTIS Database. Furthermore, information is available from the questionnaire survey of expert groups carried out for this report in many countries, mostly in ministries and associations of occupational hygienists or physicians, and that information is incorporated in this report and its annexes. Some information on a selection of diseases and exposures has also been gathered from compulsory reporting related to public health measures. Better coordination across policy areas would therefore be beneficial, and it has considerably improved prevention and monitoring in some countries, such as the Netherlands. An exchange of information between various expert groups could support a more diligent response to the risks identified across Europe.

The control measures indicated in the directive are related to the four risk categories, which makes it difficult to cover all biological agents following this general approach. Therefore, it is recommended that companies and industry sectors expand on the directive by providing guidance on how to set up surveillance where necessary and on controlling and/or preventing exposure in specific work environments. In addition, the definition of biological agents used in the directive could be broadened, as it already has been in various Member States. Substances that originate from organisms such as exotoxins and allergens, and carriers of biological agents such as organic dust and bioaerosols, that contribute substantially to the burden of exposure to biological agents in the work environment need to be covered, and a good synergy of the requirements for addressing chemical agents and biological agents, in particular microorganisms, must be ensured. These substances should be covered by national legislation, and possibly also European legislation, leading to specific control and prevention measures in the occupations at risk.

Conclusions and recommendations

Table 1 provides an overview of the most important conclusions and recommendations from the review.

Table 1: Findings and recommendations

Findings	Recommendations	Remarks
Exposure to biological agents		
Information on exposure to biological agents is scarce and does not necessarily provide an overview Exposures are normally to several biological agents of different natures and with different effects, and to complex mixtures such as organic dust	Promote research on typical exposures in some professions, in particular those that involve handling of animals and people, and those that involve travel on the part of workers or contact with travellers and migrants Improve monitoring of exposures in professions with unintentional use, which are also characterised by low levels of awareness	The Netherlands and Germany have initiated targeted research projects related to organic dust that can provide useful information for exposure assessment and monitoring, as well as prevention
Information provided by the questionnaire survey and the literature differed but was complementary. Both sources of information are required to gain a broad picture In those countries where networks are established, more and more systematic information is available and there are better links to practical prevention	Ensure a better link between the research community, the authorities and occupational safety and health (OSH) experts in workplaces to cover all potential exposures in monitoring and prevention Strengthen networks of occupational hygienists or physicians, including those established across ministries, OSH institutes and occupational medicine or hygiene associations	Examples such as the French network of occupational disease centres linked to a prevention network or the German committee on biological agents, which involves experts from the workers' side, industry and the authorities, could be followed in other countries
Information on exposure levels in workplaces very limited and available only for a few substances, for example endotoxins There is an overlap between both the chemical and biological agents area where allergens and toxins originating from microorganisms or organic dust are concerned	Measurement strategies from the chemical field could help to inform the assessment of exposures to biological agents Ensure better sharing of information on the measurement of biological agents at work and their constituents, for example through EU-OSHA's OSHwiki	Follow examples from the Netherlands and Germany to inform measurement and sampling strategies, as well as information sharing
Associations between exposures and diseases are clear for, for example, healthcare workers, who are at risk of blood-borne and other infections; forestry workers, who are at risk of tick-	Ensure broad coverage of professions that are potentially exposed to biological agents, especially professions that involve contact with	

Findings	Recommendations	Remarks
borne diseases; sex workers, who are prone to sexually transmissible infections; workers maintaining air-conditioning systems, who are at risk of legionellosis; and those whose work involves the intentional or inadvertent handling of animals, such as agricultural workers, animal breeders, animal carers or handlers, veterinarians and zoo personnel. Associations are less clear for aquacultural workers, bone button makers, border guards, fertiliser workers and outdoor game managers.	people, animals, food or plants, as regards monitoring and prevention. Emphasis needs to be put on respiratory diseases and skin diseases and on the identification of exposures among service workers	
Hardly any prevalence data on disease is reported in exposed professions, with the exception of healthcare workers and to some extent sex workers. This makes it difficult to identify professions at increased risk, identify particular tasks or exposures that put these workers at risk, assess the success of prevention measures, or even assess the ease of disease transmission	Ensure efficient registration and especially notification of diseases related to exposure to biological agents at work Consider health surveillance for certain professions to gather prevalence data Research should include the gathering of prevalence data to fill this important data gap Build on experiences from pandemics General practitioners can convey prevention messages and are important carriers of information	Build on public health experiences gained through the obligatory reporting of certain infectious diseases Establish a better link between public health and OSH to ensure that important diseases are recorded. In some countries (e.g. Germany and the Netherlands), such a link is already established, but it could be further reinforced Some local notification systems (e.g. regional recording systems in Spain) could be taken as examples to follow
Different approaches may be needed for the detection of new and emerging diseases and exposures from those applied in the traditional recording systems, where a clear link between exposure and effect needs to be established and, in some countries, a closed list of occupational diseases is set	A sentinel approach, as in public health notification systems, could be followed and the intervention logic when a potentially new risk is identified should be clearly defined to identify first signs and issue an alert for prevention	The French rnv3p system is one example that could be followed; it uses an approach that is also applied in pharmacovigilance

Findings	Recommendations	Remarks
New and emerging risks		
Climate change promotes the spread of non-endemic organisms to other areas and the spread of diseases (e.g. Rift Valley fever, yellow fever, malaria, dengue fever and chikungunya). This includes vectors of pathogens (e.g. ticks or mosquitoes)	Systematically monitor the spread of diseases and vectors Establish information exchange between countries on these issues Cooperation with public health institutions could help in monitoring the spread of diseases and outbreaks	Alert systems such as the rnv3p system established in France, following a pharmacological vigilance approach, could be helpful
Increased travelling leads to a wider spread and higher incidence of diseases not usually seen in Europe from areas where they are endemic or within Europe (e.g. Crimean-Congo haemorrhagic fever spreading from the Balkans to Portugal and Spain), or to known diseases appearing in (workplace) settings where they have never before been observed (human dirofilariasis among veterinarians in central and eastern Europe, or sporotrichosis for example in veterinarians (caused by *Sporothrix schenckii*)) Staff who are in contact with travellers (e.g. airline personnel and customs workers), transport workers (e.g. truck drivers and global trade workers), workers in war zones workers in epidemic control (e.g. field epidemiologists), journalists and media professionals), are likely to be at risk of contracting diseases such as those found among leisure and business travellers. This includes the risk of contracting avian influenza, Q fever, dengue fever, Ebola/Marburg virus infection, tularaemia, legionellosis, measles, tuberculosis, yellow fever, severe acute	Enhance research and monitoring in exposed professions Owing to the large migration flows that have been apparent in large parts of Europe in the past few years, the transfer of biological agents from the Middle East and Africa may need to be given a particular focus, especially among groups of workers who are in first contact with migrants (e.g. healthcare workers, social workers, rescue workers and customs workers)	Consider first case reports and the introduction of alert systems

Findings	Recommendations	Remarks
respiratory syndrome (SARS), cholera or meningitis		
Some diseases, such as tuberculosis, are re-emerging, and this could be linked to increased migration flows and to changing vaccination patterns and attitudes to vaccination	Address the risk of infection through contact with migrants and travellers Ensure good coordination between public health and OSH actors	
Increased exposure to fungi due to the increased collection and separation of organic waste	Carry out research to identify the relevant microorganisms and their health effects, with a particular focus on allergenic constituents of microorganisms	
Increased occurrence of multiresistant microorganisms	Control the use of antibiotics Ensure registration and recording to assess the spread	Some national recording systems and policies (e.g. in Denmark, Sweden and Norway) could serve as examples of how to address this public health threat, which potentially has a very significant impact on workers, as evidenced by the outbreaks that the questionnaire respondents reported The Netherlands has established a working group to classify and categorise multiresistant organisms
Vulnerable groups		
There is hardly any information on vulnerable groups in particular sectors and occupations and related to specific exposures, and they are not considered in research, except in relation to some allergens	Raise awareness among (general) physicians on the particular risks to certain groups as well as the potential for workplace exposure. They should be trained to consider occupational exposure Ensure that research and prevention efforts aim to identify vulnerable groups, more specifically linked to specific agents, sectors and occupations, and circumstances of use Ensure protection of these groups in workplaces and that they are considered in research, prevention and practice	

Findings	Recommendations	Remarks
	Improve knowledge about vulnerable groups, especially among occupational physicians and OSH actors	
Immunocompromised people are a particular group at risk; some research was identified as regards differing vulnerabilities to fungi such as *Candida*	Ensure that medical treatment and pre-existing disease are considered as far as data protection and confidentiality allows when setting measures in workplaces. The occupational physician has a special role to play in this respect	
Apprentices and young people in training were identified as a vulnerable group, particularly if they are working abroad, for example in medical professions. Their vulnerability is linked to a lack of experience and training, and there may also be physiological vulnerability	Training is key to better protection. Improve training programmes for new workers in work sectors and occupational groups that are identified as being at high risk of biological agent- or allergen-related diseases Ensure that particular care is taken of young people working abroad	More awareness of risks to young workers and people with pre-existing diseases is needed, as hardly any evidence was found of preventive measures, and, although data by age is collected in recording systems for diseases, no specific studies were found
The Pregnant Workers Directive includes biological agent risks. However, hardly any information regarding pregnant workers was retrieved in the literature search	Reinforce the messages of the Pregnant Workers Directive and ensure that biological agents are considered in its application Ensure protection of the unborn and breastfed child	
Monitoring systems		
Information on diseases linked to exposure to biological agents is not consistently available and sometimes reported only in very general (e.g. bacteria, fungi and parasites)	Ensure public availability of a basic set of data that should cover causative agents (exposures), industries/sectors, jobs/occupations, age and gender Information should be made more widely available and a better link between practitioners and researchers should be established Ensure all sectors and occupations as well as all groups of workers are covered by disease monitoring, recording and recognition	

Findings	Recommendations	Remarks
Information on work-related diseases linked to exposure to biological agents is normally included in the systems that record occupational diseases	Ensure regular revisions of and updates to the lists of occupational diseases with a specific emphasis given to ensuring that diseases linked to exposure to biological agents are up to date and the relevant diseases included International comparisons can support these efforts	There are examples of transnational cooperation, for example between the statutory insurance organisations of Austria, Germany and Switzerland, that could be followed
Occupational diseases are under-reported in the various systems, probably owing in part to a lack of awareness and therefore recognition on the part of registrants, as a result of inadequate guidance and training	Ensure better training of physicians who record diseases and notify them. This could include general practitioners or other disciplines in those countries that have a general obligation for any physician to notify a disease that they suspect could be linked to work	Registrants of the French rnv3p system are fully trained and regularly retrained. In addition, they belong to a network that links them with prevention specialists, and they have the opportunity to exchange experiences. Likewise, the THOR systems in the United Kingdom incorporate such experience exchange and training. These examples could be followed. Many countries have networks of experts that could provide input into monitoring systems and help set priorities for research and prevention
It is unclear whether the outputs from disease monitoring systems are suitable for informing preventive measures and whether the information is used	Ensure better dissemination of information in a suitable format for prevention actors	The French Thesaurus of Occupational Exposures (TOE), created by an expert network, allows for a level of detail that is greater than in Annex III to the Biological Agents Directive, considers links between causes and health effects, and incorporates a plausibility check on alerts; this facilitates prevention and is an example to be followed A tool for the quality assessment of occupational disease registries with respect to their ability to provide appropriate information for preventive policies on a national level, called ODIT, is available and could be applied to existing monitoring systems

Findings	Recommendations	Remarks
Exposures to biological agents are not measured frequently, and there are only a few databases available that contain measurement results Measurement results are generally not available to the general public or even prevention actors	Better use could be made of the information in the existing databases to identify typical exposures Exposure measurement and sampling methods should also cover sectors such as arable farming, animal breeding or care, and waste management, as well as healthcare Knowledge and measurement methods that are available in the field of infectious diseases and public health should be made more generally accessible to OSH actors Information should be shared across Europe. EU-OSHA could support such information sharing, for example through OSHwiki	International cooperation would be beneficial to identify typical exposure levels in specific occupations or related to specific tasks
There are particular challenges relating to the measurement of biological agents. Microorganisms are living organisms dependent on growing conditions and also temperature The identification of microorganisms can be challenging Furthermore, measurement methods do not cover allergenic components and fragments of microorganisms	Ensure that the methodologies applied are reproducible and information on methodologies is widely shared Development of measurement and identification methods could be further stimulated. Currently, methods are being developed, for example, to detect immunological reactions and to identify biological agents without cultivation The results could also be used for the development of exposure models National or European requirements for regular exposure measurements of biological agents would enhance the collection of this type of data As respiratory and skin diseases are important groups of diseases caused by biological agents, the focus should be on enhancing methods that cover the causal agents	The German GESTIS Database brings together information on the properties and occurrence of biological agents. It is a useful tool that could serve as an example for further development. Some of the exposure studies conducted by the German Federal Institute for Occupational Safety and Health also provide valuable information on exposure to biological agents in, for instance, livestock workers and waste workers Another example is FINJEM, which provides information on typical exposures in specific jobs First attempts have been made, through endotoxin and mould measurements in workplaces (in, for instance, Germany and Finland), to set exposure guidance values based on measurements

1 Background

European Agency for Safety and Health at Work (EU-OSHA) research on emerging biological risks and national reviews have highlighted a lack of knowledge and awareness of exposures to biological agents and related health problems, and the lack of a systematic approach to workplace prevention of these risk factors. Consequently, in 2015, EU-OSHA commissioned a project to address these risks in the workplace to a consortium of research organisations led by the Finnish Institute of Occupational Health (FIOH). The project was carried out by the Netherlands Organisation for Applied Scientific Research (TNO), in collaboration with the Netherlands Expertise Centre for Occupational Respiratory Disorders (NECORD), the Finnish Institute of Occupational Health (FIOH), Aarhus University (Denmark), the German Federal Institute for Occupational Safety and Health (BAuA) and the French Agency for Food, Environmental and Occupational Health and Safety (ANSES).

Worldwide, an estimated 320,000 workers are estimated to die annually from work-related infectious diseases, 5,000 of them in the European Union (EU) (Murray and Lopez, 1997; Nurminen and Karjalainen, 2001; Driscoll et al., 2005; Hämäläinen et al., 2007). In the Netherlands, 553 cases were reported in the period 2001-2006, of which two were fatal (van Wijk et al., 2010). Morbidity from work-related infectious disease is expected to be higher, although the true extent of incidence of cases is difficult to establish (ABAS, 2011; Safe Work Australia, 2011; Haagsma et al., 2012). Characterising work-related health effects caused by biological agents is often difficult, since the cause of the disease is not always directly related to the work activity; it may, rather, be related to the environment, which may be favourable to the growth of microorganisms: this is one of the reasons why it is assumed that the incidence of these health effects is under-reported. Moreover, limitations in available exposure assessment methods and a lack of health-based (recommended) occupational exposure limits (OELs) for biological agents make it difficult to identify a particular biological agent as a risk factor (Health Council of the Netherlands, 2012), which is necessary for implementing targeted preventive measures.

Furthermore, there is a general lack of knowledge and awareness of exposures to biological agents and related health problems, and a lack of a systematic approach to workplace prevention of these risk factors (EU-OSHA, 2009a, 2009b). As a consequence, awareness and identification of (emerging) biological risks is hampered, in relation to both established and growing professions and sectors, with the latter including waste or wastewater management, composting and green jobs (EU-OSHA, 2013a, 2013b), and biotechnology industries. The issue of combined exposures to multiple risk factors in, for example, the waste treatment sector, has also been highlighted as an emerging risk (EU-OSHA, 2009a). A better understanding and greater awareness of biological risks is vital for a detailed evaluation of the health effects of combined exposures.

This report presents the results of the first task forming part of the project, namely a literature review on specific work-related diseases due to biological agents and a review of selected monitoring systems.

The report aims to provide an overview of the types of biological factors and health problems relevant to workplaces, with a particular emphasis on unintentional use. When the occurrence of biological agents is an unintentional consequence of the work, as is often the case in, for example, agriculture, assessing the risks that workers are exposed to is more difficult. The report also aims to provide information on emerging issues and to highlight sectors in which workers are particularly at risk.

1.1 Definitions and legislative framework

Directive 2000/54/EC ([2]) of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work defines 'biological agents' as 'microorganisms, including those which have been genetically modified, cell cultures and human endoparasites, which may be able to provoke any infection, allergy or toxicity'. It goes on to

([2]) https://osha.europa.eu/en/legislation/directives/exposure-to-biological-agents/77 define ‘microorganism’ as ‘a microbiological entity, cellular or non-cellular, capable of replication or of transferring genetic material’.

For the purpose of this report, however, a wider definition of biological agents has been used.

‘Biological agents’ are microorganisms and other carriers of plant or animal origin that can cause (sometimes severe) adverse health effects in workers after exposure.

In addition to living (micro)organisms (e.g. bacteria, viruses, fungi, yeasts and prions), substances or structures that originate from living or dead organisms (e.g. exotoxins ([3]), endotoxins, glucans, mycotoxins and allergens) are included.

Although only a subset of all microorganisms (known as pathogens) cause disease in humans, health effects caused by biological agents (including infectious diseases, acute toxic effects, allergies and cancer) have a major impact on public health. Health risks related to biological agents occur in diverse circumstances and (occupational) environments (Houba et al., 2009; Houba and van Alphen, 2013). Those regarded as occupational hazards can be subdivided into two main groups, namely:

1. microorganisms that cause infectious diseases, for example zoonoses, which are contagious diseases that are transferred from animals to man;
2. allergenic and/or toxic agents that form bioaerosols (e.g. bacteria, endotoxins, fungi) and cause occupational diseases of the respiratory tract, conjunctiva and skin (Dutkiewicz et al., 2011 and 2015).

In many work situations, workers are exposed to dust of biological origin, often called organic dust, which consists of several biological agents, for instance proteins (or allergens) from the material itself and (micro)organisms growing in those materials.

Directive 2000/54/EC classifies biological agents regarded as occupational hazards according to their level of risk of causing human disease, the severity of that disease, its potential to spread to the community, and the availability of effective prevention or treatment, providing indications of allergenic potential and toxic effects. Based on this four-level categorisation:

- Risk Group 1 includes biological agents that are unlikely to cause human disease.
- Risk Group 2 includes biological agents that can cause human disease and may be hazardous to workers. However, these agents are unlikely to spread to the community and effective prophylaxis or treatment is usually available.
- Risk Group 3 includes biological agents that can cause severe human disease and present a serious hazard to workers; these agents may present a risk of spreading to the community, but effective prophylaxis or treatment is usually available.
- Risk Group 4 includes biological agents that causes severe human disease and are a serious hazard to workers; these agents may present a high risk of spreading to the community, and usually no effective prophylaxis or treatment is available.

Under this classification system, a list of 151 bacteria and similar organisms (of which 28 are classified as Risk Group 3), 26 fungi (of which 6 are classified as Risk Group 3), 69 parasites (of which 10 are classified as Risk Group 3) and 129 viruses (of which 52 are classified as Risk Group 3 and 11 as Risk Group 4) is presented (EU Directive 2000/54/EC, Annex III). However, the annexes to Directive 2000/54/EC are being currently updated to technical and scientific progress in the regulatory procedure with scrutiny. According to a review performed by Montano in 2014, in which the risk of spreading to the community was not considered, it was reported that 50 pathogens (25 bacteria, 16 viruses, 7 parasites and 1 fungus) potentially posed a risk to workers, with 13 belonging to Risk Group 3 (Montano, 2014). Furthermore, the resistance of microorganisms to antibiotics is expected to become an increasingly important issue in occupational settings (Kampf and Löffler, 2010; Sarker et al., 2014; Dorado-García et al., 2015; Moritz et al., 2015).

([3]) A toxin released by a living bacterial cell into its surroundings.

Occupational exposure to biological agents can occur in two ways:

- through intentional use of specific microorganisms in the primary process (e.g. in laboratories, biotechnological industries); or
- as more or less accidental or unintentional exposure resulting from processes that involve many different microorganisms or environments in which biological agents occur naturally (e.g. in composting, recycling, wastewater management, agriculture, food processing, healthcare, education) (Haagsma et al., 2012).

As a result, workers in a wide variety of occupations may be intentionally or accidentally exposed to biological agents, although the risk of exposure is not always obvious. In practice, occupational disease monitoring systems are probably unable to accurately capture how often exposure to biological agents leads to disease because some exposure situations are unintentional (not part of the primary process), some of the health effects are rather unspecific, and not all occupational safety and health (OSH) professionals are familiar with workplace risks arising from biological agents. In the Netherlands, exposure to biological agents has been identified as one of the priority occupational risks, based on the number of sectors in which exposure occurs and the number of workers exposed (Spaan et al., 2011).

The measures outlined in Directive 2000/54/EC include special control measures such as containment categories for laboratory work and industrial processes, and special attention is paid to healthcare and veterinary care facilities. In addition, Annex I to the directive contains an indicative list of activities that entail exposure to biological agents (i.e. work in food production plants; work in agriculture; work activities that involve contact with animals and/or products of animal origin; work in healthcare, including isolation and post-mortem units; work in clinical, veterinary and diagnostic laboratories, excluding diagnostic microbiological laboratories; work in refuse disposal plants; and work in sewage purification installations). The requirements for notification of selected activities to the authorities are also defined. For workers likely to be exposed to certain biological agents, employers have to keep records including information on exposure and health surveillance. The regulation sets out minimum requirements that must be implemented in national legislation. However, some EU Member States have introduced more detailed codes of practice and guidelines for the safe handling of biological agents, including guidelines for particular sectors and occupations.

2 Project objectives, scope and approach

2.1 Overall project objectives

The results of this project as a whole will enable EU-OSHA to improve knowledge and awareness of exposures to biological agents and related health problems and help support a systematic approach to workplace prevention of these risk factors. The overall objectives of the project were to:

- raise awareness of the issue of exposure to biological agents in professions that are most affected, especially those in which there is unintentional use of biological agents;
- increase the amount of information on health problems related to exposure to biological agents at work;
- support efforts to prioritise and structure the prevention of work-related health problems linked to biological agents;
- stimulate discussion at European and national levels.

Beneficiaries include:

- policy-makers at EU and national levels, including social partners;
- legislators;
- researchers;
- actors in occupational disease recognition and statistical data collection (e.g. national social security organisations);

- actors at the enterprise level (e.g. health and safety managers, health and safety representatives, trade union representatives) and intermediaries involved in setting up company policies, incl. occupational physicians;
- sectoral organisations;
- policy-makers in related areas, for example at the sectoral level, or in employment, public health or environmental policy.

The outcomes of this project are expected to:

- provide up-to-date information on health problems and diseases linked to biological agents and raise awareness among beneficiaries;
- provide information on structured approaches for their recognition and prevention that may support beneficiaries in designing policies and prevention measures, including practical advice aimed at the enterprise level;
- contribute to the sharing of information on these diseases to support the implementation of Directive 2000/54/EC, especially as regards unintentional exposure of workers and biological risks in emerging sectors and occupations.

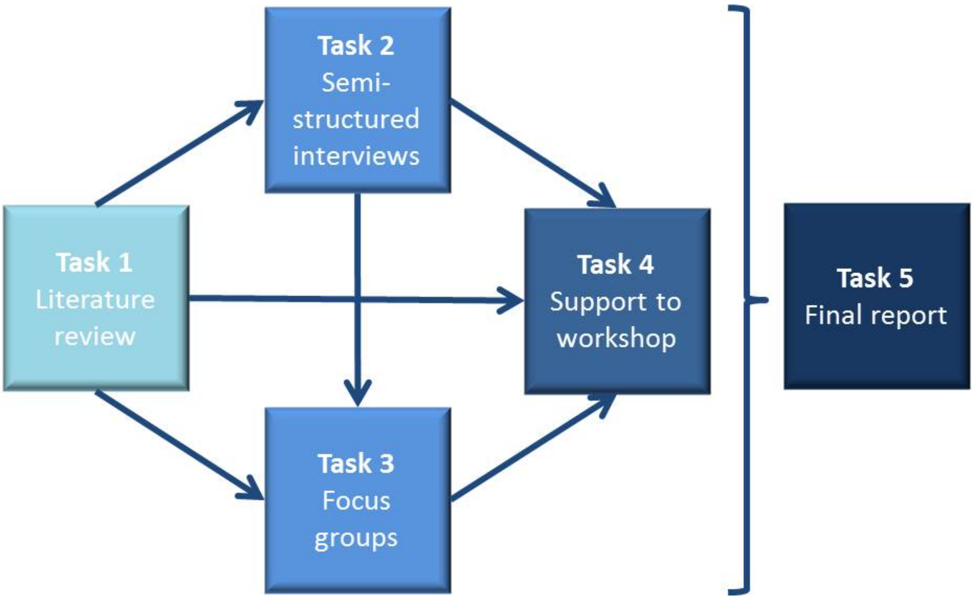
2.2 Overall project outline

The project as a whole is divided into five main tasks.

1. desk research — literature review on specific work-related diseases due to biological agents;
2. the view on policy — semi-structured interviews with experts;
3. focus groups (semi-structured) with intermediaries;
4. support for a workshop;
5. final report, including analysis and policy options.

Figure 1 summarises the above tasks and how they relate to each other.

Figure 1: Overview of how the five tasks relate to each other



2.3 Objectives of the literature review

In contrast to the situation with regard to the majority of chemical and physical factors, commonly approved criteria for assessing exposures, threshold limit values and methodological recommendations for the assessment of work-related exposures and health problems are not yet available for biological factors, with the exception of organic dust (Arbejdstilsynet, 2002), endotoxins (Health Council of the Netherlands, 2010) and some allergens such as α-amylase (Health Council of the Netherlands, 2014). A limited number of well-known diseases have been widely assessed; such assessments mainly cover the exposure of healthcare workers to selected diseases or of agricultural or forestry workers to mainly infectious diseases. A number of new diseases have been recognised (e.g. certain zoonotic infections) and workers suffering from them are compensated in some national schemes, but there is a lack of an overview regarding all relevant exposures, health effects and diseases.

The objective of the literature review is to:

- review existing information on health problems related to exposure to biological agents, paying particular attention to vulnerable workers and covering infectious agents, airborne aerosols and allergenic factors in order to provide an overview of the work-related health effects and diseases linked to exposure to biological agents at work, as well as an overview of biological agents (including those that are less well known), and to identify emerging exposures to biological agents in new professions and new industrial activities;
- provide a structured overview and typology of the work-related health effects and diseases linked to exposure to biological agents at work;
- provide an overview and typology of biological agents, with particular attention to those that are less well known;
- provide an overview of recognised and compensated occupational diseases linked to exposure to biological agents in Europe, and to identify monitoring systems that record work-related diseases linked to biological agents and/or exposure to biological agents and describe their limitations;
- identify databases that provide systematic information on biological agents and risks to workers, and identify and explore existing EU or national datasets that contain information on work-related diseases linked to biological agents and/or exposure to biological agents;
- identify monitoring systems that record these diseases and describe their limitations;
- identify major reviews related to the implementation of Directive 2000/54/EC on the protection of workers from risks related to occupational exposure to biological agents in the EU;
- identify gaps in data/knowledge, to feed, for example, into the development of exposure monitoring tools such as job-exposure matrices or exposure databases and disease registers.

3 Methodological design

The methodology applied in this review aims to meet the objectives stated above. To be able to cover these topics, the results of a scientific literature review, a questionnaire survey and an evaluation of a selection of monitoring systems were combined.

Exposure to biological agents at work may cause a wide range of occupational diseases. Moreover, the range of biological agents to which one may be exposed at work is significant. It is therefore important to gain a better understanding of the occurrence of diseases related to occupational exposure to biological agents and to identify potential emerging occupational exposure to biological agents for new professions and new industrial activities. In order to cover these topics, a systematic literature search was performed. As a starting point for any review that aims to summarise knowledge about these agents, it is important to structure the topics and research questions beforehand. For work-related diseases, knowledge of the relevant work situations, exposures and related health effects are important aspects of the knowledge base. Therefore, the review team first mapped which exposures, occupations and diseases it would be important to study. This outline served as a starting point for the design of the literature search strategy and the categorisation of the results. In addition, this framework made it possible to identify gaps in current knowledge about work-related biological exposure and related diseases.

As part of the outline, the following categories of items considered of relevance for occupational exposure and used as a starting point for the literature review were defined (see Table 2):

- occupations, sectors and workers
- biological agents
- occupational diseases.

Although it is known that they are reported in relation to exposure to biological agents, adverse pregnancy outcomes and cancer were not included in the scope of the literature review.

Table 2: Grouping of topics considered to be of relevance for the literature review into categories (occupations and workers, biological agents and work-related diseases)

Occupations/sectors/workers	Biological agents	Health effects
Laboratories (including laboratory animal workers) Healthcare (human and veterinary) Education (schools) Childcare/day care Agriculture Food processing Cacao industry Wood industry Paper industry Detergent industry Metal industry (metalworking fluids)/industry workers exposed to susceptible technical fluids (coolant circuits) Waste treatment (including composting) Wastewater treatment (including sewage treatment) Biotechnology Bio-based production, such as bio-refining of proteins Outdoor workers Travelling to other countries (occupationally) Vulnerable workers (young, old, pregnant or immuno-	Living organisms: o bacteria o viruses o moulds, fungi, yeast o prions o protozoans o genetically modified organisms (GMOs) Carriers of various biological agents: o organic dust o bioaerosols Substances or structures that originate from living or dead organisms: o exotoxins (of bacteria) o endotoxins o glucans o mycotoxins	**Infectious diseases**/toxic effects: o general symptoms: fever, diarrhoea, fatigue, muscle ache, coughing o respiratory disorders (dyspnoea, dry cough, wheezing) o skin disorders (skin irritation) o organic dust toxic syndrome ([a]) (ODTS) o zoonoses ([b]) o e.g., legionellosis, and tuberculosis o infections caused by microorganisms with antibiotic resistance o health effects related to specific substances — endotoxins: ▪ acute effects: inflammatory response in the lungs, which can lead to acute (respiratory and systemic) effects including fever, shivering, dry cough, chest tightness (in the case of byssinosis), dyspnoea, joint pain and influenza-like symptoms (all symptoms of ODTS) ▪ chronic effects: chronic bronchitis, asthma, reduced lung function/accelerated decline in lung function, increased bronchial reactivity and chronic obstructive pulmonary disease (COPD; entails chronic

Occupations/sectors/workers	Biological agents	Health effects
compromised, workers with little training or knowledge, subcontracted workers)	**Allergens,** originating from o living or dead organisms (see above) o plants o animals	bronchitis, airflow limitation that is not fully reversible). **Viral diseases** such as hepatitis, AIDS (acquired immunodeficiency syndrome) Allergenic/allergic health effects: o hypersensitivity reactions ([c]) of Types I–IV o Type I reactions: rhinitis, asthma o Type III and IV: hypersensitivity pneumonitis/extrinsic allergic alveolitis o commonly reported symptoms: ▪ wheezing and dyspnoea (lower respiratory tract) ▪ rhinorrhoea, sneezing, and nasal congestion (upper respiratory tract) ▪ itching (eyes, nose, skin) o frequently reported diseases: ▪ asthma ▪ rhinitis ▪ atopic dermatitis hypersensitivity pneumonitis)/extrinsic allergic alveolitis (acute, sub-acute, chronic)

([a]) Acute non-allergic flu-like illness, symptoms of which are fever, chills, myalgia, malaise, dyspnoea, dry cough, wheezing, headache, rhinitis, conjunctivitis, keratitis, skin irritation, hypoxia and non-cardiogenic pulmonary oedema.
([b]) Maassen et al., 2012.
([c]) Gell and Coombs classification of hypersensitivity reactions, 1963.

3.1 Scientific literature review

Search strategy

The scientific literature review focused on the identification and evaluation of reviews on the relation between biological agents and adverse health outcomes, either in the published scientific literature or in the grey literature, by means of a transparent and reproducible literature search in the following databases:

- Medline (through PubMed);
- Embase (through Scopus);
- OSH-Update (containing NIOSHTIC, ILO CISDOC, ESENER and HSE documents);
- OpenGrey (containing European grey literature).

The literature search in these databases was restricted to the period from 2010 onwards. Furthermore, only reviews written in Danish, Dutch, English, French, or German were included.

The literature search was performed using existing methods, including clustering of search terms as defined in the PICO method (used for evidence-based models) (Richardson et al., 1995). For more detail, see Annex 1, Part A.

The search terms that were chosen were combined to gather information on the following subjects:

- biological agents and/or related health effects;
- monitoring systems;
- databases;
- the Biological Agents Directive.

In addition, the EU-OSHA, Organisation for Economic Co-operation and Development (OECD) and Eurostat websites were searched for relevant information.

It should be noted that, for the literature search, only English search terms were used. Therefore, only publications that had at least some information in English were retrieved. Publications without any information in English were thus not retrieved with this literature search.

Evaluation of the output from the literature search

An initial screening was performed to check publications retrieved from the literature search for relevance with reference to a set of inclusion criteria, based on title and abstract. This initial screening was performed either using a web-based publication screening tool or manually (for more detail, see Annex 1, Part B). The following inclusion criteria were applied:

- description of exposure to biological agents and/or description of health effects due to exposure to biological agents in a work-related context;
- for the more specific searches for monitoring systems, databases or information on Directive 2000/54/EC, these subjects were added to the first criterion;
- review of existing studies or case reports.

Regarding allergens, papers about food allergens and exotoxins from microorganisms were excluded, because food allergens fall outside the scope of the literature search and the allergenic effects of exotoxins were considered less relevant in an occupational context. Furthermore, exotoxins were included as a search term for 'Biological agents (excluding allergens)' and were thus covered in the literature search as a whole.

Publications that fulfilled the inclusion criteria were retrieved and further evaluated (based on the full text) with the aim of providing an overview of work-related diseases and the exposures causing them, taking into consideration how well the information was supported by scientific evidence and the extent to which it complemented existing EU-OSHA publications related to biological factors and adverse health effects. A special emphasis was put on emerging exposures and more specifically those only recently mentioned in the reviews.

The overview was based on the following topics:

- types of exposures (biological agents);
- types of health effects;
- types of industries and occupations (including indications of, for example, sizes of companies (with particular reference to small and medium-sized enterprises (SMEs)), the presence of vulnerable workers, the likelihood of unintentional exposures, gender and diversity).

Overview of the output from the literature search

An overview of the output from the literature search for the topics 'Biological agents (excluding allergens)' and 'Allergens', as retrieved from Pubmed, Scopus, OSH-Update and OpenGrey, and described in Section 3.1.1, is provided in Figure 2 and Figure 3, as is an overview of the publications that were further evaluated after the initial screening. Within these topics, in addition to reviews specifically covering the topics themselves, articles referring to monitoring systems and databases were also included in the search, as were publications related to the implementation of Directive 2000/54/EC.

For the topic 'Biological agents (excluding allergens)', the literature search identified 1,720 papers on biological agents and/or health effects, 269 papers on monitoring systems, 559 papers on databases, and 108 papers on information regarding the Biological Agents Directive, which added up to 2,656 papers for initial screening for relevance regarding the topic 'Biological agents (excluding allergens)'.

With regard to the topic 'Allergens', the literature search identified 1,132 papers on biological agents and/or health effects, 204 papers on monitoring systems, 170 papers on databases, and 108 papers on information regarding the directive, which added up to 1,614 papers for initial screening for relevance regarding the topic 'Allergens'.

In total, the scientific literature search resulted in 4,270 papers for initial screening based on the inclusion criteria described in Section 3.1.2.

Figure 2: Overview of the output from the scientific literature search in identified databases with regard to biological agents (excluding allergens)

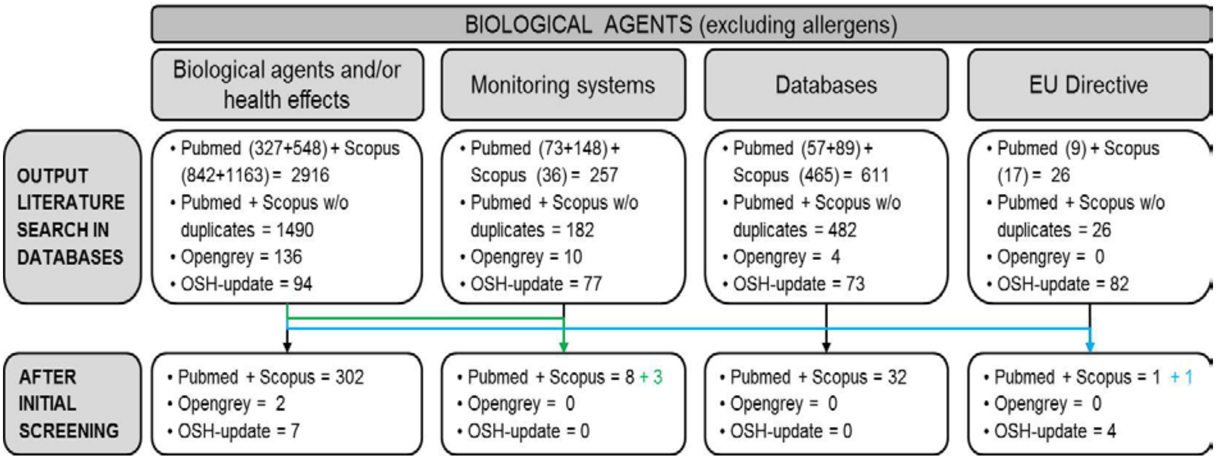
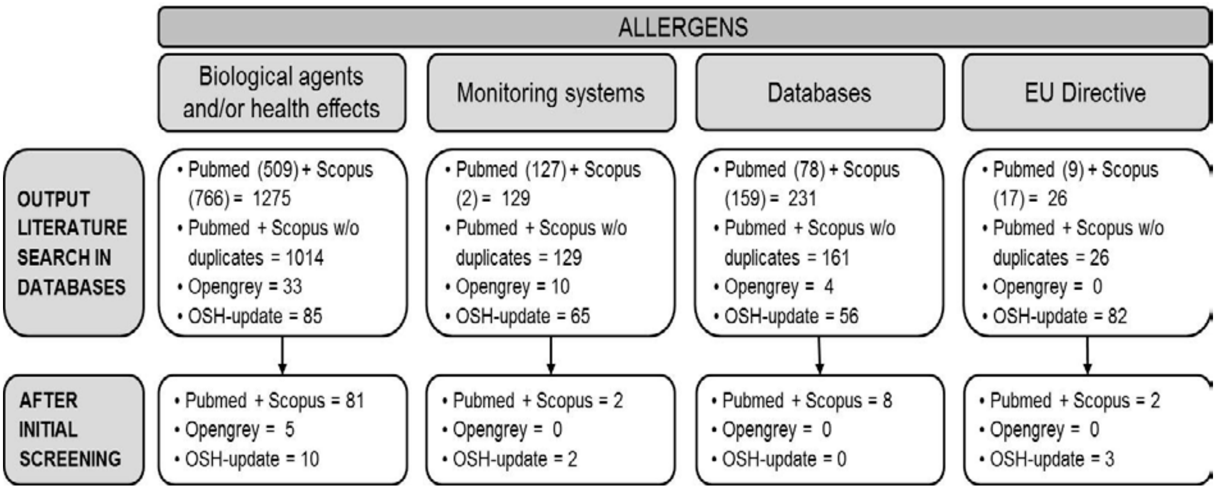


Figure 3: Overview of the output from the scientific literature search in identified databases with regard to allergens



Through initial screening for relevant papers, a condensed set of papers was selected for full evaluation (see Figure 2 and Figure 3**.**). Annex 3 provides a list by topic of the papers that met the inclusion criteria (as described in Section 3.1.2) and were thus selected for further evaluation.

For the topic 'Biological agents (excluding allergens)', 311 out of 1,720 papers on biological agents and/or health effects met the inclusion criteria, as did 11 out of 269 papers on monitoring systems, 32 out of 559 papers on databases and 6 out of 108 papers on information on the directive, which added up to 360 out of 2,656 papers.

For the topic 'Allergens', 96 out of 1,614 papers on biological agents and/or health effects met the inclusion criteria, as did 4 out of 204 papers on monitoring systems, 8 out of 170 papers on databases, and 5 out of 108 on information on the directive, which added up to 113 out of 1,614 papers.

In total, 473 papers were further evaluated. During initial screening, some papers were identified as (also) relevant for another subgroup, in which case they were reallocated or added to the specific subgroup (as shown in Figure 2 by the green and blue arrows). If, during further evaluation of the selected publications, a publication was considered to be (also) of relevance for another subgroup, the same process was applied.

In addition to the scientific literature search in the databases already mentioned, the websites of EU-OSHA, OECD and Eurostat were also searched for relevant information. The publications retrieved in this way (see Annex 3, Part F) were screened and evaluated in the same way as described above.

The information from the selected papers was collected in a structured way, according to types of exposures, health effects, and industries or occupations.

3.2 Questionnaire on national studies and monitoring systems

In Europe, various systems are used to monitor/record occupational exposures to dangerous substances and/or work-related diseases. Although information on exposures to biological agents and the recording of diseases related to these exposures may not cover all exposures in all sectors, it is known that considerable progress has been made in characterising exposures in emerging professions such as green jobs and home care. However, the way in which Member States deal with this topic varies greatly.

Therefore, a questionnaire was developed to gather information about systems from which data about exposures and related diseases could be extracted, as well as to assess whether such information is systematically collected. It was also intended to assess whether the information could be used to help target prevention in relation to the most relevant issues and the main emerging risks. Information from existing systems and initiatives could be used as a starting point for, for instance, the development of tools for monitoring exposures and work-related diseases in the Member States, taking into account current needs and barriers.

Development of the questionnaire

For the development of the questionnaire, information on monitoring programmes by the Modernet initiative ([4]) and the first insights from the literature review described above were used. By means of a

([4]) Modernet (Monitoring trends in Occupational Diseases and tracing new and Emerging Risks in a NETwork) was founded in 2008 as a collaboration between academic centres investigating occupational disease and work-related ill-health incidence in a few EU Member States (the United Kingdom, the Netherlands, France, Italy, Finland and the then Czech Republic). After Modernet received support from the EU, a funded COST (Cooperation in Science and Technology) programme took place during the period 2010-2014: 'ISCH COST Action IS1002 — Modernet, a network for the development of new techniques for discovering trends in occupational and work-related diseases and tracing new and emerging risks'. The action's objective was questionnaire (see Annex 2), the distribution of which is described in the following paragraph, respondents were asked to provide information on the following:

- Part 1: information on the respondent (name, organisation, working position/role, country, experience with regard to biological agents).
- Part 2: national monitoring systems, sentinel and alert systems, and national health provisions, including:
  - national monitoring systems on work-related diseases and on worker exposure to biological agents;
  - relevant sentinel or alert systems;
  - national public health provisions.
- Part 3: initiatives at the (inter)national level, for identifying:
  - national policy with regard to biological agents, beyond the minimum regulations specified in Directive 2000/54/EC;
  - national or local campaigns/strategies;
  - existing expert networks;
  - national reports or ongoing projects.
- Part 4: description of cases based on the experience of the respondent, for the identification of:
  - reported cases;
  - occupations in which the respondents consider exposure to biological agents in the workplace an emerging risk;
  - biological agents that the respondents consider most important;
  - work-related diseases caused by biological agents that the respondents consider most important.

The main aim of the questionnaire, however, was to identify existing systems that record work-related diseases linked to exposure to biological agents, and gather information about each of them, such as the name of the scheme; a short description; whether the information is publicly available, and, if so, in what language; a contact person; and the purpose for which this information is used (e.g. research, input for policy-making or input for prevention programmes). From those identified, a few systems were selected from which data could be extracted. This was done, inter alia, to assess whether such information is systematically collected and whether it can help target prevention in relation to the most relevant issues and emerging risks (see Chapter 4 of this report).

In addition, as a secondary aim, in Part 3 of the questionnaire, respondents were asked if they were familiar with initiatives, campaigns or strategies related to the topic. This information was intended to serve as input to the development of the interview protocol for Task 2 of this project, which involves expert interviews on prevention policies.

Part 4 of the questionnaire was intended to gather information about the topics that the respondents considered important, reports or studies on the subject, or cases of work-related disease due to biological agents, as a supplement to the scientific literature search. They were also asked what they regarded as the most relevant emerging biological risks (with regard to exposure and health effects).

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to develop a network for exchange of knowledge on, and setting the basis for, comparative evaluation and development of new techniques to enhance information on trends in occupational diseases, on discovering and validating new OSH risks more quickly (data mining, workers' and physicians' reporting, coupled with novel statistical techniques) and on the use of modern techniques to discuss and disseminate information (platforms, social media). Between 2010 and 2014, the network grew to include 12 more European countries (Norway, Iceland, Ireland, Belgium, Germany, Switzerland, Spain, Croatia, Romania, the then former Yugoslav Republic of Macedonia, Albania and Malta) and one institute from Australia (Monash University, Melbourne). After the EU funding ended, the network continued to function through the collective work and resources of its members (http://modernet.org).

For most of the questions, the number of examples the respondents were allowed to provide was limited to a maximum of three. They were asked to state which examples they considered to be the most important, so that filling in the questionnaire would not take too much time.

To make sure that the respondents had the same starting point, definitions were given for several terms used in the questionnaire, namely for 'monitoring/registration system', 'sentinel/alert system', '(national) public health provision', 'policy/regulation' and 'campaign/strategy'. Furthermore, the questionnaire provided a short description of the project as a whole, and instructions for the respondents, asking them to use their current knowledge and expertise.

An online version of the questionnaire was created by means of the Collector survey tool Survalyzer (http://www.survalyzer.com). The responses to the online version of the questionnaire were collected in a database, to which the results from questionnaires that had been completed in a Word version were later added using the same online questionnaire tool.

Distribution of the questionnaire

The questionnaire was distributed among non-selected experts operating within various networks, who completed it on a voluntary basis. These networks included:

- EU-OSHA's network of focal points: in each Member State, as well as in the EEA countries, EU-OSHA has a focal point. Each focal point manages its own national tripartite network comprising government bodies and representatives from worker and employer organisations, to which the questionnaire was distributed. The focal point network provides input into EU-OSHA's work, and the questionnaire was distributed by EU-OSHA.
- Eurofound's European Observatory of Working Life (EurWORK) (5): Eurofound works with a network of correspondents who provide national information. EurWORK originated from a merger of Eurofound's observatories on industrial relations (EIRO) and on working conditions (EWCO). Furthermore, Eurofound runs the European Working Conditions Survey, a worker survey that provides information on exposure to dangerous substances, including infectious agents.
- PEROSH is a network comprising 12 OSH institutes across the EU, all of which play key roles in OSH in their Member States, with affiliations to governments/authorities and health and accident insurance systems (6).
- Modernet is a network, with 19 participating European countries, that develops new techniques for discovering trends in occupational and work-related diseases and tracing new and emerging risks.

The online version of the questionnaire was distributed by email, either directly to the experts or via the contact people in the networks. In the case of EU-OSHA's focal point network, the questionnaire was also made available as a Word version. Some focal points provided a single questionnaire representing the views of the focal point as a whole, rather than individual questionnaires filled in by different experts'. Answers were originally collected from 18 March to 10 May 2016.

General information on respondents

Although the link to the online questionnaire was used 169 times, only 62 questionnaires were available for further analysis; 50 unique completed questionnaires were received via the Survalyzer tool, and 12 questionnaires completed in Word were added to the database.

The responses came from 29 European countries (see Table 3) and around 50 different organisations (see Annex 4, Table A4-1). Three of the respondents did not indicate which organisation they

(5) https://www.eurofound.europa.eu/observatories/eurwork

(6) The PEROSH partners aim to coordinate and cooperate on European research and development efforts in OSH, and the network enables them to create synergies and efficiently use resources and knowledge from different countries to improve the quality of research and increase the EU-wide dissemination of results (http://www.perosh.eu).

represented. For most countries (*n* = 22) one or two respondents filled in the questionnaire, although for some countries more responses were obtained (e.g. Norway, Italy and Austria). In general, where there were multiple respondents per country, the respondents represented different organisations.

Table 3: Overview of countries represented by the respondents

Country	Number of respondents
Albania	1
Austria	8
Belgium	2
Bulgaria	1
Cyprus	1
Czechia	1
Denmark	3
Estonia	1
Finland	2
France	1
Germany	2
Greece	1
Hungary	2
Ireland	2
Italy	5
Latvia	1
Lithuania	1
Luxembourg	2
Malta	1
Netherlands	4
Poland	1
Portugal	1
Slovakia	2
Spain	4
Sweden	1
United	3
Macedonia	1
Norway	5
Switzerland	2

About half of the respondents indicated that they had received the questionnaire from an EU-OSHA national focal point, and only two respondents that they had received it from EurWORK (Figure 4). Two respondents did not specify a network, and two respondents indicated that they had received the questionnaire from two networks (one of which was an EU-OSHA national focal point).

Figure 5 gives an overview of the working positions of respondents. One respondent did not indicate any, and the rest of the respondents indicated having a combination of up to four current working positions (41 respondents with 1, 16 respondents with 2, 3 respondents with 3, and 2 respondents with 4 current working positions). In general, most responses were given by respondents who were active as occupational physicians, as researchers and/or in public administration. The combinations 'researcher/occupational physician', 'public administration/occupational physician', 'policy-maker/occupational physician' and 'public administration/policy-maker' were most frequently reported.

Figure 4: Overview of networks from which respondents received the questionnaire

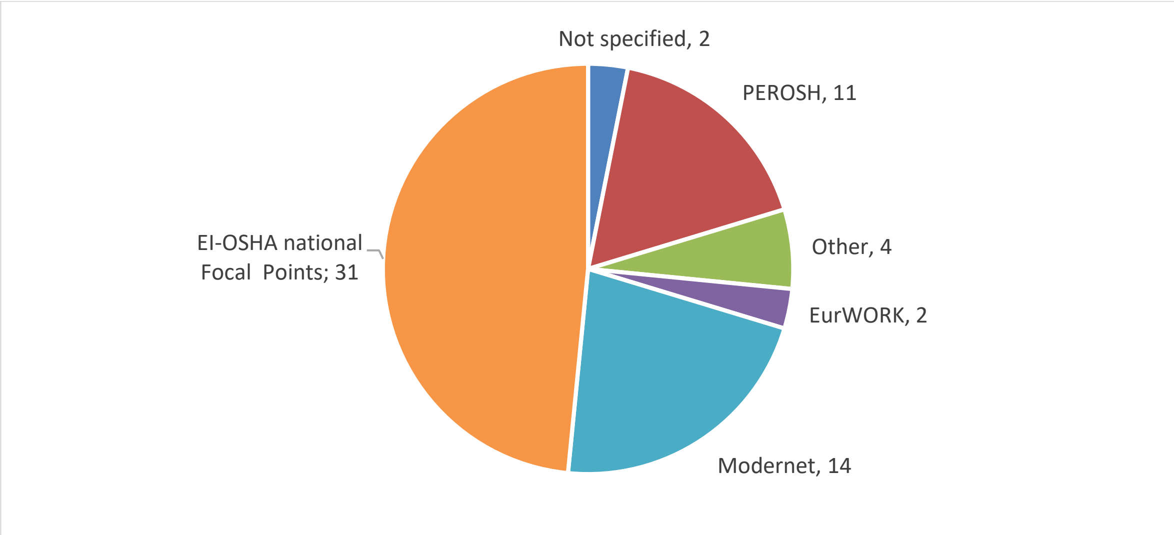
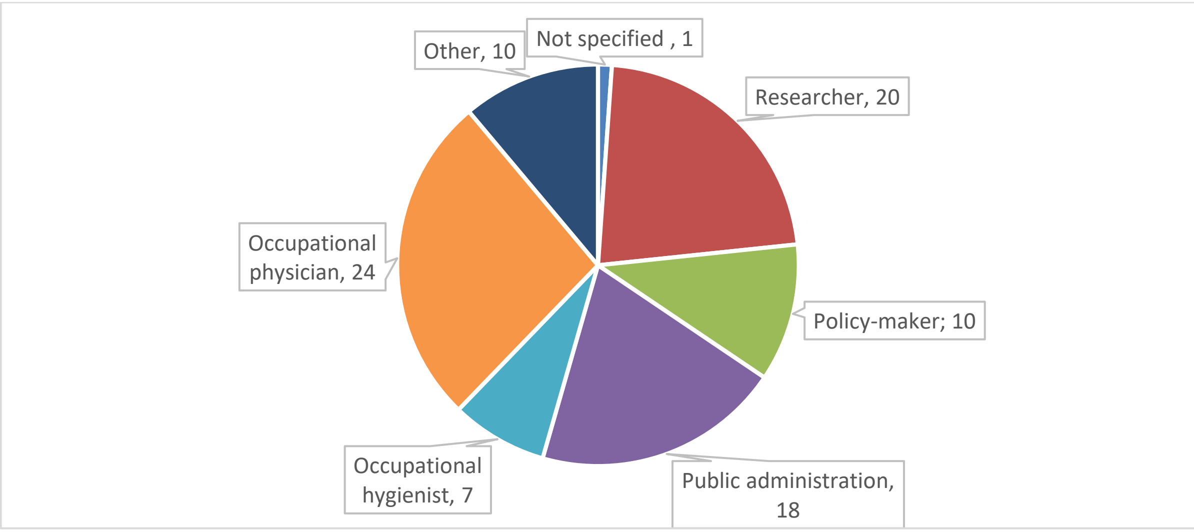


Figure 5: Overview of current working positions as indicated by respondents



The respondents were also asked about their experience regarding biological agents in the workplace. Two respondents indicated that they had 'no experience'. Both for the 28 respondents with 'some experience' and the 31 respondents with 'much experience', the above working positions seemed to be evenly represented. The countries with more than one response generally had an even distribution of respondents with 'some experience' and 'much experience' (see Annex 4, Table A4-1).

Evaluation of responses to the questionnaire

As the questionnaire was distributed among non-selected experts operating within various networks, who filled in the questionnaire on a voluntary basis, the responses do not provide a representative overview of, for instance, the systems in place in Europe. Since in most cases only one or a few respondents per country filled in the questionnaire, with variable backgrounds and levels of experience in the subject, the the questionnaire results are not considered to be representative and the responses are considered to be indicative. Owing to the exploratory nature of the questionnaire, a detailed (quantitative) evaluation was not considered appropriate.

The responses were first screened to make sure that the database contained only unique responses. In the case of multiple responses, only the last submitted questionnaire was considered. Incomplete responses (in which the questionnaire was only partly filled in) were excluded from further evaluation.

Since the responses varied greatly in terms of length and level of detail, they were grouped into more general categories based on the expertise of the project team, in order to present a clear overview. Although detailed (extensive) answers provided enough information on the topics considered to be relevant, answers with limited detail frequently meant that some of the relevant parameters were classified as 'unknown'/'not specified'. An effort was made to extract as much information as possible. In these cases, additional information was gathered by visiting a website, if information on such was provided by the respondent and if the information on the website was available in English. Additional information was occasionally available when a project member was familiar with the system referred to.

The responses are presented on the basis of the identified categories for a particular topic, on which individual answers have been collated to maintain clarity. Which individual responses were provided by one respondent is not evident from the table but this information can be found in Annex 4.

3.3 Exploring and comparing selected systems

A selection of systems from the identified national monitoring systems for exposures to biological agents and their related diseases were explored and compared in more detail. This evaluation focused on:

- generating an overview of reported exposures to biological agents;
- where possible, distinguishing the related sectors/industries/jobs;
- generating an overview of reported diseases due to exposure to biological agents;
- where possible, distinguishing the related sectors/industries/jobs;
- assessing the way in which the information generated by these systems is used, with a specific focus on whether it is used to target prevention (and, if so, in what way);
- identifying the limitations and/or benefits of these systems;
- identifying needs and potential for the successful implementation of such systems with regard to:
    - job-exposure matrices;
    - exposure databases;
    - disease registers.

The selection of systems for further evaluation was mainly based on the answers to the questionnaire. The countries that were considered to be of particular interest owing to their reputation for having the knowledge and infrastructure to deal with exposure to biological agents (France, Germany and Denmark) and the language in which the information about the system was available (bearing in mind that members of the project team spoke English, German, French, Finnish, Danish and Dutch) were taken into account. Furthermore, information from another project carried out by the consortium under the same framework contract, which focused on alert and sentinel systems, was also taken into account (EU-OSHA, 2018).

4 Results of the scientific literature review and questionnaire

4.1 Literature review — biological agents (excluding allergens) and related health effects in the occupational context

For this section, the definition of biological agents given by Directive 2000/54/EC has been used. In contrast to Section 4.3 on allergen-related health effects, agents of plant and animal origin are not covered. After initial screening, the literature search resulted in a total of 2,916 potentially relevant publications from Scopus and Pubmed, with an additional 230 publications from OpenGrey and OSH-Update. After eliminating duplicates and articles unavailable in a language covered by the project, 1,720 publications were selected for further evaluation, of which 312 were considered for full evaluation after screening of the abstracts (see Annex 5, Part A). Of these 312 publications, 13 could not be retrieved, not even after contacting the first author, and therefore remained unavailable for full evaluation. For these publications, the relevant information from the abstracts was taken into account. Thus, the total number of publications evaluated was 299.

Upon evaluation of the full publication, 128 publications were rejected because:

- The biological agents reported induced allergenic effects only; these are evaluated separately in Section 4.3 (see, for example, Jeebhay and Cartier, 2010; Prester, 2011; Newman and Newman, 2012).
- No relation to an occupation could be identified or the relation between disease state or incidence and exposure was ambiguous. For instance, a publication by Smolak (2014) reported an increased incidence of human immunodeficiency virus (HIV) infections in fishermen in Africa and Asia, but 96 % of this group reportedly had another partner in addition to their regular partner, which is not considered an occupational risk as such.
- The authors observed no health effect. For instance, the transmission of transmissible spongiform encephalopathies to healthcare workers through clinical contact or non-invasive clinical investigative procedures was investigated, but no increased risk of transmission was reported (Bauer and Kantayya, 2010).
- The disease was not relevant to the EU. An example is the zoonotic Brazilian Vaccinia virus infection (Kroon et al., 2011), which is an infection located in Brazil only, or infection risks to urban farmers in developing countries watering their crops with wastewater (Mara and Sleigh, 2010).

The relationship between occupational exposure to a specific biological agent and disease causation is not always unequivocal, especially when only a small number of publications of questionable quality exists, or when findings in publications of relatively good quality are not consistent. Although biological agent-related health issues within the agricultural sector, among healthcare workers or among sex workers are well described in the literature, only a single publication each was retrieved for the aquaculture sector, bone button makers, border guards, fertiliser workers and outdoor game managers (who are responsible for the management of wild animals that are hunted for sport). When a publication gave a precise description of the workers affected/occupation(s) (e.g. car drivers), it was used; otherwise a generic term (e.g. indoor workers) was used. As far as possible, specific terms have been used.

Health effects in specific occupations

For several occupations, a wide spectrum of agents and related diseases were identified in the literature evaluated. An overview of the most significant findings from the literature, including the emerging risks and/or vulnerable groups mentioned in the relevant studies, is provided in the text below, and a comprehensive overview of diseases caused by occupational exposure to biological agents is given in Table 5-Table 15.

Abattoir (slaughterhouse) workers

For abattoir workers, including meat inspectors and meat salvagers, several publications were retrieved that covered the risk of infections from a very broad range of viruses, bacteria, fungi and parasites, mostly related to direct contact with infected animals, organs or their body fluids, blood, fecal matter, urine and placental or fetal fluids from slaughtered animals that may be infected with pathogens of zoonotic origin.

The bacteria and related infections most frequently mentioned were:

- *Leptospira* (causing leptospirosis) (Adler and de la Peña Moctezuma, 2010; Canini, 2010; Haagsma et al., 2012; McDaniel et al., 2014; Ganter, 2015) and *Chlamyodphila* (Canini, 2010; Ganter, 2015). *Leptospira* infection has a worldwide occupational association, especially in developed countries, with agriculture and animal production (cropping, dairy farming, pig production, abattoirs). Humans usually become infected through direct occupational, recreational or domestic contact with the urine of carrier animals, or through contact with contaminated water or soil (Adler and de la Peña Moctezuma, 2010).
- *Brucella* (brucellosis) (EU-OSHA, 2009a; Canini, 2010; Haagsma et al., 2012; McDaniel et al., 2014; Ganter, 2015).
- *Coxiella burnetii* (Q fever) (EU-OSHA, 2007a; Canini, 2010; Haagsma et al., 2012; Morrissey et al., 2014; McDaniel et al., 2014; Ganter, 2015).
- Bovine tubercle bacilli (tuberculosis) (EU-OSHA, 2007a; EU-OSHA, 2009a; Canini, 2010; Ganter, 2015).

Bird-related zoonoses in abattoir workers were reviewed by Kozdrun et al. (2015), and the bacteria-related diseases they found were ornithosis, salmonellosis, campylobacteriosis, yersiniosis, colibacteriosis, erysipeloid and listeriosis. Virus-related diseases mentioned are avian influenza, West Nile virus infection, and Newcastle disease.

The most frequently mentioned viral infections related to slaughterhouse work are avian influenza, influenza-like illnesses such as louping ill virus (EU-OSHA, 2007a; Haagsma et al., 2012; Jeffries et al., 2014), and hepatitis B and E viruses (Pavio and Mansuy, 2010; Haagsma et al., 2012).

For abattoir workers, tick-borne diseases are also of concern, as workers can be infected via the blood, body fluids and tissues of infected animals (Bente et al., 2013). Crimean-Congo haemorrhagic fever, a vector-borne disease transmitted by Hyalomma ticks, is endemic to Africa, the Balkans, the Middle East and Asia (Bajpai and Nadkar, 2011). Its occurrence in Europe — notably in Spain and Portugal — has been confirmed by the presence of the Hyalomma tick in these countries, together with the use of virological or serological evidence.

Fungal infection may result in histoplasmosis and cryptococcosis, whereas parasite-related diseases include Lyme disease, Q fever, salmonellosis and tick-borne encephalitis (Kozdru et al., 2015).

An expert forecast on emerging biological risks indicates that livestock may act as a reservoir of biological agents, potentially resulting in global epidemics/zoonoses involving diseases such as SARS, avian influenza, Ebola and Marburg viruses, cholera, dengue fever, measles, meningitis, yellow fever, Q fever, legionellosis, tuberculosis and tularaemia, all of which may affect abattoir workers (EU-OSHA, 2007a).

Agricultural workers

Because of their work with crops and/or livestock, agricultural workers may be exposed to animals, animal fluids (urine, milk, etc), animal feeds, plants and parasites. Livestock workers may sometimes experience accidental needlestick injury (NSI) while vaccinating or injecting medications to animals, and this may cause serious infections (Jennissen et al., 2011).The spectrum of activities and consequential exposure to a diverse range of biological agents in agricultural work results in the prevalence of various work-related diseases in this sector. These range from outbreaks of zoonoses (Q fever) to diseases resulting from inhalation of organic dust, which brings a high risk of exposure to bacteria, viruses, fungi or biological agent-related toxins. According to Zukiewicz-Sobczak et al., (2013a), for example, in 2010 the most common occupational diseases in agriculture in Poland were reportedly (allergic) pneumoconioses (26.9 % of all occupational diseases) and infectious and parasitic diseases (24.9 %). In Poland, the incidence of occupational diseases was 418.5 per 100,000 workers among agricultural workers and foresters. Infectious and parasitic diseases prevailed among the most commonly recognised diseases (92.4 %), and Lyme disease was the most common among these (96.7 %). Although recent surveys indicate that the overall prevalence of Lyme borreliosis may be stabilising, its geographical distribution is increasing. In Europe, the annual number of cases is increasing in some areas, and tick vectors are expanding their range to higher altitudes and latitudes, suggesting that Lyme disease will remain an important health concern in the coming decades, especially in the light of economic, land use and climate change predictions (Rizzoli et al., 2011).

Not surprisingly, a significant amount of publications describe tick-borne diseases (encephalitis, Lyme disease, Crimean-Congo haemorrhagic fever, tularaemia) related to agriculture (EU-OSHA, 2009b; Canini, 2010; Bajpai and Nadkar, 2011; Dutkiewicz et al., 2011; Rizzoli et al., 2011; Haagsma et al., 2012; Nowak-Chmura and Siuda, 2012; Amicizia et al., 2013; Bente et al., 2013; Zukiewicz-Sobczak et al., 2013a; Applebaum et al., 2016) and forestry (Richard et al., 2015). It is noted that in Europe, as with abattoir workers, Crimean-Congo haemorrhagic fever is endemic in the Balkans, and virological or serological evidence confirms its presence also in Spain and Portugal (Bente et al., 2013).

With respect to other bacterial infections, leptospirosis (Adler and de la Peña Moctezuma, 2010; Dutkiewicz et al., 2011, Richard et al. 2015), Q fever and tuberculosis are the main ones referred to. Q fever (*Coxiella burnetii*) is well described among dairy workers and (livestock) farmers, mostly related to outbreaks in the period 2001-2010, for example in the Netherlands (Dutkiewicz et al., 2011; Dorko et al., 2012; Haagsma et al., 2012; Honarmand, 2012; Morrissey et al., 2014; Ganter, 2015). The major infection route for farmers is via inhalation of aerosols from urine, faeces and birth by-products. *Coxiella burnetii* persists in the environment in a resistant spore-like form.

In addition to Q fever, tuberculosis is one of the bacterial infections most referred to in literature (EU-OSHA, 2008; De Kantor et al., 2010; Dungan, 2010; Trajman and Menzies, 2010; Hardin et al., 2011; Ganter, 2015). Bovine tuberculosis is associated with airborne acquired infection in animal keepers and meat industry workers from countries in which bovine tuberculosis remains a problem. In addition to infection via inhalation, dermal infection also seems to be relevant in relation to tuberculosis (EU-OSHA, 2008). *Mycobacterium bovis* infection in humans, however, appears to be relatively rare (De Kantor et al., 2010). Furthermore, methicillin-resistant *Staphylococcus aureus* (MRSA) is one of the bacterial risks frequently reported (EU-OSHA, 2007a; Doyle et al., 2012; Stefani et al., 2012; Guardabassi et al., 2013; Montano, 2014).

Hepatitis E among pig farmers (Dungan, 2010; Lewis et al., 2010; Pavio and Mansuy, 2010; Wilhelm et al., 2011; Haagsma et al., 2012; De Schrijver et al., 2015; Sayed et al., 2015) and swine and avian influenza among pig and poultry farmers (EU-OSHA, 2009b; Dungan, 2010; Trajman and Menzies, 2010; Dutkiewicz et al., 2011; Gangurde et al., 2011; Haagsma et al., 2012; Jeffries et al., 2014; Kozdrun et al., 2015; Van Kerkhove et al., 2011) are the viral infections referred to most in the agricultural context.

Relatively few fungal infections in agricultural workers were identified in the reviewed literature. Onychomycosis (nail infections), sycosis (inflammation of hair follicles, especially of the beard area) and suppurating tinea kerion (fungal ringworm infection of the hair follicles of the scalp (and occasionally the beard)) are mentioned by EU-OSHA (2008) and dermatomycoses by Seyfarth and Eisner (2010).

With regard to exposure to organic dust and/or endotoxins as a component of organic dust and respiratory effects, several publications described an increased risk of COPD, interstitial lung disease and more generic airway effects such as coughing, irritation, lung function decline and chest congestion (EU-OSHA, 2007a; Cambra-López et al., 2010; Smit, 2011; Szczyrek et al., 2011; Tsapko et al., 2011; Diaz-Guzman et al., 2012; May et al., 2012; Basinas et al., 2013; Duquenne et al., 2013; Samadi et al., 2013; Omland et al., 2014; Nordgren and Bailey, 2016); immune-related effects arising from organic dust (endotoxin) exposure among (livestock) farmers are mentioned (EU-OSHA, 2007a), whereas others indicate a reduction in the risk of lung cancer (Lenters et al., 2010; Lundin and Checkoway, 2009).

In central and eastern Europe, cases of human dirofilariasis, a parasitic disease caused by the species *Dirofilaria repens* and *Dirofilaria immitis* and transmitted by mosquitoes, are noted as an emerging zoonosis by Dutkiewicz et al. (2011). No vulnerable groups were identified.

Pet shop workers

Halsby et al. (2014) reviewed the zoonotic risks from pet shops. Pet shops can be the focus of very large outbreaks of disease, transmitted from animal to animal and then through several owners or visitors. Bacterial, viral and fungal diseases were identified, and ranged in severity from mild to life threatening. Salmonellosis and psittacosis were the most commonly documented diseases, however more unusual infections such as tularemia were also identified. Many related to infections in pet shop workers. The animals involved in the transmission of these infections included birds, mammals and rodents, and covered both common household pets, such as dogs and cats, and more exotic creatures, such as iguanas and prairie dogs. Some zoonotic infections were associated with a variety of different companion animals (e.g. salmonellosis), whereas others were associated with only a narrow range of species (e.g. psittacosis). The diseases identified through this review are referenced in Tables 5 – 15.

Healthcare workers

Based on the publications retrieved for healthcare workers, the main topics are influenza, tuberculosis, hepatitis and HIV infection.

According to Kuster et al. (2011), healthcare workers are at a higher risk of asymptomatic, but not symptomatic, influenza infection. Their cumulative exposure to influenza (or the influenza vaccine) over time may be higher than that of other workers, so that prior immunity reduces symptom severity. In relation to pandemic influenza situations, an evaluation of personal protective equipment (PPE), namely N95 masks or surgical masks, to protect healthcare workers from influenza infection concluded that ocular protection should also be included to prevent infection via the mucous membrane of the eyes (Gralton and McLaws, 2010). As regards influenza and *Bordetella pertussis*, the causative agent of pertussis or whooping cough, as well as measles, a major discussion is under way regarding vaccination rates among healthcare workers (Talbot et al., 2010; Aguilar-Díaz et al., 2011; Maltezou and Tsakris, 2011; Bechini et al., 2012; Blasi et al., 2012; Burnett et al., 2012; Prematunge et al., 2012; Beškovnik et al., 2013; Randall et al., 2013; Fiebelkorn et al., 2014)) and their reasons for reluctance regarding vaccination, despite being identified as a risk group acting as potential amplifiers of infection among their patients (no authors listed, 2010; Aguilar-Díaz et al., 2011; Dolan et al., 2013). However, the possible transfer of biological agents from healthcare workers to patients falls outside the scope of this review and is not taken into account.

The majority of healthcare worker-related publications that were identified in the literature search related to hepatitis B virus, hepatitis C virus or HIV infections via sharps or needlestick injuries (Alavi and Hajiani, 2011; Alghamdi and Alkhodair, 2011; Deuffic-Burban et al., 2011; Khan and Attaullah, 2011; Noorali et al., 2011; Shrosbree et al., 2011; Valim and Marziale, 2011; Goniewicz et al., 2012; Haagsma et al., 2012; Hadaway, 2012; Darius et al., 2013; Kouyoumjian et al., 2013; Zhen et al., 2013; Elseviers et al., 2014; Brewczyńska et al., 2015; Lewis et al., 2015; Trevisan et al., 2015; Coppola et al., 2016). Injuries may also be linked to the use of catheters (Hadaway, 2012), which is increasing, for example in interventional cardiology (Smilowitz et al., 2013). Hepatitis C infections were also linked to dialysis centres (Shaheen and Idris, 2015)

Healthcare workers working abroad are at risk of acquiring some emerging infections such as Middle East respiratory syndrome coronavirus (MERS-CoV), Ebola virus disease (Ebola), severe acute respiratory syndrome (SARS), and avian influenza (Suwantarat and Apisamtharat, 2015) and infection control measures may be limited during an initial encounter, at the beginning of outbreak and with an overwhelming number of patient cases. Kortepeter et al. (2010) reviewed the risks to healthcare workers in developing-world clinical settings (needlestick injuries, haemorrhagic fever viruses, severe viral respiratory disease, and (multiresistant) tuberculosis), with suggestions for risk mitigation. They highlighted the fact that surveillance systems do not classify this group separately from business or leisure travelers but record them instead as tourists, missionaries, or others. Furthermore, this is a diverse group, ranging from short-term travelers to workers in refugee camps; consequently, their individual activities and travel destinations around the globe pose varied risks.

Needlestick injuries

Healthcare workers worldwide are especially exposed to injury by sharp instruments in the course of their duties. The most frequently executed procedures with injury risk are intramuscular or subcutaneous injection (22 %), taking blood samples or intravenous cannulation (20 %) and repeatedly replacing the cap on an already used needle (30 %) (Goniewicz et al., 2012). De Carli et al. (2014) found that phlebotomy([7]) was the procedure carrying the highest risk of exposure and infection, involved in 30–50% of HIV and HCV cases following accidental blood exposures since the 1990s in Italy and France. In laboratories, problems in the management of sharps containers, recapping, needle disassembly by hand and blood transfer from syringes into tubes were observed and accounted for two-thirds of injuries. Sharps and needlestick injuries among healthcare workers are a significant risk for seroconversion ([8]) of hepatitis and HIV. The amount of publications on this topic identified in the literature search was large. Factors affecting the risk of seroconversion include the type of needle (closed or hollow), the HIV RNA level and the volume of inoculated ([9]) blood, and the depth of the injury (Shrosbree et al., 2011).

An overview of the prevalence data found in the literature on hepatitis and HIV seroconversion via sharps and needles in healthcare workers is provided in Table 4.

Table 4: Overview of prevalence data found in the literature evaluated for hepatitis and HIV seroconversion via sharps and needles in healthcare workers

Type of injury	Incidence (%)	Hepatitis B seroconversion (%)	Hepatitis C seroconversion (%)	HIV seroconversion (%)	Study
Sharps	3.7	0.42	0.05-1.3	0.04-0.32	Elseviers et al., 2014
Sharps and needlestick		6-30	0.5-10	0.09-0.3	Hadaway, 2012
Needlestick	59 ([a])				Kouyoumjian et al., 2013
Needlestick				0.3 ([b]) 0.09 ([c])	Shrosbree et al., 2011
Sharps and needlestick		10-30	4-10	0.1-0.3	Trevisan, Nicolli and Chiara, 2015
Unsafe sharps handling, muco-cutaneous exposure from body fluid splashes, and glove perforation from excessive wear		2-40	2.7-10	0.3	Tso and Athreya, 2013

([a]) Occupational injuries among healthcare workers are common, although they are under-reported. In one study, 59 % of healthcare workers reported a needlestick injury in the previous year.

([b]) Assuming that no post-exposure chemoprophylaxis is given to healthcare workers.

([c]) Risk of mucous membrane exposure.

([7]) Phlebotomy (from the Greek words phleba-, meaning "vein", and -tomy, meaning "to make an incision of") is the process of making an incision in a vein with a needle.

([8]) During an infection or immunisation, antigens enter the blood, and the immune system begins to produce antibodies in response. In immunology, seroconversion is the time period during which a specific antibody develops and becomes detectable in the blood. After seroconversion has occurred, the disease can be detected in blood tests for the antibody.

([9]) Inoculate: introduce (an infective agent) into an organism.

Several publications looked at the efficiency of devices and policies to prevent needlestick injuries (Hadaway, 2012; Lavoie et al., 2014).

Pedrosa et al. (2011) also investigated other exposure pathways for infection with partly serious viral diseases to healthcare and laboratory workers and found that aerosol inhalation was an important pathway too, for example lymphocytic choriomeningitis virus, hantavirus infections, and coxsackievirus infections.

Hepatitis

According to Eurostat, health and social work and public administration accounted for the majority of cases of hepatitis C infection (97 %), hepatitis A infection (88 %) and hepatitis B infection (60 %) among reported recognised occupational infectious diseases in 12 European countries in 2001 (Karjalainen and Niederlaender, 2004). Askarian et al. (2011) cited a study from the 1990s that found that 14.4 % and 1.4 % of hospital workers were infected with hepatitis B virus and hepatitis C virus, respectively. In an evaluation of the development of Hepatitis C worldwide, Alter et al. (2007) found a dramatic increase in infections. Hepatitis C-infected people serve as a reservoir for transmission to others and are at risk for developing chronic liver disease, cirrhosis, and primary hepatocellular carcinoma. It has been estimated that hepatititis C accounts for 27% of cirrhosis and 25% of hepatic cancer worldwide (Alter et al., 2007). Likewise, an estimated 257 million people are living with hepatitis B virus infection (defined as hepatitis B surface antigen positive). In 2015, hepatitis B resulted in 887,000 deaths, mostly from complications (including cirrhosis and hepatocellular carcinoma). The hepatitis B virus can survive in dried blood for up to seven days at 25°C and is significantly more infectious than either hepatitis C or HIV, with a reported transmission rate of up to 30% from needlestick injuries (WHO, 2018). In an appreciation of the Canadian situation, Bhat et al. (2012) analysed the situation of infected healthcare workers and recommended to set guidelines to standardise monitoring of hepatitis B infection among healthcare workers to improve health care workplace safety and patient care, and clearly define the conditions under which infected healthcare workers are allowed to work. A guideline with the same scope that includes students recommends setting up a panel for specific exposure-prone situations (CDC, 2012). The risk of hepatitis B and C transmission in healthcare settings has also generated considerable attention regarding legal consequences (Bobinski, 2010) and more studies have touched on the measures for prevention of infection between different collectives (Michelin et al., 2010; Lewis et al., 2015).

The hepatitis B surface antigen (HBsAg) is most frequently used to screen for the presence of infection, which may not be the most appropriate measure of infectivity. Shortly after the appearance of HBsAg, another antigen, called the hepatitis B e antigen (HBeAg), will appear. Traditionally, the presence of HBeAg in a host's serum is associated with much higher rates of viral replication and increased infectivity; however, variants of the hepatitis B virus do not produce the e antigen. Hepatitis B virus seroconversion is reportedly high (approximately 30 %) if the source patient is HBe antigen (HBeAg) positive, although it is less than 6 % if the source is HBs antigen (HBsAg) positive (Trevisan et al., 2015).

In dental care settings, microorganisms can be transmitted through direct contact with contaminated instruments or surfaces, splash or spray of infectious fluids or materials in the mucosa of the eyes or mouth, and by inhalation of airborne infectious agents (Younai, 2010).The highest prevalence of hepatitis B is reported among dentists (Mahboobi et al., 2010; Askarian et al., 2011), with infection rates among dentists that are 3 to 10 times higher than the general population (Younai, 2010). However, the prevalence of hepatitis C among dentists is reportedly similar to that in the general population (Garbin et al., 2014; Mahboobi et al., 2014; Pozzetto et al., 2014) .

HIV

According to Wild and Dellinger (2013), international guidelines recommend universal screening for HIV in healthcare settings only when the undiagnosed prevalence of HIV is > 0.1 %, or the diagnosed prevalence is > 0.2 %. For low-prevalence countries such as Austria, which has recorded only four cases of occupational HIV infection in 15 years of documentation, a more focused testing strategy was recommended instead. In addition, there is no convincing evidence that knowledge of the serostatus of a patient leads to changes in relation to PPE use by healthcare workers (Wild and Dellinger, 2013), indicating that universal screening may not always be an effective measure to prevent infections in healthcare workers, and that more needs to be done to increase workers' awareness and improve prevention. A review conducted in low- and middle-income countries showed that workplace programmes for health workers may increase the uptake of HIV testing and the awareness of post-exposure prophylaxis to prevent HIV infection (Yassi et al., 2013), in line with the ILO guidelines for improving health workers' access to HIV and TB prevention, treatment, care and support services. The guidelines provide a framework for workplace policies, programmes, and training (ILO/WHO, 2010) . Rey (2011) reviewed different antiretroviral combinations used after exposure, including of workers, their safety profile, the recommendations and indications of post exposure prophylaxis.

Tuberculosis

Tuberculosis is one of the best known, most studied occupational respiratory infectious diseases, caused by mycobacteria transmitted through the air. Healthcare workers are a well-known risk group (EU-OSHA, 2007a; EU-OSHA, 2009b; Ling and Menzies, 2010; Haagsma et al., 2012; Alavi and Alavi, 2013; Narasimhan et al., 2013; Montano, 2014; Brewczyńska et al., 2015); it is estimated that they have twice the chance of becoming infected in high-income countries and up to 10 times the chance in low- and middle-income countries (Trajman and Menzies, 2010). Eurostat has reported that health and social work together with public administration accounted for the majority of the cases of tuberculosis (88 %) notified in 12 European countries in 2001 (Karjalainen and Niederlaender, 2004; Eurostat, 2010). In addition to transmission via the air, entry via the skin due to needlestick injury is described in the literature (Goniewicz et al., 2012; Haagsma et al., 2012), and there are concerns about the possible risks of viable *Mycobacteria tuberculosis* potentially present in surgical smoke (Chowdhury et al., 2011). Among healthcare workers in high-income countries, the overall incidence of tuberculosis in the general population and in native-born healthcare workers was less than 10 and 25, respectively, per 100,000 per year (Narasimhan et al., 2013, citing Seidler et al., 2005). Seidler et al. found the risk of tuberculosis to be elevated in hospital workers in wards with tuberculosis patients; nurses in hospitals; nurses attending HIV-positive or drug-addicted patients; pathology and laboratory workers; respiratory therapists and physiotherapists; physicians in internal medicine, anaesthesia, surgery and psychiatry; non-medical hospital personnel in housekeeping and transport work; funeral home employees; and prison employees. The development of tuberculosis in an exposed individual is a two-stage process following infection. In most infected persons, infection is contained by the immune system and bacteria become walled off in caseous granulomas, or tubercles. In about 5 % of infected cases, rapid progression to tuberculosis will occur within the first 2 years after infection (Narasimhan et al., 2013), but the risk of progression is much higher, at about 10 % of infected cases within the first year, in HIV-positive and other immunocompromised individuals.

Surgical smoke

For healthcare workers, a number of publications were retrieved on the risks posed by surgical smoke (Chowdhury et al., 2011; Lewin et al., 2011; Pierce et al., 2011; Khajuria et al., 2013; Mowbray et al., 2013; Okoshi et al., 2015). Surgical smoke plume is a dangerous by-product generated from the use of lasers, electrosurgical pencils, ultrasonic devices, and other surgical energy-based devices. As these instruments cauterise blood vessels and destroy (vaporise) tissue, fluid and blood, a gaseous material known as surgical smoke plume is created. It is estimated that approximately 95 % of all surgical procedures produce some degree of surgical plume. Bioaerosols may be produced in surgical smoke generated at low temperatures, for example when using harmonic scissors ([10]), and this smoke may contain live multidrug resistant *Mycobacterium tuberculosis* or viral DNA of hepatitis B virus, hepatitis C virus, HIV or human papillomavirus (Chowdhury et al., 2011; Pierce et al., 2011; Mowbray et al., 2013).

([10]) A surgical instrument used to simultaneously cut and cauterise tissue.

Evidence of pathogen transmission via surgical smoke is reportedly inconsistent (Pierce et al., 2011). However, the risk of transmission of an infectious disease if bacterial or viral fragments are inhaled via surgical smoke, owing to the use of ultrasonic scissors, lasers or electrocautery (Okoshi et al., 2015), is of concern. No epidemiological studies have been conducted with regard to bacterial transfer via surgical smoke (Pierce et al., 2011). However, virological analyses have suggested or confirmed a causative link between occupational exposure to human papillomavirus DNA in the laser plume generated by medical lasers and the occurrence of laryngeal papillomatosis (Pierce et al., 2011). Khajuria et al. (2013) and Mohebati et al. (2010) reviewed prevention measures applicable to surgeons and auxiliary staff.

Other issues

According to Garg et al. (2012), dental unit waterlines may be a source of infection for patients and for dental workers. They therefore propose a set of hygiene measures to protect both collectives. Jayanthi et al. (2013) describe the oral manifestations of prion diseases and alert to the potential, albeit low, risk to dental workers, as prion proteins resist conventional sterilization methods used in dental clinics and laboratories.

Hersi et al. (2015) reviewed the protective measures, in particular PPE, for workers caring for patients with filovirus diseases such as Ebola and Marburg virus infections, for the WHO guidance on the topic and recommended provision of training to healthcare workers in affected regions as a “key strategy” for preventing transmission. WHO developed job aids for HCWs on how to put on and remove PPE, and provided training on clinical management to healthcare workers. The case of an auxiliary nurse infected in Spain by an Ebola patient returning from an endemic region (WHO, 2014) illustrates that to avoid cases of serious diseases similar prevention approaches need to be taken in Europe. A preparedness plan is essential to cope with the importation of such diseases and limit their subsequent spread (Wong and Wong, 2015). An article by Lupton (2015) captures the author’s own experience of working in a treatment centre in Sierra Leone, to inform healthcare workers considering deployment to West Africa to work in a treatment centre.

Quite a few articles were retrieved that discussed hygienic measures to prevent the spread of microorganisms with multiple antibiotic resistance and nosocomial infections (e.g. Kampf and Löffler, 2010; Mani et al., 2010; De Oliveira et al., 2012; Jadhav et al., 2013; Landelle et al., 2013; Rothe et al., 2013; Yezli et al., 2014). DeOliveira et al. (2012) and Mitchell et al. (2015) referred to the role of healthcare apparel and clothing in the transmission of pathogens and Yezli et al. (2014) and Volquind et al. (2013) to operating room surfaces, in particular anesthesis equipment which is complex and may be difficult to clean. Ulger et al. (2015) investigated the role of mobile phones in disease transmission, as mobile phones are rarely cleaned after handling. There may be repeated contamination between the hands and face (e.g., nose, ears, and lips). They may transmit microorganisms, including multiple resistant strains, after contact with patients, and can be a source of bacterial cross-contamination.

Utsumi et al. (2010) investigated disease outbreaks in elderly care facilities, and found a variety of infectious agents with high median attack rates for healthcare workers were caused by *Chlamydia pneumoniae* (41%), noroviruses (42%) and scabies (36%)

Vulnerable groups

Nurses in training or young healthcare workers are reported to be a vulnerable group for hepatitis B infections (Zandi et al., 2011) and measles in countries with low vaccine coverage (Fiebelkorn et al., 2014). Medical trainees are also at considerable risk of contracting HIV and other locally endemic diseases such as malaria, dengue fever, traveller’s diarrhoea and sexually transmissible infections, as well as nosocomial transmission of blood or body fluid-borne pathogens such as hepatitis B and hepatitis C, when they participate in the healthcare systems of resource-poor countries (Kortepeter et al., 2010; Mohan et al., 2010; Panosian, 2010; Rossouw et al., 2014).

Although HIV has been assessed to be of the greatest concern to pregnant orthopaedic surgeons because of the potentially fatal health consequences for the foetus if the mother goes untreated (Keene et al., 2011), in general other studies (Downes et al., 2014) have identified no additional risk with regard to HIV or hepatitis for pregnant or lactating workers. Pregnant healthcare workers with occupational exposure to communicable diseases should, however, be evaluated immediately for appropriate post-exposure prophylaxis and monitored for the development of active infection (Lynch and Spivak, 2015). As pregnancy does not seem to be an independent risk factor for healthcare workers, primary prevention with vaccination and the use of appropriate infection control precautions is imperative to prevent occupationally acquired infectious diseases, as for all healthcare workers (Chin et al., 2014).

Furthermore, laundry workers who handle hospital textiles may be at risk of infection from contamination for example by by *Sarcoptes scabei*, *Microsporum canis*, *Salmonella typhimurium/hadar*, or the hepatitis A virus (Fijan et al., 2012).

Veterinarians

It may not be surprising that veterinarians and their assistants are at increased risk of a broad spectrum of diseases, as they are frequently exposed to diseased animals. Infection transfer may be the result of bites or other direct animal contact, or of bites by vectors (e.g. in the case of tick-borne diseases). Relevant diseases include infections with (methicillin-resistant) *Staphylococcus aureus* (Doyle et al., 2012; Haagsma et al., 2012; Guardabassi et al., 2013), (swine/avian) influenza virus, *Brucella* spp., *Bartonella henselae*, *Campylobacter* spp., *Chlamydophila psitacci*, *Clostridium tetani*, *Coxiella burnettii*, *Pasteurella multocida*, *Salmonella* spp., *Toxoplasma gondii* (Haagsma et al., 2012) and many other bacteria-, virus-, fungi- or vector-related infections (EU-OSHA, 2007a; EU-OSHA, 2008; EU-OSHA, 2009b; Breitschwerdt et al., 2010; Canini, 2010; Lewis et al., 2010; Pavio and Mansuy, 2010; Seyfarth and Eisner, 2010; Stewardson and Grayson, 2010; Wang et al., 2010; Dutkiewicz et al., 2011; Hardin et al., 2011; Dorko et al., 2012; Honarmand, 2012; Chethan Kumar et al., 2013; Islam et al., 2013; Samadi et al., 2013; Jeffries et al., 2014; McDaniel et al., 2014; Montano, 2014; Ganter, 2015; Kozdruń et al., 2015; Sayed et al., 2015). It should be noted that Doyle et al. (2012) reported increased colonisation with MRSA but that there were no indications of increased illness among veterinarians.

Zoonotic diseases account for up to 30 % of cases of occupational illnesses reported in zoos in India among zoo and wildlife veterinarians (Chethan Kumar et al., 2013), and, although the situation in India may be different, because of worldwide breeding programmes, veterinarians in European zoos may also be exposed to exotic biological agents.

Increased risks are reported due to climate change because the geographical range of certain biological agents is expanding. This was reported for the agents causing Rift Valley fever, yellow fever, malaria, dengue fever and chikungunya (Applebaum et al., 2016). Moreover, an increasing number of *Bartonella* species have been identified as zoonotic pathogens, transmitted by animal bites and scratches, arthropods and even needlestick injuries (Breitschwerdt et al., 2010). Infections due to the fungus *Sporothrix schenckii* (inducing sporotrichosis) in veterinarians is reported as a new risk category, as zoonotic transmission has been described in isolated cases or in small outbreaks (Barros et al., 2011).

No publications were retrieved identifying vulnerable groups in relation to occupational diseases in veterinarians.

An overview of biological agents, including bacteria, fungi, viruses and parasites, as well as exposures to mixtures and subcellular pathogens, is provided in Table 5-Table 15, and Table 15-Table 19, respectively.

Sex workers

Owing to the nature of their occupation, sex workers are at risk of sexually transmissible infections, among which the most important are HIV, hepatitis B and C, syphilis, herpes, chlamydia, gonorrhoea and trichomoniasis.

The majority of publications retrieved regarding sex workers related to HIV infections. Europe has a low endemicity for HIV, whereas Africa and Asia are high-endemicity areas (Farr and Wilson, 2010; Steen et al., 2012; Platt et al., 2013a; Dokubo et al., 2013; Djomand et al., 2014). A significant amount of the HIV-related publications retrieved concerned high-endemicity areas. Publications in which, for example, the epidemiology of HIV is evaluated in high-risk groups in Africa, South America or Asia (see, for example, Malta et al., 2010; Vallely et al., 2010; Alavi and Samast Shustari, 2013, Kouyoumjian et al., 2013; Miller et al., 2013; Papworth et al., 2013; Craig et al., 2014; Gruskin et al., 2014; Singh et al., 2014; MacAllister et al., 2015; Melhem et al., 2015; Zhang et al., 2015) were not taken into account in this report because they were not considered to reflect the situation in Europe (based on sociodemographic differences) and were of limited additional relevance. Similarly, publications relating to the prevention of sexually transmissible infections in China or Africa concerning, for example, education and condom promotion (Hong et al., 2011; Ng et al., 2011; Chersich et al., 2013) were not considered relevant.

The HIV infection rate in Europe reportedly remains low among female sex workers who do not inject drugs (< 1 %), but for other sexually transmissible infections the infection rate is high, particularly for syphilis and gonorrhoea. Hepatitis B and C, chlamydia, gonorrhoea, trichomoniasis, herpes and syphilis infections are mentioned in only a few publications (Poon et al., 2011; Haagsma et al., 2012; Ross et al., 2012; Steen et al., 2012; Cui et al., 2013; Kouyoumjian et al., 2013; Platt et al., 2013a; Platt et al., 2013b; Alonso et al., 2015). Moreover, half of these may be of limited relevance, as they concern regions or countries outside Europe (Adam, 2011; Poon et al., 2011; Steen et al., 2012; Kouyoumjian et al., 2013; Alonso et al., 2015). These sexually transmissible infections are of significant relevance for sex workers, although HIV is considered the major focus, possibly owing to the potentially fatal outcome and long-term impact on quality of life.

Prevention of sexually transmissible infections

With regard to the prevention of sexually transmissible infections among sex workers, prevention programmes are reported to be not always effective. Female sex workers experience high levels of violence and lack access to services, and they often work on the street (Platt et al., 2013b; Shannon et al., 2015). Findings show that for prevention programmes aimed at reducing sexually transmittable infections among sex workers to be effective, interventions should be embedded in strategies that address the social welfare of sex workers and experiences of violence and migration, and provide access to services or social support and antiretroviral therapy (Adam, 2011, Scorgie et al., 2012; Dunkle et al., 2013; Qiao et al., 2014; Vun et al., 2014; Shannon et al., 2015). Platt et al. (2013b) concluded that epidemiological and intervention studies of HIV among vulnerable populations needed to better assess how factors combine to increase or reduce the risk of HIV infection or other sexually transmissible infections. Awareness-raising about effective measures to prevent infection may be needed (Cassell et al., 2014). For instance, over one third of Chinese female sex workers believed that vaginal douching could help prevent sexually transmissible infection, when it was in fact associated with a doubled history of infection (Ross et al., 2012) and condom use was reduced. Several successful behavioral interventions have been reported in middle to low-income countries (Ota et al., 2012) including interventions to reduce HIV/STI incidence and prevalence, change behavior, promote condom use, improve condom availability, and increase sexual health knowledge. However, it should be noted that evidence from randomised controlled trials on the effectiveness of behavioural interventions to reduce the transmission of HIV infection among sex workers and their clients in high-income countries (Ota et al., 2011) is limited.

According to Wilson (2015), HIV and sexually transmissible infection prevention programmes aimed at sex workers receive limited domestic financing in many countries and have not evolved adequately to address informal sex workers, male and transgender sex workers, and mobile and internet-based sex workers. Overall, in low- and middle-income countries, community empowerment-based HIV prevention was associated with significant improvements across HIV outcomes (Kerrigan et al., 2013). By boosting women's economic independence and microenterprise development, having direct income effects, the women's need to rely on transactional sex may be reduced (Cui et al., 2013). Craig et al. (2014) and Djomand et al. (2014), recommend shifting funding allocations towards priority poupulations, as programmes targeting populations at highest risk were found to be most cost-effective while programmes targeting the general public were not cost-effective or much less cost-effective than targeted programmes.

Waste workers and wastewater workers

A relatively large amount of publications was retrieved on waste workers (waste collectors, waste composting workers, waste handlers and related occupations). Kuijer and Sluiter (2010) reviewed health outcomes in waste collectors and found that strong evidence was available that exposure to bioaerosols exceeds recommendations. There is also moderate evidence of an increased risk of respiratory complaints, whereas limited evidence exists of an increased risk of gastrointestinal disorders. The related diseases are respiratory symptoms such as bronchitis, gastrointestinal symptoms such as diarrhoea and nausea, and infections such as hepatitis (A and C), HIV, syphilis (Kuijer and Sluiter, 2010) and hepatitis B (Kuijer and Sluiter, 2010; Corrao et al., 2013).

Increased exposures to endotoxins (EU-OSHA, 2007a; Lawniczek-Walczyk and Gorny, 2010; Duquenne et al., 2013), mycotoxins (Fromme et al., 2016), beta-glucans via organic dust (Lawniczek-Walczyk and Gorny, 2010) and bioaerosols (Anzivino-Viricel et al., 2012; Pearson et al., 2015; Walser et al., 2015) were related to various adverse health outcomes including respiratory inflammatory reactions, organic dust toxic syndrome (ODTS), high fever, eye, nose and throat irritation, coughing, itching, a reduction in lung function (one-second forced expiratory volume (FEV1)), an increase in the prevalence of atopy and myeloperoxidase production (an indicator of immune system activity).

Composting

Exposure to organic dust in the workplace at composting facilities is associated with adverse acute and chronic respiratory health effects, including mucosal membrane irritation, chronic bronchitis and an accelerated decline in forced vital capacity. The pattern of health effects differs from those found in other workplaces with exposure to organic dust, possibly because of the high concentrations of thermo-tolerant/thermophilic actinomycetes and filamentous fungi in composting plants.

The bioaerosol components identified in a review by Pearson et al. as potentially harmful are:

- Fungi and fungal spores—including the thermotolerant species *Aspergillus fumigatus*;

- Bacteria—including gram-negative bacteria and the spore-producing gram-positive bacteria *actinomycetes*;
- Endotoxin—structural components of some bacteria released through cell wall damage, including lipopolysaccharides (LPS) or lipo-oligo-saccharides;
- Dust or particulate matter (PM) containing microbial fragments;
- Beta(1→3) glucans—polysaccharides found in the cell walls of certain fungi, particularly Aspergillus species.

It is possible that mycotoxins, which are toxic secondary metabolites of fungi (one of the most potent of these is aflatoxin, which is mainly produced by *Aspergillus flavus*) may also be emitted during the composting process (Pearson et al., 2015)

Dependent on particle size, bioaerosols may penetrate deep into the lungs and become embedded in alveoli . For bioaerosols emitted from composting facilities, the following health effects have been identified:

- Allergic asthma, rhinitis, hypersensitivity pneumonitis extrinsic allergic alveolitis, allergic bronchopulmonary aspergillosis (ABPA), eye and skin irritations;
- Toxic non-allergic asthma, rhinitis, mucous membrane irritations, chronic bronchitis, chronic airway obstruction such as chronic obstructive pulmonary disease (COPD), organic dust toxic syndrome (ODTS), toxic pneumonitis;
- Infectious aspergillosis, zygomycosis; immunocompromised individuals are more susceptible at lower concentrations of the relevant pathogens. (Pearson et al., 2015)

EU-OSHA has identified as potential emerging risks the biohazards linked to work with new bacteria developed in bioengineering, and increased exposure to bacteria and fungi due to increased collection and separation of organic waste (EU-OSHA, 2013a).

Wastewater

According to Korzeniewska (2011), workers in wastewater treatment plants would quite certainly contract a disease as a result of exposure to biological agents within one year if they were not already immune or suitably protected. Sewage and unstable sludge contain various pathogens such as viruses, bacteria, and human and animal parasites. These microorganisms can be transmitted to the ambient air in wastewater droplets, which are generated during aeration or mechanical moving of the sewage. Bioaerosols generated during wastewater treatment may therefore pose a potential health hazard to workers of these plants. The use of wastewater and excreta in agriculture is a common practice in some parts of the world and may lead to serious infections, including diarrhea, skin infection, parasitic infection and bacterial infection (Lam et al., 2015).

A causal relationship between exposure to non-infectious airborne biohazards endotoxins, (1-3)-beta-D-glucans of bacteria and fungi) and the occurrence of gastrointestinal symptoms, fever, respiratory symptoms, skin disorders, eye irritation, headache, fatigue and nausea among workers in sewage treatment plants has also been reported (Korzeniewska, 2011). Moreover, leptospirosis has been reported among wastewater and sewage workers (Dutkiewicz et al., 2011).

Metalworkers

There are known outbreaks of pneumococcal diseases among welders (e.g. Patterson et al. 2015). *Streptococcus pneumoniae* is a Gram-positive coccus known to colonise the nasopharyngeal tract and can cause a spectrum of disease such as otitis media, pneumonia and invasive pneumococcal disease Welders have an increased risk of invasive pneumococcal disease, and although not fully understood, this may relate to components of the fumes serving as a nutrient to increase adherence of the pneumococci to the lung tissue or inhalation of the fumes causing damage to the lung's immune defences. The UK HSE guidelines (HSE, 2014a) recommend that 23-valent pneumococcal polysaccharide vaccine should be considered for people whose work exposes them to frequent or continuous exposure to metal fume (e.g. welders).

Armed forces

Pages et al. (2010) reported that the vector-borne diseases West Nile encephalitis and chikungunya are a new potential threat to Western armed forces overseas. Moreover, the following known diseases in tropical areas also affect Western armed forces overseas: malaria, dengue fever, sand fly fever, leishmaniasis, Rift valley fever, tick-borne spotted fevers, African tick bite fever, ehrlichiosis, Q fever, tularaemia, Crimean-Congo haemorrhagic fever, scrub typhus, sleeping sickness and Chagas disease (Pages et al., 2010). Hepatitis B, C and E (Khan and Attaullah, 2011; Freshwater, 2013a and b), fungal skin diseases (Seyfarth and Eisner, 2010; Leite et al., 2014), tinea (Leite et al., 2014) and coccidiosis (Maves and Crum-Cianflone, 2012) were also identified as risks to military personnel. As regards the risk of transmission of hepatitis B and C viruses among armed forces operating in high hepatitis B prevalence areas for years, Freshwater (2013a) reported that transmission from local people during mass-casualty scenarios to UK armed forces had been a concern for years. It was recommended that anyone with penetrating injuries should be subject to an accelerated vaccination regime to prevent the transmission of hepatitis B virus. According to Freshwater (2013a) this is also advised in situations in low hepatitis B virus areas such as the 2005 London bombing incident, in relation to which universal vaccination of UK armed forces against hepatitis B virus was recommended.

Hepatitis E virus was first discovered during the Soviet occupation of Afghanistan in the 1980s after an outbreak of unexplained hepatitis at a military camp. The prevalence is high in certain operational areas (28.5% in Afghanistan), and Freshwater (2013b) recommends to pay attention to food and water supplies together with scrupulous attention to environmental hygiene. He also mentions a much higher risk of fulminant hepatitis in pregnant women, with a mortality rate of up to 25%.

Other issues

Hepatitis E

Hepatitis E virus appears to be an emerging problem in several industrialised countries, where it is mostly associated either with travelling to a hepatitis E virus endemic area, for example in the case of airline personnel (EU-OSHA, 2007a; Freshwater, 2013b), or with contact with pigs (being a major reservoir of hepatitis E virus). Other occupations with a known risk of hepatitis E virus infection, other than those mentioned above, are hunters (Pavio and Mansuy, 2010) and sewage workers (Lewis et al., 2010). In general, the groups at particular risk of hepatitis E virus infection and its ensuing complications are elderly men, pregnant women, immunocompromised patients (e.g. transplant recipients and HIV-infected patients) and patients with pre-existing liver disease (Sayed et al., 2015).

Water-borne diseases

It is generally accepted that working areas with air-conditioning systems, high humidity or systems containing stagnant warm water are amenable to the growth of *Legionella* (EU-OSHA, 2011a). Workers at risk are automotive plant workers, construction workers, plumbers, water system workers, biological treatment plant workers and wastewater treatment workers, workers in cleaning and disinfection jobs in contaminated areas, cooling tower workers, air-conditioning maintenance workers, professional (bus) drivers (Pontiac fever), forestry workers, gardeners, healthcare workers, journalists, laboratory personnel, ship repair workers, mine workers, offshore workers, paper mill workers, pet shop workers, plant and machine operators/assemblers, plastic factory workers, print plant workers, railway conductors, sewage workers, subway personnel, textile plant workers, turbine operators, vehicle washers, welders, workers in war zones and zoo personnel (EU-OSHA, 2007a; EU-OSHA, 2009b; Dutkiewicz et al., 2011; EU-OSHA, 2011a; Haagsma et al., 2012; Applebaum et al., 2016).

Occupational risk of leptospirosis was identified on several occasions and related to trout farms and aquaculture. Other water-borne work-related diseases were mentioned only on a single occasion (e.g. Myers, 2010), or Janda and Abbott, 2014, related to Shewanella infections in marine environments.

Lagriffoul et al. (2010) reviewed risks of bacteria-derived additives in artificial snow (mainly snowmakers during additive-mixing and dilution tank cleaning steps), with risks from *Pseudomonas syringae* estimated to be negligible to low if workers comply with safety precautions.

Parasites

Jenkins et al. (2013) reviewed future trends in the importance of parasites for human health in Alaska and Canada. The incidence of human exposure to endemic helminth zoonoses (e.g. Diphyllobothrium, *Trichinella*, and *Echinococcus*) appears to be declining, while water-borne protozoans such as *Giardia*, *Cryptosporidium*, and *Toxoplasma* may be emerging in a warming North. They expect parasites that undergo temperature-dependent development in the environment (such as *Toxoplasma*, ascarid and anisakid nematodes, and diphyllobothriid cestodes) to undergo accelerated development in endemic areas and temperature-adapted strains/species to move north, resulting in faunal shifts. Food-borne pathogens (e.g. *Trichinella*, *Toxoplasma*, anisakid nematodes, and diphyllobothriid cestodes) may be increasingly important as animal products are exported and tourists and workers become more mobile, and domestic animals are imported. They suggest enhanced surveillance in animals and people, better detection methods, and monitoring and evaluation of veterinary and public health services will be needed to better assess trends.

Overview of infectious agents

An overview of occupations, biological agents (excluding allergens) and related infectious diseases is given in Table 5-Table 15, where they are grouped by agent category (bacteria, fungi, etc.). If no biological agent or no disease was mentioned in the literature, the cell in question has been left blank.

Table 5: Overview of occupations, biological agents and related infectious diseases for the 'bacteria' category, by occupation

Occupation	Agent	Disease/health effect
Abattoir worker	*Bacillus anthracis*	Anthrax
	Bartonella henselae	Bartonellosis, cat scratch fever
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Campylobacter spp.	*Campylobacter* infection
	Chlamydophila psittaci	Psittacosis
	Coxiella burnetii	Q fever
	Erysipelothrix rhusiopathiae	Erysipeloid
	Leptospira spp., *Leptospira hardjo*, *pomona*	Leptospirosis
	Listeria monocytogenes	Listeriosis
	Mycobacterium bovis/marinum/tuberculosis	Tuberculosis
	Pasteurella spp., *Pasteurella multocida*	Pasteurellosis
	Pyrogenic germs	
	Salmonella	Salmonellosis
	Staphylococcus aureus spp.	
	Streptococcus pyogenes	

Occupation	Agent	Disease/health effect
Abattoir worker (poultry)	*Borrelia burgdorferi*	Lyme borreliosis
	Campylobacter spp.	Campylobacteriosis
	Chlamydophila psittaci	Ornithosis
	Coxiella burnetii	Q fever
	Erysipelothrix rhusiopathiae	Erysipeloid
	Listeria monocytogenes	Listeriosis
	Escherichia coli	Colibacteriosis
	Salmonella spp.	Salmonellosis
	Yersinia	Yersiniosis
Agricultural equipment manufacturing plant worker	*Legionella* spp.	Legionellosis
Agriculture	*Anaplasma phagocytophilum*	Anaplasmosis
	Bacillus anthracis	Anthrax
	Borrelia burgdorferi	Lyme borreliosis
	Bartonella henselae	Cat scratch fever, bartonellosis
	Brucella spp.	Brucellosis
	Campylobacter spp.	*Campylobacter* infection
	Coxiella burnetii	Q fever
	Francisella tularensis holartica/tularensis	Tularaemia
	Chlamydophila psittaci	Psittacosis
	Erysipelothrix rhusiopathiae	Erysipeloid
	Escherichia coli	Colibacteriosis
	Leptospira spp.	Leptospirosis
	MRSA	
	Mycobacterium bovis/marinum	Tuberculosis
	Pasteurella multocida	Pasteurellosis
	Pyrogenic germs	
	Streptococcus suis	Meningitis
Agriculture (animal worker/breeder)	*Bacillus anthracis*	Anthrax
	Bartonella henselae	Bartonellosis, cat scratch fever
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Chlamydophila psittaci	Leptospirosis

Occupation	Agent	Disease/health effect
	Coxiella burnetii	Q fever
	Erysipelothrix rhusiopathiae	Erysipeloid
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Leptospira	Leptospirosis
	Mycobacterium marinum, *Mycobacterium tuberculosis/bovis/caprae*	Tuberculosis
	Pasteurella, *Pasteurella multocida*	Pasteurellosis
	Pyrogenic germs	
	Salmonella	Salmonellosis
Agriculture (animal worker/breeder (ornamental birds))	*Chlamydophila psittaci*	Ornithosis
	Campylobacter spp.	Campylobacteriosis
	Escherichia coli	Colibacteriosis
	Erysipelothrix rhusiopathiae	Erysipeloid
	Listeria monocytogenes	Listeriosis
	Salmonella	Salmonellosis
	Yersinia	Yersiniosis
Agriculture (animal worker/cattle worker, livestock handler)	*Bacillus anthracis*	Anthrax
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Campylobacter spp.	*Campylobacter* infection
	Coxiella burnetii	Q fever
	Leptospira spp.	Leptospirosis
	Listeria monocytogenes	Listeriosis
	Staphylococcus aureus	
	Streptococcus spp.	
Agriculture (animal worker/livestock farmer)	*Bacillus anthracis*	Anthrax
	Brucella spp.	Brucellosis
	Campylobacter	*Campylobacter* infection
	Coxiella burnetii	Q fever
	Leptospira	Leptospirosis
	Listeria monocytogenes	Listeriosis

Occupation	Agent	Disease/health effect
	Mycobacterium bovis/tuberculosis	Tuberculosis
	Salmonella	Salmonellosis
Agriculture (animal worker/pig farmer)	*Streptococcus suis*	Meningitis
Agriculture (animal worker/poultry and pig farmer)	*Campylobacter* spp.	Campylobacteriosis
	Chlamydophila psittaci	Ornithosis/psittacosis
	Escherichia coli	Colibacteriosis
	Erysipelothrix rhusiopathiae	Erysipeloid
	Listeria monocytogenes	Listeriosis
	Mycobacterium tuberculosis	Tuberculosis
	Salmonella	Salmonellosis
	Yersinia	Yersiniosis
Agriculture (animal worker/poultry farmer)	*Borrelia burgdorferi*	Lyme borreliosis
	Coxiella burnetii	Q fever
	Salmonella	Salmonellosis
Agriculture (crop worker)	*Bacillus thuringiensis*	Respiratory health effects
	Bacillus subtilis	
	Borrelia burgdorferi	Lyme borreliosis
	Coxiella burnettii	Q fever
	Escherichia coli	Colibacteriosis
	Leptospira	Leptospirosis
Airline personnel	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	*Legionella*
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Animal worker (birds)	*Chlamydophila psittaci*	Ornithosis/psittacosis
Animal worker (carer)	*Bartonella henselae*	Bartonellosis
	Borrelia burgdorferi	Lyme borreliosis
	Chlamydophila psittaci	Psittacosis
	Leptospira spp.	Leptospirosis

Occupation	Agent	Disease/health effect
Animal worker (contact with live or dead animals, animal secretions)	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Animal worker (handler)	*Bacillus anthracis*	Anthrax
	Bartonella henselae	Bartonellosis, cat scratch fever
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Campylobacter	*Campylobacter* enteritis
	Chlamydophila psittaci	Psittacosis
	Coxiella burnetii	Q fever
	Francisella tularensis	Tularaemia
	Leptospira spp.	Leptospirosis
	Mycobacterium bovis/marinum	Tuberculosis
	Pasteurella multocida	Pasteurellosis
	Pyrogenic germs	
	Swine erysipelas bacilli	Erysipeloid
Animal worker (trader)	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Aquaculture	*Mycobacterium marinum/balnei*	Tuberculosis
	Leptospira	Leptospirosis
Automotive plant worker	*Legionella* spp.	Legionellosis
Biological treatment plant worker	*Legionella* spp.	Legionellosis
Bone button maker	*Erysipelothrix rhusiopathiae*	Erysipeloid
Border guard	*Anaplasma phagocytophilum*	Anaplasmosis
	Borrelia burgdorferi	Lyme borreliosis
Butcher	*Bacillus anthracis*	Anthrax
	Chlamydophila psittaci	Ornithosis/psittacosis

Occupation	Agent	Disease/health effect
	Brucella spp.	Brucellosis
	Campylobacter spp.	*Campylobacter* infection
	Coxiella burnetii	Q fever
	Erysipelothrix rhusiopathiae	Erysipeloid
	Leptospira spp.	Leptospirosis
	Listeria monocytogenes	Listeriosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
	Corynebacterium pseudotuberculosis	Caseous lymphadenitis
	Salmonella	Salmonellosis
	Staphylococcus	
Cleaner	*Leptospira* spp.	Leptospirosis
	Mycobacterium tuberculosis	Tuberculosis
	Rickettsia akari	Rickettsialpox
	Rickettsia typhi	Murine typhus
	Spirillum minus, *Streptobacillus moniliformis*	Rat bite fever
Cleaner (cleaning and disinfection jobs in contaminated areas)	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Construction worker	Bacterial agents	Skin infections
	Legionella spp.	Legionellosis
Construction worker (plumber)	*Legionella* spp.	Legionellosis
Construction worker (plumber, water system worker)	*Legionella* spp.	Legionellosis
Cooling tower worker (including air-conditioning systems, maintenance)	*Legionella* spp.	Legionellosis
Customs worker	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis

Occupation	Agent	Disease/health effect
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Diver	*Campylobacter jejuni*	*Campylobacter* infection
Driver (professional)	*Legionella* spp.	Legionellosis
Educational worker	Bacterial agents	Nasal inflammation
	Mycobacterium tuberculosis	Tuberculosis
	Neisseria	
Emergency services worker (ambulance/fire/police/rescue)	*Mycobacterium tuberculosis*	Tuberculosis
Epidemic control worker	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Fertiliser worker	*Erysipelothrix rhusiopathiae*	Erysipeloid
Fishing industry (fisherman, fish handler)	*Leptospira* spp.	Leptospirosis
	Erysipelothrix rhusiopathiae	Erysipeloid
Food processing worker (in contact with animals)	MRSA	
Forestry worker	*Anaplasma phagocytophilum*	Anaplasmosis
	Bacillus anthracis	Anthrax
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Coxiella burnetii	Q fever
	Francisella tularensis/holartica	Tularaemia
	Legionella spp.	Legionellosis
	Leptospira	Leptospirosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Funeral service worker	*Mycobacterium tuberculosis*	Tuberculosis
Furrier	*Erysipelothrix rhusiopathiae*	Erysipeloid
Gardener	*Anaplasma phagocytophilum*	Anaplasmosis
	Borrelia burgdorferi	Lyme borreliosis

Occupation	Agent	Disease/health effect
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
Global trade worker	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Healthcare worker	*Bacillus anthracis*	Anthrax
	Bacillus cereus	
	Bartonella henselae	Cat scratch fever
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Campylobacter	*Campylobacter* enteritis
	Chlamydophila psittaci	Psittacosis
	Coxiella burnettii	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	MRSA	
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
	Salmonella aureus	
	Treponema pallidum	Syphilis
	Salmonella spp.	Salmonellosis
	Streptococcus pyogenes	
	Vancomycin-resistant enterococci	
Healthcare worker (dental care)	*Legionella* spp.	Legionellosis
Hotel staff	*Treponema pallidum*	Syphilis
Hunter	*Anaplasma phagocytophilum*	Anaplasmosis
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Francisella tularensis	Tularaemia
	Leptospira	Leptospirosis

Occupation	Agent	Disease/health effect
Journalist/media professional	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Laboratory worker	*Bacillus anthracis*	Anthrax
	Bartonella henselae	Bartonellosis, cat scratch fever
	Chlamydophila psittaci	Psittacosis
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Campylobacter spp.	*Campylobacter* infection
	Corynebacterium pseudotuberculosis	Caseous lymphadenitis
	Coxiella burnettii	Q fever
	Erysipelothrix rhusiopathiae	Erysipeloid
	Francisella tularensis holartica/tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Leptospira spp.	Leptospirosis
	Listeria monocytogenes	Listeriosis
	MRSA	
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
	Pasteurella multocida	Pasteurellosis
	Salmonella spp.	Salmonellosis
	Staphylococcus aureus	
	Streptococcus spp.	
Laundry worker	*Salmonella hadar*	
	Salmonella typhimurium	
Leather worker	*Erysipelothrix rhusiopathiae*	Erysipeloid
Librarian or art conservator	*Anaplasma*	Anaplasmosis
	Bartonella	Bartonellosis
	Borrelia burgdorferi	Lyme borreliosis
	Coxiella burnetii	Q fever
	MRSA	

Occupation	Agent	Disease/health effect
Maintenance worker	*Legionella* spp.	Legionellosis
Manufacturing worker	*Brucella* bacteria (*abortus*, *ovis*, *melitensis*, *suis*, *canis*)	Brucellosis
Meat industry worker	*Coxiella burnetii*	Q fever
	Erysipelothrix rhusiopathiae	Erysipeloid
	Mycobacterium bovis	Tuberculosis
Military personnel (overseas work)	*Anaplasma*	Anaplasmosis
	Coxiella burnetii	Q fever
	Francisella tularensis	Tularaemia
Mine worker	*Legionella* spp.	Legionellosis
Naturalist	*Erysipelothrix rhusiopathiae*	Erysipeloid
Natural science researcher	*Borrelia burgdorferi*	Lyme borreliosis
	Francisella tularensis	Tularaemia
	Leptospira	Leptospirosis
Office worker	*Legionella* spp.	Legionellosis
	Mycobacterium tuberculosis	Tuberculosis
Offshore worker (oil and gas installations)	*Legionella* spp.	Legionellosis
Outdoor game manager	*Borrelia burgdorferi*	Lyme borreliosis
	Francisella tularensis	Tularaemia
	Leptospira	Leptospirosis
Paper industry worker	*Legionella* spp.	Legionellosis
Pet shop worker	*Bartonella henselae*	Cat scratch fever
	Chlamydophila psittaci	Psittacosis
	Coxiella burnetii	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Leptospira spp.	Leptospirosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
	Salmonella	Salmonellosis

Occupation	Agent	Disease/health effect
Plant and machine operator or assembler	*Legionella* spp. *Mycobacterium chelonae*	Legionellosis Tuberculosis
Plastic factory worker	*Legionella* spp.	Legionellosis
Print plant worker (stagnant warm water)	*Legionella* spp.	Legionellosis
Prison guard	*Mycobacterium tuberculosis*	Tuberculosis
Railway conductor	*Legionella* spp.	Legionellosis
Seaman, sailor	*Treponema pallidum*	Syphilis
Sewage worker	*Erysipelothrix rhusiopathiae* *Legionella* spp.	Erysipeloid Legionellosis
Sex worker/adult movie actor	*Treponema pallidum*	Syphilis
Snowmaker	*Pseudomonas syringae*	
Soap maker	*Erysipelothrix rhusiopathiae*	Erysipeloid
Subway personnel	*Legionella* spp.	Legionellosis
Taxidermist	*Bartonella henselae* *Chlamydophila psittaci* *Francisella tularensis*	Cat scratch fever Ornithosis/psittacosis Tularaemia
Textile industry worker	*Legionella* spp.	Legionellosis
Trader in venison	*Francisella tularensis*	Tularaemia
Traveller (worker required to travel frequently by air)	*Coxiella burnetii* *Francisella tularensis* *Legionella* spp. *Mycobacterium tuberculosis/bovis/caprae*	Q fever Tularaemia Legionellosis Tuberculosis
Turbine operator	*Legionella* spp.	Legionellosis
Vehicle washer	*Legionella* spp.	Legionellosis
Veterinarian	*Bacillus anthracis* *Bartonella henselae* *Borrelia burgdorferi*	Anthrax Bartonellosis, cat scratch fever Lyme borreliosis

Occupation	Agent	Disease/health effect
	Brucella spp., *Brucella* bacteria (*abortus*, *ovis*, *melitensis*, *suis*, *canis*), *Brucella* antigen	Brucellosis
	Campylobacter spp.	Campylobacteriosis, *Campylobacter* infection
	Chlamyodphila psittaci	Chlamydial diseases, melioidosis, psittacosis
	Corynebacterium pseudotuberculosis	Caseous lymphadenitis
	Coxiella burnettii	Q fever
	Erysipelothrix rhusiopathiae	*Erysipeloid*
	Escherichia coli	Colibacillosis, colibacteriosis
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Leptospira spp.	Leptospirosis
	Listeria monocytogenes	Listeriosis
	MRSA	
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
	Pasteurella spp.	Pasteurellosis
	Pasteurella multocida	
	Pyrogenic germs	
	Salmonella spp.	Salmonellosis
	Staphylococcus	
	Streptococcus spp.	
	Yersinia	Yersiniosis
Waste worker	*Brucella* spp.	Brucellosis
	Campylobacter	*Campylobacter* infection
	Escherichia coli	Colibacteriosis
	Legionella spp.	Legionellosis
	Mycobacterium	Tuberculosis
	Salmonella	Salmonellosis
	Staphylococcus	
	Treponema pallidum	Syphilis
Wastewater treatment worker	*Legionella* spp.	Legionellosis

Occupation	Agent	Disease/health effect
Welder	*Legionella* spp.	Legionellosis
Worker in contact with animals	*Erysipelothrix rhusiopathiae*	Erysipeloid
Worker in war zones	*Coxiella burnetii*	Q fever
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
Worker in workplace with mist machines	*Legionella* spp.	Legionellosis
Zoo personnel	*Bacillus anthracis*	Anthrax
	Borrelia burgdorferi	Lyme borreliosis
	Brucella spp.	Brucellosis
	Campylobacter spp.	Campylobacteriosis
	Chlamydophila psittaci	Psittacosis
	Erysipelothrix rhusiopathiae	Erysipeloid
	Escherichia coli	Colibacillosis, colibacteriosis
	Francisella tularensis	Tularaemia
	Legionella spp.	Legionellosis
	Listeria monocytogenes	Listeriosis
	Mycobacterium tuberculosis/bovis/caprae	Tuberculosis
	Salmonella	Salmonellosis
	Yersinia	Yersiniosis

Table 6: Overview of occupations, biological agents and related infectious diseases for the 'bacteria' category, by agent

Agent	Occupation/sector	Disease/health effect
Bacterial agents	Construction worker	Skin infections
Bacterial agents	Education	Nasal inflammation
Anaplasma	Librarian or art conservator	Anaplasmosis
Anaplasma phagocytophilum (may be vector transmitted)	Agricultural worker Border guard	Anaplasmosis

Agent	Occupation/sector	Disease/health effect
	Forestry worker Gardener Hunter Military personnel (overseas work)	
Bacillus anthracis	Abattoir worker Agricultural worker Agriculture (animal worker/breeder, cattle worker, livestock handler, livestock farmer) Animal worker (handler) Butcher Forestry worker Healthcare worker Laboratory worker Veterinarian Zoo personnel	Anthrax
Bacillus cereus	Healthcare worker	
Bacillus subtilis	Agriculture (crop worker)	Respiratory health effects
Bacillus thuringiensis	Agriculture (crop worker)	Respiratory health effects
Bartonella spp.	Librarian or art conservator Veterinarian	Bartonellosis
Bartonella henselae	Abattoir worker Agriculture Agriculture (animal worker/breeder) Animal worker (carer, handler) Healthcare worker Laboratory worker Pet shop worker Taxidermist Veterinarian	Bartonellosis Cat scratch fever
Borrelia burgdorferi (vector transmitted)	Abattoir worker Abattoir worker (poultry)	Lyme borreliosis

Agent	Occupation/sector	Disease/health effect
	Agriculture Agriculture (animal worker/breeder, cattle worker, livestock handler, poultry farmer) Agriculture (crop worker) Animal worker (carer, handler) Border guard Forestry worker Gardener Healthcare worker Hunter Laboratory worker Librarian or art conservator Natural science researcher Outdoor game manager Veterinarian Zoo personnel	
Brucella spp.	Abattoir worker Agricultur Agriculture (animal worker/breeder, cattle worker, livestock handler, livestock farmer) Animal worker (handler) Butcher Forestry worker Healthcare worker Hunter Laboratory worker Veterinarian Waste worker Zoo personnel	Brucellosis
Brucella bacteria (*abortus*, *ovis*, *melitensis*, *suis*, *canis*)	Manufacturing worker Veterinarian	Brucellosis
Campylobacter spp.	Abattoir worker Abattoir worker (poultry)	*Campylobacter* infection Campylobacteriosis

Agent	Occupation/sector	Disease/health effect
	Agriculture Agriculture (animal worker/breeder (ornamental birds), cattle worker, livestock handler, livestock farmer, poultry farmer) Animal worker (handler) Butcher Healthcare worker Laboratory worker Veterinarian Waste worker Zoo personnel	*Campylobacter* enteritis
Campylobacter jejuni	Diver (other craft and related worker)	*Campylobacter* infection
Chlamydophila psittaci	Abattoir worker Abattoir worker (poultry) Agriculture Agriculture (animal worker/breeder (ornamental birds), breeder, poultry farmer) Animal worker (with birds, carer, handler) Butcher Healthcare worker Laboratory worker Pet shop worker Taxidermist Zoo personnel	*Chlamydophila* infection Ornithosis/psittacosis
Chlamydophila psittaci	Veterinarian	Psittacosis Chlamydial diseases Melioidosis
Corynebacterium pseudotuberculosis	Butcher Laboratory worker Veterinarian	Caseous lymphadenitis
Coxiella burnetii (may be vector transmitted)	Abattoir worker Abattoir worker (poultry)	Q fever

Agent	Occupation/sector	Disease/health effect
	Agriculture	
	Agriculture (animal worker/breeder, cattle worker, livestock handler, livestock farmer, poultry farmer)	
	Agriculture (crop worker)	
	Airline personnel	
	Animal worker (contact with live or dead animals, animal secretions)	
	Animal worker (handler, trader)	
	Butcher	
	Cleaner (cleaning and disinfection jobs in contaminated areas)	
	Customs worker	
	Epidemic control worker	
	Forestry worker	
	Global trade worker	
	Healthcare worker	
	Journalist/media professional	
	Laboratory worker	
	Librarian or art conservator	
	Meat industry worker	
	Military personnel (overseas work)	
	Pet shop worker	
	Traveller (worker required to travel frequently by air')	
	Veterinarian	
	Worker in war zones	
Erysipelothrix rhusiopathiae	Abattoir worker	Erysipeloid
Swine erysipelas bacilli	Abattoir worker (poultry)	Rouget/*Erysipelothrix rhusiopathiae* infection
	Agriculture	
	Agriculture (animal worker/breeder (ornamental birds), breeder, poultry farmer)	
	Animal worker (handler)	
	Bone button maker	
	Butcher	
	Fertiliser worker	

Agent	Occupation/sector	Disease/health effect
	Fishing industry worker (fisherman, fish handler)	
	Furrier	
	Laboratory worker	
	Leather worker	
	Meat industry worker	
	Naturalist	
	Sewage worker	
	Soap maker	
	Veterinarian	
	Worker in contact with animals	
	Zoo personnel	
Escherichia coli	Abattoir worker (poultry)	Colibacillosis
	Agriculture	Colibacteriosis
	Agriculture (animal worker/breeder (ornamental birds), poultry farmer)	
	Agriculture (crop worker)	
	Veterinarian	
	Waste worker	
	Zoo personnel	
Francisella tularensis (may be vector transmitted)	Agriculture	Tularaemia
	Agriculture (animal worker/breeder)	
	Airline personnel	
	Animal worker (contact with live or dead animals, animal secretions)	
	Animal worker (handler, trader)	
	Cleaner (cleaning and disinfection jobs in contaminated areas)	
	Customs worker	
	Epidemic control worker	
	Gardener	
	Global trade worker	
	Healthcare worker	
	Hunter	
	Journalist/media professional	
	Laboratory worker	

Agent	Occupation/sector	Disease/health effect
	Military personnel (overseas work)	
	Natural science researcher	
	Outdoor game manager	
	Pet shop worker	
	Taxidermist	
	Trader in venison	
	Traveller (worker required to travel frequently by air')	
	Veterinarian	
	Worker in war zones	
	Zoo personnel	
Francisella tularensis holartica/tularensis	Agriculture	Tularaemia
	Forestry worker	
	Laboratory worker	
Legionella spp.	Agricultural equipment manufacturing plant worker	Legionellosis
	Agriculture (animal worker/breeder)	
	Airline personnel	
	Animal worker (contact with live or dead animals, animal secretions)	
	Animal worker (trader)	
	Automotive plant worker	
	Biological treatment plant worker	
	Cleaner (cleaning and disinfection jobs in contaminated areas)	
	Construction worker (including plumber, water system worker)	
	Cooling tower worker (including air-conditioning systems, maintenance)	
	Customs worker	
	Driver (professional)	
	Epidemic control worker	
	Forestry worker	
	Gardener	
	Global trade worker	
	Healthcare worker	

Agent	Occupation/sector	Disease/health effect
	Healthcare worker (dental care) Journalist/media professional Laboratory worker Maintenance worker Mine worker Office worker Offshore worker (oil and gas installations) Paper industry worker Pet shop worker Plant and machine operator or assembler Plastic factory worker Print plant worker (stagnant warm water) Railway conductor Sewage worker, wastewater treatment worker Subway personnel Textile industry worker Traveller (worker required to travel frequently by air) Turbine operator Vehicle washer Veterinarian Waste worker Welder Worker in war zones Worker in workplace with mist machines Zoo personnel	
Leptospira spp. (may be vector transmitted) *Leptospira hardjo* *Leptospira pomona*	Abattoir worker Agriculture Agriculture (animal worker/breeder, livestock farmer, cattle worker, livestock handler) Agriculture (crop worker) Animal worker (carer, handler)	Leptospirosis

Agent	Occupation/sector	Disease/health effect
	Aquaculture	
	Butcher	
	Cleaner (buildings)	
	Fish industry (fisherman, fish handler)	
	Forestry worker	
	Hunter	
	Laboratory worker	
	Natural science researcher	
	Outdoor game manager	
	Pet shop worker	
	Veterinarian	
Listeria monocytogenes	Abattoir worker	Listeriosis
	Abattoir worker (poultry)	
	Agriculture (animal worker/breeder (ornamental birds), cattle worker, livestock handler, livestock farmer, poultry farmer)	
	Butcher	
	Laboratory worker	
	Veterinarian	
	Zoo personnel	
Mycobacterium chelonae	Plant and machine operator or assembler	Tuberculosis
Mycobacterium marinum	Abattoir worker	Tuberculosis
	Agriculture	
	Agriculture (animal worker/breeder)	
	Animal worker (handler)	
Mycobacterium marinum/balnei	Aquaculture	Tuberculosis
Mycobacterium tuberculosis/bovis/caprae	Abattoir worker	Tuberculosis
	Agriculture	
	Agriculture (animal worker/breeder, livestock farmer, poultry and pig farmer)	
	Airline personnel	
	Animal worker (contact with live or dead animals, animal secretions)	

Agent	Occupation/sector	Disease/health effect
	Animal worker (handler, trader)	
	Butcher	
	Cleaner	
	Cleaner (cleaning and disinfection jobs in contaminated areas)	
	Customs worker	
	Education	
	Emergency services (ambulance/fire/police/rescue)	
	Epidemic control worker	
	Forestry worker	
	Funeral service worker	
	Global trade worker	
	Healthcare worker	
	Journalist/media professional	
	Laboratory worker	
	Meat industry worker	
	Office worker	
	Pet shop worker	
	Prison guard	
	Traveller (worker required to travel frequently by air)	
	Veterinarian	
	Waste worker	
	Worker in war zones	
	Zoo personnel	
Neisseria	Education	*Neisseria* meningitis
Pasteurella	Abattoir worker	Pasteurellosis
Pasteurella multocida	Agriculture	
	Agriculture (animal worker/breeder)	
	Animal worker (handler)	
	Laboratory worker	
	Veterinarian	
Pseudomonas syringae	Snowmaker	
Pyrogenic germs	Abattoir worker	

Agent	Occupation/sector	Disease/health effect
	Agriculture Agriculture (animal worker/breeder) Animal worker (handler) Veterinarian	
Rickettsia akari (vector transmitted by infected mouse mites)	Cleaner	Rickettsialpox
Rickettsia typhi (vector transmitted)	Cleaner	Murine typhus
Salmonella spp.	Abattoir worker Abattoir worker (poultry) Agriculture (animal worker/breeder, breeder (ornamental birds), livestock farmer, poultry farmer) Butcher Healthcare worker Laboratory worker Pet shop worker Veterinarian Waste worker Zoo personnel	Salmonellosis
Salmonella hadar *Salmonella typhimurium*	Laundry worker	
Spirillum minus *Streptobacillus moniliformis*	Cleaner	Rat bite fever
Staphylococcus spp. *Staphylococcus aureus*	Abattoir worker Agriculture (animal worker/cattle worker, livestock handler) Butcher Laboratory worker Waste worker	
Streptococcus spp.	Agriculture (animal worker/cattle worker, livestock handler) Laboratory worker Veterinarian	

Agent	Occupation/sector	Disease/health effect
Streptococcus pyogenes	Abattoir worker Healthcare worker	
Streptococcus suis	Agriculture Agriculture (animal worker/pig farmer)	Meningitis
Treponema pallidum	Healthcare worker Hotel staff Seaman, sailor Sex worker/adult movie actor Waste worker	Syphilis
Yersinia (*enterocolitica*)	Abattoir worker (poultry) Agriculture (animal worker/breeder (ornamental birds), poultry farmer) Veterinarian Zoo personnel	Yersiniosis
Drug-resistant bacteria		
MRSA	Agriculture Food processing worker (in contact with animals) Healthcare worker Laboratory worker Librarian or art conservator Veterinarian	
Vancomycin-resistant enterococci	Healthcare worker	

Table 7: Overview of occupations, biological agents and related infectious diseases for the 'fungi' category, by occupation

Occupation	Agent	Disease/health effect
Abattoir worker	Dermatophytes *Epidermophyton* *Microsporum* spp. *Trichophyton* spp.	Dermatomycoses Ringworm Dermatomycosis, tinea
Abattoir worker (poultry)		Cryptococcosis

Occupation	Agent	Disease/health effect
		Histoplasmosis
Agriculture	*Acremonium* sp.	Dermatomycoses
	Anthropophilic dermatophytes	Dermatomycoses (e.g. tinea pedis, athlete's foot, onychomycosis)
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Blastomyces dermatitidis	Blastomycosis
	Cladosporium carrioni	Chromomycosis
	Coccidioides immitis/posadasii	Coccidioidomycosis
	Conidiobolus sp.	Dermatomycoses
	Dermatophytes	Dermatomycoses
	Epidermophyton	
	Fonsecaea pedrosoi	Chromomycosis
	Fusarium sp.	Dermatomycoses
	Histoplasma capsulatum	Histoplasmosis
	Indoor moulds	Sick building syndrome, asthma, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Phialophora verrucosa	Chromomycosis
	Pseudallescheria boydii	Dermatomycoses
	Rhinocladiella aquaspersa	Chromomycosis
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Sporotrichosis
	Trichophyton	Dermatomycoses
	Zoophilic dermatophytes (calves, *Trichophyton verrucosum*)	Dermatomycoses
	Zygomycetes	Dermatomycoses
Agriculture (animal worker/breeder)	Dermatophytes	Dermatomycoses
	Epidermophyton	

Occupation	Agent	Disease/health effect
	Trichophyton	Dermatomycoses
Agriculture (animal worker/cattle worker, livestock handler)	*Trichophyton* spp.	Dermatomycosis, tinea
Agriculture (animal worker/livestock farmer)	Zoophilic dermatophytes	Dermatomycoses
Agriculture (animal worker/poultry farmer)	*Cryptococcus neoformans/gattii*	Cryptococcosis
	Histoplasma capsulatum	Histoplasmosis
Agriculture (crop worker)	*Trichoderma harzianum*	Respiratory health effects
Animal worker (fur farms)	Zoophilic dermatophytes	Dermatomycoses
Aquarist	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Conidiobolus sp.	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Pseudallescheria boydii	Dermatomycoses
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Dermatomycoses
	Zygomycetes	Dermatomycoses
Archaeologist	*Coccidioides immitis/posadasii*	Coccidioidomycosis
Butcher	*Microsporum* spp.	Ringworm
Caretaker	*Sporothrix schenckii*	Sporotrichosis
Chapman (travelling salesperson)	*Cladosporium carrioni*	Chromomycosis
	Fonsecaea pedrosoi	Chromomycosis
	Phialophora verrucosa	Chromomycosis
	Rhinocladiella aquaspersa	Chromomycosis
Composting site worker	*Aspergillus fumigatus*	Pulmonary and respiratory diseases
Construction worker	*Cladosporium carrioni*	Chromomycosis

Occupation	Agent	Disease/health effect
	Fonsecaea pedrosoi	Chromomycosis
	Indoor moulds	Sick building syndrome, asthma, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
	Mycotic agents	Dermatomycoses
	Phialophora verrucosa	Chromomycosis
	Rhinocladiella aquaspersa	Chromomycosis
Construction worker (hazardous materials removal)	Indoor moulds	Sick building syndrome, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
Cotton mill worker	Indoor moulds	Sick building syndrome, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
Desert worker	*Coccidioides immitis/posadasii*	Coccidioidomycosis
Development worker	Tropical fungi	Dermatomycoses (e.g. mycetoma)
Driver (professional)	*Cladosporium carrioni*	Chromomycosis
	Dermatophytes (calves, *Trichophyton verrucosum*)	Dermatomycoses (e.g. *Trichophyton verrucosum* infection)
	Fonsecaea pedrosoi	Chromomycosis
	Phialophora verrucosa	Chromomycosis
	Rhinocladiella aquaspersa	Chromomycosis
Education	Indoor moulds	Sick building syndrome, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
Fishing industry worker (fisherman, fish-handler)	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses

Occupation	Agent	Disease/health effect
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Conidiobolus sp.	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Pseudallescheria boydii	Dermatomycoses
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Dermatomycoses
	Zygomycetes	Dermatomycoses
Florist/floral worker	Geophilic dermatophytes (e.g. *Sporothrix schenckii*)	Dermatomycoses (e.g. rose breeder's disease)
	Microsporum fulvum/gypseum	Dermatomycoses
Forestry worker	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Conidiobolus sp.	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Pseudallescheria boydii	Dermatomycoses
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Dermatomycoses
	Zygomycetes	Dermatomycoses
Gardener	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Conidiobolus sp.	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Geophilic dermatophytes (e.g. *Sporothrix schenckii*)	Dermatomycoses (e.g. rose breeder's disease)
	Lacazia loboi	Dermatomycoses
	Microsporum fulvum	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses

Occupation	Agent	Disease/health effect
	Microsporum gypseum	Dermatomycoses
	Pseudallescheria boydii	Dermatomycoses
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Dermatomycoses/Sporotrichosis
	Zygomycetes	Dermatomycoses
Greenhouse worker	Geophilic dermatophytes (e.g. *Sporothrix schenckii*)	Dermatomycoses (e.g. rose breeder's disease)
	Microsporum fulvum/gypseum	Dermatomycoses
Healthcare worker	*Blastomyces dermatitidis*	Blastomycosis
	Coccidioides immitis/posadasii	Coccidioidomycosis
	Histoplasma capsulatum	Histoplasmosis
	Indoor moulds	Sick building syndrome, asthma, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
Healthcare worker (dental care)	Mycotic agents (onychoses)	Skin infections
Hotel staff (room maid)	*Cladosporium carrioni*	Chromomycosis
	Fonsecaea pedrosoi	Chromomycosis
	Phialophora verrucosa	Chromomycosis
	Rhinocladiella aquaspersa	Chromomycosis
Hunter	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Conidiobolus sp.	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Pseudallescheria boydii	Dermatomycoses
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Dermatomycoses
	Zygomycetes	Dermatomycoses

Occupation	Agent	Disease/health effect
Industrial worker or meat factory worker	Anthropophilic dermatophytes	Dermatomycoses (e.g. tinea pedis, athlete's foot)
Laboratory worker	*Microsporum* spp.	Ringworm
	Microsporum canis	Dermatomycoses
	Trichophyton spp.	Dermatomycosis, tinea
	Trichophyton mentagrophyte	Dermatomycoses
	Zoophilic dermatophytes	Dermatomycoses
Laundry worker	*Microsporum canis*	Dermatomycoses
Legal consultant	*Cladosporium carrioni*	Chromomycosis
	Fonsecaea pedrosoi	Chromomycosis
	Phialophora verrucosa	Chromomycosis
	Rhinocladiella aquaspersa	Chromomycosis
Locksmith	*Cladosporium carrioni*	Chromomycosis
	Fonsecaea pedrosoi	Chromomycosis
	Phialophora verrucosa	Chromomycosis
	Rhinocladiella aquaspersa	Chromomycosis
Military personnel	*Coccidioides immitis/posadasii*	Coccidioidomycosis
	Microsporum canis	Dermatomycoses
	Microsporum gypseum	Dermatomycoses
	Trichophyton interdigitale	Dermatomycosis, tinea
	Trichophyton mentagrophytes	Dermatomycosis, tinea
	Trichophyton rubrum	Dermatomycosis, tinea
	Trichophyton tonsurans	Dermatomycosis, tinea
	Trichophyton verrucosum	Dermatomycosis, tinea
Mine worker	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Conidiobolus sp.	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Pseudallescheria boydii	Dermatomycoses

Occupation	Agent	Disease/health effect
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Sporotrichosis
	Zygomycetes	Dermatomycoses
Office worker	Indoor moulds	Sick building syndrome, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, irritation of the nose, throat, eye and skin
Outdoor worker	*Aspergillus*	Mycotic keratitis (cornea infection)
	Candida albicans	Mycotic keratitis (cornea infection)
	Fusarium sp.	Dermatomycoses
	Phaeohyphomycetes	Mycotic keratitis (cornea infection)
	Scedosporium apiospermum	Mycotic keratitis (cornea infection)
Pet shop worker		Dermal lesions, ringworm
Shepherd	*Trichophyton verrucosum*	*Trichophyton verrucosum* infection
	Zoophilic dermatophytes	Dermatomycoses
Technician	*Sporothrix schenckii*	Sporotrichosis
Veterinarian	*Acremonium* sp.	Dermatomycoses
	Basidiobulus ranarum	Dermatomycoses
	Black fungi (pathogen of chromoblastomycosis)	Dermatomycoses
	Coccidioides immitis/posadasii	Coccidioidomycosis
	Conidiobolus sp.	Dermatomycoses
	Cryptococcus	Cryptococcosis
	Dermatophytes	Dermatomycoses
	Fusarium sp.	Dermatomycoses
	Histoplasma	Histoplasmosis
	Lacazia loboi	Dermatomycoses
	Madurella mycetomatis	Dermatomycoses
	Microsporum spp.	Ringworm
	Microsporum canis	Dermatomycoses

Occupation	Agent	Disease/health effect
	Mycotic agents (onychoses)	Skin infections
	Pseudallescheria boydii	Dermatomycoses
	Scedosporium sp.	Dermatomycoses
	Sporothrix schenckii	Sporotrichosis, dermatomycoses
	Trichophyton spp.	Dermatomycosis, tinea
	Zygomycetes	Dermatomycoses
Waste worker	*Alternaria*	
	Aspergillus	Mycotic keratitis (cornea infection)
	Cladosporium	Skin and nail infections
	Cryptococcus	
	Geotrichum	
	Indoor moulds	Sick building syndrome, asthma, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
	Penicillium	
	Rhodotorula	
	Trichoderma	
Wood industry worker	Mould spores	Reduction in lung function
	Sporothrix schenckii	Sporotrichosis
Zoo personnel	*Coccidioides immitis/posadasii*	Coccidioidomycosis
	Cryptococcus neoformans/gattii	Cryptococcosis
	Histoplasma capsulatum	Histoplasmosis

Table 8: Overview of occupations, biological agents and related infectious diseases for the 'fungi' category, by agent

Agent	Occupation	Disease/health effect
Dermatophytes		
Anthropophilic dermatophytes	Agricultural worker	Dermatomycoses (e.g. tinea pedis, athlete's foot, onychomycosis)
	Industrial worker or meat factory worker	

Agent	Occupation	Disease/health effect
Dermatophytes	Abattoir worker Agriculture Agriculture (animal worker/breeder) Veterinarian	Dermatomycoses
Geophilic dermatophytes (e.g. *Sporothrix schenckii*)	Florist/floral worker Gardener Greenhouse worker	Dermatomycoses (e.g. rose breeder's disease)
Zoophilic dermatophytes (calves, *Trichophyton verrucosum*)	Agriculture Agriculture (animal worker/livestock farmer) Animal worker (fur farms) Laboratory worker Shepherd	Dermatomycoses
Specific fungi		
Acremonium sp.	Agriculture Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker Gardener Hunter Mine worker Veterinarian	Dermatomycoses
Alternaria	Waste worker	
Aspergillus	Outdoor worker Waste worker	Mycotic keratitis (cornea infection)
Aspergillus fumigatus	Composting site worker	Pulmonary and respiratory diseases
Basidiobulus ranarum	Agricultural worker Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker	Dermatomycoses

Agent	Occupation	Disease/health effect
	Gardener Hunter Mine worker Veterinarian	
Black fungi (pathogen of chromoblastomycosis)	Agriculture Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker Gardener Hunter Mine worker Veterinarian	Dermatomycoses
Candida albicans	Outdoor worker	Mycotic keratitis (cornea infection)
Cladosporium	Waste worker	
Cladosporium carrioni	Agriculture Chapman (travelling salesperson) Construction worker Driver (professional) Hotel staff (room maid) Legal consultant Locksmith	Chromomycosis
Coccidioides	Agriculture Healthcare worker Veterinarian Zoo personnel	Coccidioidomycosis
Coccidioides immitis/posadasii	Archaeologist Desert worker Military personnel	Coccidioidomycosis
Conidiobolus sp.	Agriculture Aquarist	Dermatomycoses

Agent	Occupation	Disease/health effect
	Fishing industry worker (fisherman, fish handler)	
	Forestry worker	
	Gardener	
	Hunter	
	Mine worker	
	Veterinarian	
Cryptococcus	Abattoir worker (poultry)	Cryptococcosis
	Agriculture (animal worker/poultry farmer)	
	Veterinarian	
	Waste worker	
	Zoo personnel	
Epidermophyton	Abattoir worker	
	Agriculture	
	Agriculture (animal worker/breeder)	
Fonsecaea pedrosoi	Agriculture	Chromomycosis
	Chapman (travelling salesperson)	
	Construction worker	
	Driver (professional)	
	Hotel staff (room maid)	
	Legal consultant	
	Locksmith	
Fusarium sp.	Agriculture	Dermatomycoses
	Aquarist	
	Fishing industry worker (fisherman, fish handler)	
	Forestry worker	
	Gardener	
	Hunter	
	Mine worker	
	Outdoor worker	
	Veterinarian	

Agent	Occupation	Disease/health effect
Geotrichum	Waste worker	
Histoplasma capsulatum	Abattoir worker (poultry) Agriculture Agriculture (animal worker/poultry farmer) Healthcare worker Veterinarian Zoo personnel	Histoplasmosis
Lacazia loboi	Agriculture Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker Gardener Hunter Mine worker Veterinarian	Dermatomycoses
Madurella mycetomatis	Agriculture Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker Gardener Hunter Mine worker Veterinarian	Dermatomycoses
Microsporum spp.	Abattoir worker Butcher Laboratory worker Pet shop worker Veterinarian	Ringworm
Microsporum canis	Laundry worker Military personnel Laboratory worker	Dermatomycoses

Agent	Occupation	Disease/health effect
	Veterinarian	
Microsporum fulvum	Florist/floral worker Gardener Greenhouse worker	Dermatomycoses
Microsporum gypseum	Florist/floral worker Gardener Military personnel Greenhouse worker	Dermatomycoses
Penicillium	Waste worker	
Phaeohyphomycetes	Outdoor worker	Mycotic keratitis (cornea infection)
Phialophora verrucosa	Agriculture Chapman (travelling salesperson) Construction worker Driver (professional) Hotel staff (room maid) Legal consultant Locksmith	Chromomycosis
Pseudallescheria boydii	Agriculture Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker Gardener Hunter Mine worker Veterinarian	Dermatomycoses
Rhinocladiella aquaspersa	Agricultural worker Chapman (travelling salesperson) Construction worker Driver (professional) Hotel staff (room maid)	Chromomycosis

Agent	Occupation	Disease/health effect
	Legal consultant	
	Locksmith	
Rhodotorula	Waste worker	
Scedosporium sp.	Agriculture	Dermatomycoses
	Aquarist	
	Fishing industry worker (fisherman, fish handler)	
	Forestry worker	
	Gardener	
	Hunter	
	Mine worker	
	Veterinarian	
Scedosporium apiospermum	Outdoor worker	Mycotic keratitis (cornea infection)
Sporothrix schenckii	Agriculture	Sporotrichosis
	Aquarist	
	Caretaker	
	Fishing industry worker (fisherman, fish handler)	
	Forestry worker	
	Gardener	
	Hunter	
	Mine worker	
	Technician	
	Veterinarian	
	Wood industry worker	
Trichoderma	Waste worker	
Trichophyton spp.	Abattoir worker	Dermatomycosis, tinea
	Agriculture	
	Agriculture (animal worker/breeder)	
	Agriculture (animal worker/cattle worker, livestock handler)	
	Laboratory worker	

Agent	Occupation	Disease/health effect
	Veterinarian	
Trichoderma harzianum	Agriculture (crop worker)	Respiratory health effects
Trichophyton interdigitale	Military personnel	Dermatomycosis, tinea
Trichophyton mentagrophyte	Laboratory worker Military personnel	Dermatomycoses
Trichophyton rubrum	Military personnel	Dermatomycosis, tinea
Trichophyton tonsurans	Military personnel	Dermatomycosis, tinea
Trichophyton verrucosum	Driver (professional) Military personnel Shepherd	Dermatomycosis, tinea
Zygomycetes	Agriculture Aquarist Fishing industry worker (fisherman, fish handler) Forestry worker Hunter Gardener Mine worker Veterinarian	Dermatomycoses
Unspecific groups		
Indoor moulds	Agriculture Construction worker Construction worker (hazardous materials removal) Cotton mill worker Education Healthcare worker Office worker Waste worker	Sick building syndrome, asthma, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin
Mould spores	Wood industry worker	Reduction in lung function
	Agriculture Healthcare worker	Blastomycosis

Agent	Occupation	Disease/health effect
Mycotic agents	Construction worker	Dermatomycoses
Mycotic agents (onychoses)	Healthcare worker (dental care) Veterinarian	Skin infections
Tropical fungi	Development worker	Dermatomycoses (e.g. mycetoma)

Table 9: Overview of occupations, biological agents and related infectious diseases for the 'oomycota' category

Agent	Occupation	Disease
Phytium insidosum	Agriculture Aquarist Fishing industry (fisherman, fish handler) Forestry worker Gardener Hunter Mine worker Veterinarian	Dermatomycoses

Table 10: Overview of occupations, biological agents and related infectious diseases for the 'parasites' category, by occupation

Occupation	Agent	Disease/health effect
Abattoir worker	*Echinococcus*	Echinococcosis
	Fleas and worms	
	Toxocara canis	Toxocariasis
	Toxoplasma gondii	Toxoplasmosis
Agriculture	*Dirofilaria repens*	Dirofilariasis
	Cryptosporidium spp.	Cryptosporidiosis
	Toxocara canis	Toxocariasis
	Toxoplasma gondii	Toxoplasmosis
Agricultural worker (animal worker/breeder)	Tapeworms of the *Echinococcus* type	Echinococcosis
Agriculture (crop worker)	*Toxocara canis*	Toxocariasis

Occupation	Agent	Disease/health effect
Animal worker (carer)	*Toxocara canis*	Toxocariasis
	Toxoplasma gondii	Toxoplasmosis
Animal worker (handler)	*Cryptosporidium* spp.	Cryptosporidiosis
Caretaker	*Cryptosporidium parvum*	Cryptosporidiosis
Forestry worker	*Toxoplasma gondii*	Toxoplasmosis
Healthcare worker	*Babesia*	Babesiosis
	Cryptosporidium spp.	Cryptosporidiosis
Hunter	*Toxocara canis*	Toxocariasis
Librarian or art conservator	*Babesia*	Malaria
Military personnel (overseas work)	*Plasmodium falciparum/knowlesi/malariae/ovale/vivax*	Malaria
	Trypanosoma cruzi	Chagas disease
Pet shop worker	*Toxoplasma gondii*	
Veterinarian	*Ancylostoma braziliense*	Cutaneous larva migrans
	Babesia	Babesiosis
	Babesia canis	Canine babesiosis
	Balantidium coli	Balantidiasis
	Brugia malayi	Malayan filariasis
	Cryptosporidium spp.	Cryptosporidiosis
	Dirofilaria repens	Dirofilariasis
	Giardia lamblia	Giardiasis
	Leishmania	Leishmaniasis
	Tapeworms of the *Echinococcus* type	Echinococcosis (hydatidosis)
	Taenia	Coenuriasis
	Taenia multiceps/serialis/brauni/glomerate (larval stage)	Taeniasis
	Toxocara canis	Toxocariasis
	Toxoplasma gondii	Toxoplasmosis
	Trichinella	Trichinellosis
	Trypanosoma cruzi	Chagas disease

Occupation	Agent	Disease/health effect
	Trypanosoma	Trypanosomiasis
		Visceral larva migrans
Waste worker	*Toxoplasma gondii*	Toxoplasmosis
Zoo personnel	*Ancylostoma braziliense*	Cutaneous larva migrans
	Babesia	Babesiosis
	Balantidium coli	Balantidiasis
	Brugia malayi	Malayan filariasis
	Cryptosporidium spp.	Cryptosporidiosis
	Dirofilaria repens	Dirofilariasis
	Echinococcus	Echinococcosis
	Giardia lamblia	Giardiasis
	Leishmania	Leishmaniasis
	Plasmodium	Malaria
	Taenia	Taeniasis
	Taenia multiceps/serialis/brauni/glomerate (larval stage)	Coenuriasis
	Toxoplasma gondii	Toxoplasmosis
	Trichinella	Trichinellosis
	Trypanosoma	Trypanosomiasis
	Trypanosoma cruzi	Chagas disease
		Visceral larva migrans

Table 11: Overview of occupations, biological agents and related infectious diseases for the 'parasites' category, by agent

Agent	Occupation	Disease/health effect
Ancylostoma braziliense	Veterinarian	Cutaneous larva migrans
	Zoo personnel	
Babesia	Librarian or art conservator	Malaria
	Healthcare worker	Babesiosis
	Veterinarian	Babesiosis
	Zoo personnel	Babesiosis

Agent	Occupation	Disease/health effect
Babesia canis	Veterinarian	Canine babesiosis
Balantidium coli	Veterinarian Zoo personnel	Balantidiasis
Brugia malayi	Veterinarian Zoo personnel	Malayan filariasis
Cryptosporidium spp.	Agriculture Animal worker (handler) Healthcare worker Veterinarian Zoo personnel	Cryptosporidiosis
Cryptosporidium parvum	Caretaker	Cryptosporidiosis
Dirofilaria repens	Agriculture Veterinarian Zoo personnel	Dirofilariasis
Echinococcus	Abattoir worker Agriculture (animal worker/breeder) Veterinarian Zoo personnel	Echinococcosis (Hydatidosis)
Fleas and worms	Abattoir worker	
Giardia lamblia	Veterinarian Zoo personnel	Giardiasis
Leishmania	Veterinarian Zoo personnel	Leishmaniasis
Plasmodium	Agriculture Zoo personnel	Malaria
Plasmodium falciparum/knowlesi/ malariae/ovale/vivax	Military personnel (overseas work)	Malaria
Taenia	Veterinarian Zoo personnel	Taeniasis

Agent	Occupation	Disease/health effect
Taenia multiceps/serialis/brauni/glomerate (larval stage)	Veterinarian Zoo personnel	Coenuriasis, Coenurosis
Toxocara canis	Abattoir worker Agricultur Agricultur (crop worker) Animal worker (carer) Hunter Veterinarian	Toxocariasis
Toxoplasma gondii	Abattoir worker Agricultur Animal worker (carer) Forestry worker Pet shop worker Veterinarian Waste worker Zoo personnel	Toxoplasmosis
Trichinella	Veterinarian Zoo personnel	Trichinellosis
Trypanosoma	Military personnel (overseas work)	
Trypanosoma	Veterinarian Zoo personnel	Trypanosomiasis
Trypanosoma cruzi	Military personnel (overseas work) Veterinarian Zoo personnel	Chagas disease
	Veterinarian Zoo personnel	Visceral larva migrans

Table 12: Overview of occupations, biological agents and related infectious diseases for the 'other organisms' category

Occupation	Agent	Disease/ health effect
Archaea		
Agriculture Wastewater treatment worker	Archaea in bioaerosols	Sensitisation
Arthropods		
Animal worker (handler) Laundry worker	*Sarcoptes scabei*	Scabies

Table 13: Overview of occupations, biological agents and related infectious diseases for the 'prion' category

Occupation	Disease
Abattoir worker	New variant Creutzfeldt-Jacob disease
Agriculture (animal worker/cattle worker, livestock handler)	New variant Creutzfeldt-Jacob disease
Laboratory worker	New variant Creutzfeldt-Jacob disease
Veterinarian	New variant Creutzfeldt-Jacob disease

Table 14: Overview of occupations, biological agents and related infectious diseases for the 'virus' category, by occupation

Occupation	Agent	Disease/health effect
Abattoir worker	Cowpox virus	Cowpox
	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Dengue virus	Dengue fever
	Ebola virus	Haemorrhagic shock, death
	Hepatitis E virus	Hepatitis E
	Influenza A virus	Influenza
	Louping ill virus	Influenza-like illness
	Lyssa virus	Rabies
	Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles

Occupation	Agent	Disease/health effect
	Papillomavirus	Plantar warts, butcher's warts
	Parapoxvirus	Contagious ecthyma
	RNA virus of the genus *Flavivirus*	Yellow fever
	SARS coronavirus	SARS
	Vesicular stomatitis (Indiana) virus	Vesicular stomatitis
Abattoir worker (poultry)	Avian influenza virus	Avian influenza
	Newcastle disease virus	Newcastle disease
	Tick-borne encephalitis virus	Tick-borne encephalitis
	West Nile virus	West Nile virus infection
Agriculture	Chikungunya virus	Chikungunya
	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Cowpox virus	Cowpox
	Dengue virus	Dengue fever
	Hanta virus	Hanta
	Hendra and Nipah viruses	Hendra and Nipah virus diseases
	Hepatitis C and E viruses	Hepatitis C and E
	Influenza A (H7N7)	Influenza
	Influenza virus	Influenza
		Influenza-like illness
	(Swine and avian) influenza virus	Influenza
	Louping ill virus	Meningitis
	Lymphocytic choriomeningitis virus	
	Lyssa virus	Rabies
	Monkeypox virus	Monkeypox
	Newcastle disease virus	Newcastle disease
	Papillomavirus	Plantar warts, butcher's warts
	Parapoxvirus	Contagious ecthyma
	Rift Valley fever virus	Rift Valley fever
	RNA virus of the genus *Flavivirus*	Yellow fever
	Tick-borne encephalitis virus	Encephalitis

Occupation	Agent	Disease/health effect
	West Nile virus	West Nile virus infection
Agriculture (animal worker/breeder)	Avian influenza virus	Avian influenza
	Cowpox virus	Cowpox
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	Papillomavirus	Plantar warts, butcher's warts
	Parapoxvirus	Contagious ecthyma
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Agriculture (animal worker/breeder (ornamental birds))	Avian influenza virus	Avian influenza
	Newcastle disease virus	Newcastle disease
	West Nile virus	West Nile virus infection
Agriculture (animal worker/pig farmer)	Hepatitis E virus	Hepatitis E
	Swine influenza (*Orthomyxoviridae* type A: H1N1 virus)	Influenza-like illness, namely chills, fever, sore throat, muscle pains, severe headache, coughing, weakness, and general discomfort
Agriculture (animal worker/poultry and pig farmer)	Influenza (H5N1, H7N1, H7N7, H1N1), coronavirus A	Influenza
Agriculture (animal worker/poultry farmer)	Avian influenza virus	Avian influenza
	Newcastle disease virus	Newcastle disease
	Tick-borne encephalitis virus	Tick-borne encephalitis
	West Nile virus	West Nile virus infection
Airline personnel	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Hepatitis E virus	Hepatitis E
	Lassa virus	Lassa fever
	Measles virus	Measles
	RNA virus of the genus *Flavivirus*	Yellow fever
	SARS coronavirus	SARS

Occupation	Agent	Disease/health effect
Animal worker (birds)	Influenza A virus (e.g. H5N1 strain)	Influenza
Animal worker (carer)	Hanta virus	Hanta
	Influenza virus	Influenza
	Simian foamy virus	Simian foamy virus infection
	Simian parvovirus	
	Simian type D retrovirus	
Animal worker (contact with live or dead animals, animal secretions)	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Animal worker (handler)	Cowpox virus	Cowpox
	Hendra and Nipah viruses	Hendra and Nipah virus diseases
	Influenza virus	Influenza
	Lymphocytic choriomeningitis	Meningitis
	Lyssa virus	Rabies
	Monkeypox virus	Monkeypox
	Newcastle disease virus	Newcastle disease
	Papillomavirus	Plantar warts, butcher's warts
	Parapoxvirus	Contagious ecthyma
Animal worker (trader)	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Beautician	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
Border guard	Tick-borne encephalitis virus	Encephalitis

Occupation	Agent	Disease/health effect
Butcher	Louping ill virus	Influenza-like illness
	Lyssa virus	Rabies
	Orf virus (*Parapoxvirus ovis*)	Orf
		Vesicular stomatitis
Caretaker	Cytomegalovirus	
	Hepatitis A virus	Hepatitis A
	Human parvovirus	Parvo
	Varicella zoster virus	
Cleaner	Arenavirus	Neurological symptoms and haemorrhagic fever
	Hanta virus	Hanta
	Hepatitis A, B and C viruses	Hepatitis A, B and C
	HIV	AIDS
	Lassa virus	Lassa fever
	Lymphocytic choriomeningitis virus	Meningitis
Cleaner (cleaning and disinfection jobs in contaminated areas)	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the genus *Flavivirus*	Yellow fever
	SARS coronavirus	SARS
Cleaner (dealing with dead rodents, their faeces and/or nesting materials)	Hanta virus	Hanta
Construction worker (plumber, electrician, telephone installer)	Hanta virus	Hanta
Customs worker	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever

Occupation	Agent	Disease/health effect
	SARS coronavirus	SARS
Driver (professional)	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
	SARS coronavirus	SARS
Educational worker	Cytomegalovirus	
	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
Emergency services (ambulance/fire/police/rescue)	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
Epidemic control worker	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Food processing worker (preparation, serving)	SARS coronavirus	SARS
Forestry worker	Hanta virus	Hanta
	Lyssa virus	Rabies
	Tick-borne encephalitis virus	Encephalitis
Funeral services worker	SARS coronavirus	SARS
Gardener	Tick-borne encephalitis virus	Encephalitis
Global trade worker	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Ground/soil worker, in uninhabited premises	Hanta virus	Hanta

Occupation	Agent	Disease/health effect
Healthcare worker	Avian influenza virus	Avian influenza
	Coronavirus A	SARS
	Coltivirus	Colorado tick fever
	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Cytomegalovirus	
	Dengue virus	Dengue fever
	Ebola virus	Haemorrhagic shock, death
	Hendra and Nipah viruses	Hendra and Nipah virus diseases
	Hanta virus	Hanta
	Hepatitis A, B, C and D viruses	Hepatitis A, B, C and D
	Herpes simplex	Herpes
	Herpes B	B virus infection
	HIV	AIDS
	Influenza virus	Influenza
	Lymphocytic choriomeningitis	Meningitis
	Lyssa virus	Rabies
	Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	Monkeypox virus	Monkeypox
	Mumps virus	Mumps
	Newcastle disease virus	Newcastle disease
	Papillomavirus	Plantar warts, butcher's warts
	Parvovirus B19	Parvo
	Rift Valley fever virus	Rift Valley fever
	RNA virus of the *Flavivirus* genus	Yellow fever
	Rotavirus	
	Human respiratory syncytial virus	
	Rubella virus	Rubella
	SARS coronavirus	SARS
	Varicella zoster virus	
	West Nile virus	West Nile fever

Occupation	Agent	Disease/health effect
Healthcare worker (dental care)	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Ebola virus	Haemorrhagic shock, death
	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
	Lassa virus	Lassa fever
	Marburg virus	Haemorrhagic shock, death
Hunter	Avian influenza virus	Avian influenza
	Hanta virus	Hanta
	Hepatitis E virus	Hepatitis E
	Tick-borne encephalitis virus	Encephalitis
Journalist/media professional	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Laboratory worker	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola virus	Haemorrhagic shock, death
	Hanta virus	Hanta
	Hendra and Nipah viruses	Hendra and Nipah virus diseases
	Hepatitis A, B and C viruses	Hepatitis A, B and C
	Herpes B	B virus infection
	HIV	AIDS
	Influenza virus	Influenza
	Lymphocytic choriomeningitis virus	Meningitis
	Lyssa virus	Rabies
	Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	Newcastle disease virus	Newcastle disease
	Orf virus (*Parapoxvirus ovis*)	Orf

Occupation	Agent	Disease/health effect
	Rhinovirus	
	RNA virus of the genus *Flavivirus*	Yellow fever
	SARS coronavirus	SARS
	Simian foamy virus	Simian foamy virus infection
	Vesicular stomatitis (Indiana) virus	Vesicular stomatitis
Laundry worker	Hepatitis A virus	Hepatitis A
Librarian or art conservator	Hanta virus	Hanta
	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
	Influenza virus	Influenza
Maintenance worker	Hanta virus	Hanta
	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
Meat industry worker	Chikungunya virus	Chikungunya
	Dengue virus	Dengue fever
	Rift Valley fever virus	Rift Valley fever
	RNA virus of the *Flavivirus* genus	Yellow fever
Military personnel	Hepatitis B and C viruses	Hepatitis B and C
	Herpes simplex virus type 2	Herpes
	HIV	AIDS
Military personnel (overseas work)	Chikungunya virus	Chikungunya
	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Dengue virus	Dengue fever
	Rift Valley fever virus	Rift valley fever
	West Nile virus	West Nile encephalitis
	Phlebovirus	Sand fly fever
Mortuary worker	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
Office worker	Influenza virus	Influenza

Occupation	Agent	Disease/health effect
Ornithologist	Avian influenza virus	Avian influenza
Pest control worker	Avian influenza virus	Avian influenza
Pet shop worker	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Influenza A virus (e.g. H5N1 strain)	Influenza
	Measles virus	Measles
	Monkey pox virus	Monkeypox
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Seaman, sailor	HIV	AIDS
Sewage worker	Avian influenza virus	Avian influenza
	Hepatitis E virus	Hepatitis E
Sex worker/adult movie actor	Hepatitis B and C viruses	Hepatitis B and C
	Herpes simplex virus 2	Herpes
	HIV	AIDS
Social services	Hepatitis B and C viruses	Hepatitis B and C
	HIV	AIDS
Traveller (required to travel for work)	Hepatitis E virus	Hepatitis E
Traveller (worker required to travel frequently by air)	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Veterinarian	Avian influenza virus	Avian influenza
	Buffalopox virus	Buffalopox
	Chikungunya virus	Chikungunya
	Coltivirus	Colorado tick fever

Occupation	Agent	Disease/health effect
	Cowpox virus	Cowpox
	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Eastern equine encephalitis-virus	Equine encephalomyelitis
	Foot-and-mouth disease virus (FMDV)	Foot-and-mouth disease
	Hanta virus	Hantavirus pulmonary syndrome
	Hendra virus	Hendra virus disease
	Hepatitis A, B, C and E viruses	Hepatitis A, B, C and E
	Herpes B, B virus	Cercopithecine herpes virus 1 infection (B virus disease of macaques)
	Influenza virus	Influenza
	Japanese encephalitis virus	Japanese encephalitis
	Kyasanur forest disease virus (KFDV)	Kyasanur forest disease (a haemorrhagic fever)
	Louping ill virus	Influenza-like illness
	Lymphocytic choriomeningitis	Meningitis
	Lyssa virus	Rabies
	Measles virus	Measles
	Murray Valley encephalitis virus	Murray Valley encephalitis
	Monkeypox virus	Monkeypox
	Papillomavirus	Plantar warts, butcher's warts
	Parapoxvirus	Contagious ecthyma
	Newcastle disease virus	Newcastle disease
	Orf virus (*Parapoxvirus ovis*)	Contagious ecthyma (Orf)
	Rift Valley fever virus	Rift Valley fever
	RNA virus of the *Flavivirus* genus	Yellow fever
	Russian spring-summer encephalitis virus	Russian spring-summer encephalitis
	SARS coronavirus	SARS
	St Louis encephalitis virus	St Louis encephalitis
	Tanapoxvirus	Tanapox

Occupation	Agent	Disease/health effect
	Tick-borne encephalitis virus	Tick-borne encephalitis
	Vesicular stomatitis (Indiana) virus	Vesicular stomatitis
	West Nile virus	West Nile fever
		Viral haemorrhagic fevers
	Yabapoxvirus	Yabapox
Waste worker	Hepatitis A, B and C viruses	Hepatitis A, B and C
	HIV	AIDS
Worker in war zones	Avian influenza virus	Avian influenza
	Dengue virus	Dengue fever
	Ebola/Marburg virus	Haemorrhagic shock, death
	Measles virus	Measles
	RNA virus of the *Flavivirus* genus	Yellow fever
	SARS coronavirus	SARS
Zoo personnel	Avian influenza virus	Avian influenza
	Buffalopox virus	Buffalopox
	Coltivirus	Colorado tick fever
	Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
	Dengue virus	Dengue fever
	Eastern equine encephalitis virus	Equine encephalomyelitis
	Ebola/Marburg virus	Haemorrhagic shock, death
	FMDV	Foot-and-mouth disease
	Hanta virus	Hantavirus pulmonary syndrome
	Hendra virus	Hendra virus infection
	Hepatitis E virus	Hepatitis E
	Herpes B, B virus	Cercopithecine herpes virus 1 infection (B virus disease of macaques)
	Influenza A virus	Influenza type A
	Japanese encephalitis virus	Japanese encephalitis
	KFDV	Kyasanur forest disease
	Louping ill virus	Influenza-like illness

Occupation	Agent	Disease/health effect
	Lymphocytic choriomeningitis virus	Meningitis
	Lyssa virus	Rabies
	Measles virus	Measles
	Murray Valley encephalitis virus	Murray Valley encephalitis
	Newcastle disease virus	Newcastle disease
	Nipah virus	Nipah virus infection
	Rift Valley fever virus	Rift Valley fever
	RNA virus of the *Flavivirus* genus	Yellow fever
	Russian spring-summer encephalitis virus	Russian spring-summer encephalitis
	St Louis encephalitis virus	St Louis encephalitis
	SARS coronavirus	SARS
	Tanapoxvirus	Tanapox
	Tick-borne encephalitis virus	Tick-borne encephalitis
	West Nile virus	West Nile fever
		Viral haemorrhagic fevers
	Yabapoxvirus	Yabapox

Table 15: Overview of occupations, biological agents and related infectious diseases for the 'virus' category, by agent

Agent	Occupation	Disease/health effect
Avian influenza virus	Abattoir worker (poultry)	Avian influenza
	Agriculture (animal worker/breeder (ornamental birds), breeder, poultry farmer)	
	Airline personnel	
	Animal worker (contact with live or dead animals, animal secretions)	
	Animal worker (trader)	
	Cleaner (cleaning and disinfection jobs in contaminated areas)	
	Customs worker	
	Epidemic control worker	
	Global trade worker	
	Healthcare worker	

Agent	Occupation	Disease/health effect
	Hunter Journalist/media professional Laboratory worker Ornithologist Pest control worker Pet shop worker Sewage worker Traveller (worker required to travel frequently by air) Veterinarian	
Buffalopox virus	Veterinarian Zoo personnel	Buffalopox
Chikungunya virus	Agricultural worker Meat industry worker Military personnel (overseas work) Veterinarian	Chikungunya
Coltivirus	Healthcare worker Veterinarian Zoo personnel	Colorado tick fever
Cowpox virus	Abattoir worker Agriculture Agriculture (animal worker/breeder) Animal worker (handler) Veterinarian	Cowpox
Crimean-Congo haemorrhagic fever virus (vector transmitted)	Abattoir worker Agriculture Healthcare worker Healthcare worker (dental care) Military personnel (overseas work) Veterinarian Zoo personnel	Crimean-Congo haemorrhagic fever
Cytomegalovirus	Caretaker Educational worker	

Agent	Occupation	Disease/health effect
	Healthcare worker	
Dengue virus	Abattoir worker Agriculture Agriculture (animal worker/breeder) Airline personnel Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Cleaner (cleaning and disinfection jobs in contaminated areas) Customs worker Epidemic control worker Global trade worker Healthcare worker Journalist/media professional Laboratory worker Meat industry worker Military personnel (overseas work) Pet shop worker Traveller (worker required to travel frequently by air) Veterinarian Worker in war zones Zoo personnel	Dengue fever
Eastern equine encephalitis virus	Veterinarian Zoo personnel	Equine encephalomyelitis
Ebola virus	Abattoir worker Agriculture (animal worker/breeder) Airline personnel Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Cleaner (cleaning and disinfection jobs in contaminated areas)	Haemorrhagic shock, death

Agent	Occupation	Disease/health effect
	Customs worker Epidemic control worker Global trade worker Healthcare worker Healthcare worker (dental care) Journalist/media professional Laboratory worker Pet shop worker Traveller (worker required to travel frequently by air) Veterinarian Worker in war zones Zoo personnel	
FMDV	Veterinarian Zoo personnel	Foot-and-mouth disease
Hanta virus	Agriculture worker Animal worker (carer) Cleaner Cleaner (dealing with dead rodents, their faeces and/or nesting materials) Construction worker (plumber, electrician, telephone installer) Forestry worker Ground/soil worker, in uninhabited premises Healthcare worker Hunter Laboratory worker Librarian or art conservator Maintenance worker Veterinarian Zoo personnel	Hanta Hantavirus pulmonary syndrome
Hendra and Nipah viruses	Agricultural worker Animal worker (handler) Healthcare worker	Hendra and Nipah virus diseases

Agent	Occupation	Disease/health effect
	Laboratory worker	
Hendra virus	Veterinarian Zoo personnel	Hendra virus disease
Hepatitis A virus	Caretaker Cleaner Healthcare worker Laboratory worker Laundry worker Veterinarian Waste worker	Hepatitis A
Hepatitis B virus	Beautician Cleaner Driver (professional) Education Emergency services (ambulance/fire/police/rescue) Healthcare worker Healthcare worker (dental care) Laboratory worker Librarian or art conservator Maintenance worker Military personnel Mortuary worker Sex worker/adult movie actor Social services Veterinarian Waste worker	Hepatitis B
Hepatitis C virus	Agriculture Beautician Cleaner Driver (professional) Education Emergency services (ambulance/fire/police/rescue)	Hepatitis C

Agent	Occupation	Disease/health effect
	Healthcare worker Healthcare worker (dental care) Laboratory worker Librarian or art conservator Maintenance worker Military personnel Mortuary worker Sex worker/adult movie actor Social services Veterinarian Waste worker	
Hepatitis D virus	Healthcare worker	Hepatitis D
Hepatitis E virus	Abattoir worker Agriculture Agriculture (animal worker/pig farmer) Airline personnel Healthcare worker Hunter Sewage worker Traveller (required to travel for work) Veterinarian Zoo personnel	Hepatitis E
Herpes B Herpes simian B virus	Healthcare worker Laboratory worker Veterinarian Zoo personnel	B virus infection Cercopithecine herpes virus 1 (B virus disease of macaques)
Herpes simplex	Healthcare worker	Herpes
Herpes simplex virus type 2	Military personnel Sex worker/adult movie actor	Herpes
HIV	Beautician Cleaner Driver (professional)	AIDS

Agent	Occupation	Disease/health effect
	Education Emergency services (ambulance/fire/police/rescue) Healthcare worker Healthcare worker (dental care) Laboratory worker Librarian or art conservator Maintenance worker Military personnel Mortuary worker Seaman, sailor Sex worker/adult movie actor Social services Waste worker	
Human parvovirus Parvovirus B19	Caretaker Healthcare worker	Parvo
Human respiratory syncytial virus	Healthcare worker	
Influenza (H5N1, H7N1, H7N7, H1N1), Coronavirus A	Agriculture (animal worker/poultry and pig farmer)	Influenza
Influenza A (H7N7)	Agriculture	Influenza
Influenza A virus	Abattoir worker Zoo personnel	Influenza type A
Influenza A virus (e.g. H5N1 strain)	Animal worker (birds) Animal care worker/pet shop worker	Influenza
Influenza virus	Agriculture worker Animal worker (carer, handler) Healthcare worker Laboratory worker Librarian or art conservator Office worker Veterinarian	Influenza

Agent	Occupation	Disease/health effect
	Worker in war zones Zoo personnel	
Japanese encephalitis virus	Veterinarian Zoo personnel	Japanese encephalitis
KFDV	Veterinarian Zoo personnel	Kyasanur forest disease
Lassa virus (vector borne)	Airline personnel Cleaner Healthcare worker (dental care)	Lassa fever
Louping ill virus	Abattoir worker Agriculture Butcher Veterinarian Zoo personnel	Influenza-like illness
Lymphocytic choriomeningitis virus (vector borne)	Agriculture Animal worker (handler) Cleaner Healthcare worker Laboratory worker Veterinarian Zoo personnel	Meningitis
Lyssa virus	Abattoir worker Agriculture Animal worker (handler) Butcher Forestry worker Healthcare worker Laboratory worker Veterinarian Zoo personnel	Rabies
Marburg virus	Abattoir worker Agriculture (animal worker/breeder)	Haemorrhagic shock, death

Agent	Occupation	Disease/health effect
	Airline personnel	
	Animal worker (contact with live or dead animals, animal secretions)	
	Animal worker (trader)	
	Cleaner (cleaning and disinfection jobs in contaminated areas)	
	Customs worker	
	Epidemic control worker	
	Global trade worker	
	Healthcare worker	
	Healthcare worker (dental care)	
	Journalist/media professional	
	Laboratory worker	
	Pet (shop) worker	
	Traveller (worker required to travel frequently by air)	
	Veterinarian	
	Worker in war zones	
	Zoo personnel	
Measles virus	Abattoir worker Agriculture (animal worker/breeder) Airline personnel Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Cleaner (cleaning and disinfection jobs in contaminated areas) Customs worker Epidemic control worker Global trade worker Healthcare worker Journalist/media professional Laboratory worker Pet (shop) worker Traveller (worker required to travel frequently by air)	Measles

Agent	Occupation	Disease/health effect
	Veterinarian Worker in war zones Zoo personnel	
Monkeypox virus	Agricultural worker Animal worker (handler) Healthcare worker Pet (shop) worker Veterinarian	Monkeypox
Mumps virus	Healthcare worker	
Murray Valley encephalitis virus	Veterinarian Zoo personnel	Murray Valley encephalitis
Newcastle disease virus	Abattoir worker (poultry) Agricultural worker Agriculture (animal worker/breeder ornamental birds, poultry farmer) Animal worker (handler) Healthcare worker Laboratory worker Veterinarian Zoo personnel	Newcastle disease
Nipah virus	Zoo personnel	Nipah virus infection
Papillomavirus	Abattoir worker Agriculture Agriculture (animal worker/breeder) Animal worker (handler) Healthcare worker Veterinarian	Plantar warts, butcher's warts
Parapoxvirus	Abattoir worker Agriculture Agriculture (animal worker/breeder) Animal worker (handler) Veterinarian	Contagious ecthyma

Agent	Occupation	Disease/health effect
Orf virus (*Parapoxvirus ovis*)	Butcher Laboratory worker Veterinarian	Orf Contagious ecthyma (Orf)
Phlebovirus (vector transmitted)	Military personnel (overseas work)	Sand fly fever
Rift Valley fever virus	Agriculture Healthcare worker Meat industry worker Military personnel (overseas work) Veterinarian Zoo personnel	Rift Valley fever
RNA virus of the *Flavivirus* genus	Abattoir worker Agriculture Agriculture (animal worker/breeder) Airline personnel Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Cleaner (cleaning and disinfection jobs in contaminated areas) Customs worker Epidemic control worker Global trade worker Healthcare worker Journalist/media professional Laboratory worker Meat industry worker Pet (shop) worker Traveller (worker required to travel frequently by air) Veterinarian Worker in war zones Zoo personnel	Yellow fever
Rhinovirus	Laboratory worker	

Agent	Occupation	Disease/health effect
Rotavirus	Healthcare worker	Rotavirus diarrhoea
Rubella virus	Healthcare worker	Rubella
Russian spring-summer encephalitis virus	Veterinarian Zoo personnel	Russian spring-summer encephalitis
St Louis encephalitis virus	Veterinarian Zoo personnel	St Louis encephalitis
SARS coronavirus Coronavirus A	Abattoir worker Agriculture (animal worker/breeder) Airline personnel Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Cleaner (cleaning and disinfection jobs in contaminated areas) Customs worker Driver (professional) Epidemic control worker Food processing worker (preparation, serving) Funeral services worker Global trade worker Healthcare worker Journalist/media professional Laboratory worker Pet shop worker Traveller (worker required to travel frequently by air) Veterinarian Worker in war zones Zoo personnel	SARS
Simian foamy virus	Animal worker (carer) Laboratory worker	Simian foamy virus infection
Simian parvovirus	Animal worker (carer)	

Agent	Occupation	Disease/health effect
Simian type D retrovirus	Animal worker (carer)	
(Swine and avian) influenza virus	Agriculture	Influenza
Swine influenza (*Orthomyxoviridae* type A: H1N1 virus)	Agriculture (animal worker/pig farmer)	Influenza-like illness, namely chills, fever, sore throat, muscle pains, severe headache, coughing, weakness, and general discomfort
Tanapoxvirus	Veterinarian Zoo personnel	Tanapox
Tick-borne encephalitis virus (vector transmitted)	Abattoir worker (poultry) Agriculture Agriculture (animal worker/poultry farmer) Border guard Forestry worker Gardener Hunter Veterinarian Zoo personnel	Tick-borne encephalitis
Varicella zoster virus	Caretaker Healthcare worker	
Vesicular stomatitis (Indiana) virus	Abattoir worker Butcher Laboratory worker Veterinarian	Vesicular stomatitis
West Nile virus	Abattoir worker (poultry) Agriculture Agriculture (animal worker/breeder ornamental birds, poultry farmer) Healthcare worker Military personnel (overseas work) Veterinarian Zoo personnel	West Nile virus infection West Nile fever West Nile encephalitis
Yabapoxvirus	Veterinarian	Yabapox

Agent	Occupation	Disease/health effect
	Zoo personnel	
	Veterinarian Zoo personnel	Viral haemorrhagic fevers

4.2 Organic dust and effects of toxins

Organic dust and bacterial and fungal endotoxins produce a wide range of effects, including infections, toxic effects, carcinogenic effects and allergenic effects; these are presented in Tables 16-19. Ochratoxin A is a nephrotoxic mycotoxin that has received particular attention because of the toxic effects, widespread occurrence in contaminated food and feed chain, suspected causal effect on nephropathies, and, more recently, possibility of exposure by inhalation in domicile and occupational settings (Duarte et al. 2011). Ochratoxin A has also been proven to induce diverse toxic effects including teratogenicity, carcinogenicity, immunotoxicity and potential endocrine disruption (Woo and El-Nezami, 2016).

Increasingly, feed additives for livestock, such as amino acids and vitamins, are being produced by Gram-negative bacteria, particularly *Escherichia coli*. Workers can therefore be exposed to possibly harmful amounts of endotoxin from these products (Wallaceet al., 2016). Workers in sewage plants, poultry sheds, sawmills and materials recycling facilities are particularly exposed to high levels of respirable endotoxins, which leads to chronic bronchitis and diminished lung function (Wallace et al. 2016).

Table 16: Overview of health effects and related diseases for the ‘toxins/subcellular pathogens’ category, by occupation

Occupation	Agent	Disease/health effect
Agriculture	Bacterial endotoxins Endotoxins Mycotoxins	COPD
Agriculture (animal worker/poultry farmer)	Aflatoxins	Hepatotoxic, carcinogenic and immunosuppressive effects
Cotton mill worker	Endotoxins produced by *Pantoea agglomerans*	Reduced lung function caused by inflammation reaction
Feed production worker	Aflatoxins	Hepatotoxic, carcinogenic and immunosuppressive effects
Food processing (coffee, cocoa beans, spices)	Ochratoxin A	Carcinogenic, nephrotoxic, teratogenic and immunotoxic effects
Food processing (herbs and grains)	Aflatoxins	Hepatotoxic, carcinogenic and immunosuppressive effects

Occupation	Agent	Disease/health effect
Malt factory worker	Ochratoxin A	Carcinogenic, nephrotoxic, teratogenic and immunotoxic effects
Veterinarian	Bacterial endotoxins Mycotoxins	
Waste worker	Aflatoxins	Hepatotoxic, carcinogenic and immunosuppressive effects
	Ochratoxin A	Carcinogenic, nephrotoxic, teratogenic and immunotoxic effects

Table 17: Overview of occupations, biological agents and related diseases for the 'toxins/subcellular pathogens' category, by agent

Agent	Occupation	Disease
Aflatoxins	Agriculture (animal worker/poultry farmer) Feed production worker Food processing (herbs and grains) Waste worker	Hepatotoxic, carcinogenic and immunosuppressive effects
Bacterial endotoxins	Agriculture Veterinarian	
Endotoxins	Agriculture	COPD
Endotoxins produced by *Pantoea agglomerans*	Cotton mill worker	Reduced lung function caused by inflammation reactions
Mycotoxins	Agriculture Veterinarian	
Ochratoxin A	Food processing (coffee, cocoa beans, spices) Malt factory worker Waste worker	Carcinogenic, nephrotoxic, teratogenic and immunotoxic effects

Table 18: Overview of health effects and related diseases for the 'organic dust' category, by occupation

Occupation	Agent	Disease/health effect
Agriculture	Organic dust	Lung disease (COPD, interstitial lung disease), high fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)
Agriculture (animal worker/pig farmer)	Organic dust (endotoxin)	Progressive decline in lung function
Agriculture (animal worker/pigs)	Organic dust	ODTS, COPD
Agriculture (animal worker/poultry and pig farmer)	Organic dust (endotoxins, mould spores, infectious agents)	Respiratory disease, lower forced expiratory volume
Agriculture (crop farming)	Organic dust	Lung disease (COPD, interstitial lung disease)
Agriculture (greenhouse worker, mushroom worker)	Organic dust	Lung disease (COPD, interstitial lung disease)
Archaeologist	Organic dust	Blastomycosis Coccidioidomycosis Paracoccidioidomycosis
Biomass power generation worker	Bioaerosols	Irritation (ocular, dermal)
Composting site worker	Organic dust (bacteria, beta-glucans, endotoxins, fungi)	Cough, dyspnoea, eye irritation
Construction worker	Organic dust	Lymphocytic choriomeningitis Histoplasmosis Hanta Leptospirosis
Construction worker (demolition)	Organic dust	Blastomycosis Coccidioidomycosis Histoplasmosis
Dock worker	Organic dust	Hanta Leptospirosis Lymphocytic choriomeningitis

Occupation	Agent	Disease/health effect
Food processing (herbs and grains)	Organic dust (endotoxins)	High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)
Grain processing	Organic dust (endotoxins)	
Greenhouse worker	Organic dust (endotoxins)	High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)
Hunter	Organic dust	Blastomycosis Coccidioidomycosis Hanta Leptospirosis Lymphocytic choriomeningitis
Laboratory worker	Organic dust (endotoxins)	Fever, infectious diseases, acute toxic effects, ODTS, chronic bronchitis, asthma-like syndromes, septic shock, organ failure, death.
Librarian or art conservator	Bioaerosols	Lung disease
Maintenance worker	Organic dust	Histoplasmosis Leptospirosis Lymphocytic choriomeningitis
Manufacturing worker (metalworker)	Organic dust (endotoxins)	
Office worker	Organic dust (endotoxins)	High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)
Outdoor worker	Organic dust	Blastomycosis Coccidioidomycosis Leptospirosis Lymphocytic choriomeningitis Hanta
Paper industry worker	Organic dust (beta-glucans)	
Pest control worker	Organic dust	Hanta

Occupation	Agent	Disease/health effect
		Leptospirosis Lung disease (COPD, interstitial lung disease) Lymphocytic choriomeningitis
Sewage worker	Organic dust (beta-glucans) Organic dust (endotoxins)	Fever, infectious diseases, acute toxic effects, ODTS, organ failure, death.
Textile industry worker	Organic dust (endotoxins)	High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure), COPD
Waste worker	Organic dust (beta-glucans) Organic dust (endotoxins)	High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)
Wood industry worker	Organic dust (endotoxins) Organic dust (endotoxins, fungal spores, glucans)	High fever, coughing, irritation of the respiratory system, chest congestion Respiratory disease

Table 19: Overview of occupations, biological agents and related diseases for the 'organic dust' category, by health effect

Disease/health effect	Agent	Occupation
Progressive decline in lung function	Organic dust (endotoxins)	Agriculture (animal worker/pig farmer)
Blastomycosis	Organic dust	Archaeologist Construction worker (demolition) Hunter Outdoor worker
Coccidioidomycosis	Organic dust	Archaeologist Construction worker (demolition) Hunter Outdoor worker

Disease/health effect	Agent	Occupation
Cough, dyspnoea, eye irritation	Organic dust (bacteria, beta-glucans, endotoxins, fungi)	Composting site worker
Fever, infectious diseases, acute toxic effects, ODTS, chronic bronchitis, asthma-like syndromes, septic shock, organ failure, death.	Organic dust (endotoxins)	Laboratory worker
Fever, infectious diseases, acute toxic effects, ODTS, organ failure, death.	Organic dust (endotoxins)	Sewage worker
Hanta	Organic dust	Construction worker Dock worker Hunter Outdoor worker Pest control worker
High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)	Organic dust (endotoxins)	Food processing (herbs and grains) Greenhouse worker Office worker Waste worker Wood industry worker
High fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure), COPD	Organic dust (endotoxins)	Textile industry worker
Histoplasmosis	Organic dust	Construction worker Construction worker (demolition) Maintenance worker
Irritation (ocular, dermal)	Bioaerosols	Biomass power generation worker
Leptospirosis	Organic dust	Construction worker Dock worker Hunter Maintenance worker Outdoor worker

Disease/health effect	Agent	Occupation
		Pest control worker
Lung disease	Bioaerosols	Librarian or art conservator
Lung disease (COPD, interstitial lung disease)	Organic dust	Agriculture (crop farming) Agriculture (greenhouse worker, mushroom worker) Pest control worker
Lung disease (COPD, interstitial lung disease), high fever, coughing, irritation of the respiratory system, chest congestion (inhalation exposure)	Organic dust	Agriculture
Lymphocytic choriomeningitis	Organic dust	Agriculture Construction worker Dock worker Hunter Maintenance worker Outdoor worker Pest control worker
ODTS, COPD	Organic dust	Agriculture (animal worker/pigs)
Paracoccidioidomycosis	Organic dust	Archaeologist
Respiratory disease, lower forced expiratory volume	Organic dust (endotoxins, infectious agents, mould spores)	Agriculture (animal worker/poultry and pig farmer)
Respiratory disease	Organic dust (endotoxins, fungal spores, glucans)	Wood industry worker
	Organic dust	Indoor worker
	Organic dust (beta-glucans)	Paper industry worker Sewage worker Waste worker
	Organic dust (endotoxins)	Grain processing Manufacturing worker (metalworker)

4.3 Literature review — allergens and related health effects in the occupational context

Allergens are a specific category of biological agents that need to be treated with particular care. An allergy is a hypersensitivity reaction that is initiated by a specific immune response to a foreign agent, an allergen, at an exposure level that is normally tolerated. One of the characteristics of an allergy is increased sensitivity of the immune system (sensitisation), induced by earlier exposure. Sensitisation may be asymptomatic, insofar as the sensitised individual experiences no physical symptoms. Several instances of exposure may be required before evidence of allergic sensitisation is seen. The risk of sensitisation differs among individuals, and genetic predisposition plays a role. In a sensitised person, renewed exposure often leads ultimately to allergic respiratory symptoms (i.e. allergic rhinitis, rhinoconjunctivitis and asthma). Although respiratory allergic symptoms may be mild to begin with, they may become more serious as exposure continues, potentially leading to irreversible health problems. and thus prevention of these exposures is important (Health Council of the Netherlands, 2008).

For the purpose of this report, biological agents as defined in Directive 2000/54/EC and antigens of plant and animal origin, as well as substances produced by microorganisms, were included among the occupational allergens targeted by the research. To be considered of relevance, strictly, the literature would need to describe an explicit relation between a biological agent and an allergy or allergen-related disease. In practice, and as illustrated by Table 20-Table 36, it is not always easy to identify what exactly causes an allergic reaction, and the literature covers a range of allergens (e.g. microorganisms and allergens originating from plants, animals, insects and even foodstuffs), irrespective of whether they are biological agents in the narrow sense of the term.

For a description of the search methodology, please refer to Section 3.1.1. After initial screening, the literature search resulted in a total of 81 potentially relevant publications from Scopus and Pubmed, with an additional 15 publications from OpenGrey and OSH-Update. After eliminating duplicates and articles unavailable in a language covered by project, 82 publications were selected for further evaluation (see Annex 5, Part B). Of these 82 publications, some could not be retrieved, not even after contacting the first author, and therefore remained unavailable for evaluation (four publications). One publication was not evaluated because an updated version was retrieved and evaluated instead. The total number of publications evaluated was 77.

In section 4.3.1-4.3.2, a description of various sources of allergens is given, followed by an account of allergens relevant to certain occupations. A small number of publications detailed allergens related to buildings in general, which can be considered relevant for office workers but also for other occupations (Gerardi, 2010; Zukiewicz-Sobczak et al., 2013b; Méheust et al., 2014; Tarlo and Lemiere, 2014). In addition, Raulf et al. (2014) discussed monitoring of general airborne allergens, while studies by Quirce and Bernstein (2011) and Zacharisen and Fink (2011), for example, included allergens originating from certain bacteria, fungi, insects and insect stings related to an occupation. Quirce and Bernstein (2011), Baur (2013) and Baur and Baheke (2014) reported comprehensive lists of allergens related to occupations, among which were enzymes in the detergent industry (e.g. Esperase) and in the pharmaceutical industry (e.g. lactase). Moreover, Rosenman and Beckett (2015) described a database of agents causing occupational asthma, referring to an overview that can be accessed via their website (CSST, 2018). These data have been included in the present evaluation.

Most of the remaining literature connected an occupation with one or more allergens, or with an overarching group of allergens. Although the allergens' exact chemical name was rarely available, details on the types of allergens in question were provided in the source literature. Table 20-Table 24 provide an overview, based on the literature, of occupations, related diseases and allergens, grouped by agent category. They summarise the information extracted from the publications that were considered relevant. For an overview of the evaluation of each publication, see Annex 5, Part B. If no biological agent or no disease was mentioned in the literature, the cell in question has been left blank.

Triggers of allergic reactions in workers exposed to biological agents

In this section, an overview of sources of allergenic factors is given. As can be seen, it is not always possible to clearly establish that an allergic effect is caused by a constituent of a biological agent rather than by a chemical substance of other biological origin, which illustrates the difficulties in identifying precisely the allergens mentioned above. The agents responsible for occupational asthma, for instance, are classically divided according to their molecular weight. High-molecular-weight (HMW) agents (>10 kDa[3]) include proteins and microorganisms of animal and vegetable origins. Low-molecular-weight (LMW) agents include wood dust, drugs, metals, and other chemicals (Lemiere et al. 2012). Wood dust is a common cause of occupational asthma. There is potential for high exposure to wood dust during furniture and wood manufacturing processes (Wiggans et al., 2016).

Fungi

Although fungi can be infectious and toxic, inhalation of fungi is more commonly associated with sensitisation and allergic diseases. Fungal allergy can manifest in various ways, for example asthma, rhinitis, conjunctivitis, urticaria and atopic dermatitis. Fungal allergens have been investigated systematically only in relation to *Aspergillus fumigatus*, *Alternaria alternata* and *Cladosporium herbarum*. Not much is known about the allergens, although it is known that many fungi have homologous allergens, and cross-reactivity is common. Owing to this high cross-reactivity, very few species-specific allergens have been identified. In addition, there is little information on fungal allergens in occupational environments other than agriculture.

Apart from fungi in buildings and farming, some work has been done within wood industry-related workplaces, in the forestry and sawmilling sectors, but on the whole it is rare for fungal allergens to be measured in other occupational settings (Prester, 2011). Nevertheless, Quirce and Bernstein (2011) and Quirce and Diaz-Perales (2013) reported that, for bakers, in addition to flour, other allergen sources including fungal enzymes and moulds should be considered (Quirce and Bernstein, 2011; Quirce and Diaz-Perales, 2013). Moreover, Zacharisen and Fink (2011) reported occupational hypersensitivity pneumonitis in the food industry, among workers dealing with dry sausage moulds, mouldy cheese, mouldy brewing malt and soy sauce production processes, namely sausage/salami makers, cheese makers, mill workers, malt workers and soy sauce brewing workers, respectively.

Dutkiewicz et al. (2011) note β-1,3-glucanase as a general fungal allergen. It should be noted that this is not a protein exclusive to fungi, as the rubber tree contains it as well (Raulf, 2016). This example illustrates the difficulty of differentiating allergens originating from biological agents in the narrow sense — that is, microorganisms — from other allergens.

Fungi may cause allergic rhinitis and allergic asthma, as well as hypersensitivity pneumonitis. The comparatively large size of fungal allergens means that, unlike other allergens, they cannot easily penetrate the lower lung. This property of fungal allergens, coupled with their relatively low antigenicity, suggests that they pose a less significant risk to indoor workers through inhalation than non-fungal allergens. On the other hand, fungal *spores* are particularly small, may easily penetrate the upper and lower respiratory tracts and are especially harmful to the lungs of the immunocompromised (Zukiewicz-Sobczak, 2013; Zukiewicz-Sobczak et al., 2013b). Allergies to spores of fungi occur in the form of inhaled allergies, food allergies, contact allergies (skin reactions) and allergic reaction in response to fungal infection. Spores can also cause infectious diseases.

The main indoor fungi are *Penicillium* spp., *Aspergillus* spp., and *Cladosporium* spp. Professional groups particularly exposed to these fungi are workers in the agriculture and food industries, the staff of museums, libraries and archives, and art conservators. These groups are expected to come into contact with fungi via ventilation and air-conditioning hoses, stock, settling dust, wooden shelves and barrier constructions (Zukiewicz-Sobczak et al., 2013b). Prester (2011) cites the same three fungi as Zukiewicz-Sobczak et al. (2013b) but adds *Alternaria* spp.

In healthy buildings, the indoor airborne fungi composition is similar to that of the outdoor fungi. However, fungi can become more relevant in certain situations. For example, *Stachybotrys atra* and *Stachybotrys alternans*, black fungi, may grow on insulation material and fibreboard inside buildings (Gerardi, 2010), and may pose a risk to, for instance, office workers.

Alternaria and *Cladosporium* are the most common fungi outdoors worldwide. In the wake of a natural disaster such as a tornado or a flood, rescue workers and medical personnel may need to work among dilapidated buildings, in which moulds have optimal conditions for growth, and protection measures should be taken (Johanning et al., 2014). Gabrio (2010) reports that in Central Europe approximately 200 mould species are estimated to be present indoors and outdoors. Most are associated with certain sources, for example

- *Cladosporium herbarum*, *Alternaria alternata*, *Botrytis cinerea* – vegetation,
- *Aspergillus fumigatus* – composting, rotting of plant material,
- many *Penicillium* species – perishing foods, decomposing foods, waste, biowaste,
- *Stachybotrys chartarum*, *Acremonium* spp. – very moist, cellulosic construction material,
- *Phialophora* spp., *Engyodontium album* – moist plaster,
- *Aspergillus penicillioides*, *Aspergillus restrictus*, *Eurotium* spp., *Wallemia sebi* – cellulosic material with slightly increased moisture,
- *Aspergillus versicolor*, *Chaetomium* spp.,*Trichoderma* spp. – moist building fabric,
- *Eurotium* spp. – moist leather (shoes, etc.), animal husbandry,
- *Wallemia sebi*, *Eurotium* spp. – animal caging with litter.

Depending on vegetation, moulds are always present in the ambient air. In Central Europe the concentration of moulds in the ambient air is approximately 100 cultivable mould spores per m^3 in winter and several thousand in summer. In cases of indoor moisture damage the following “indicating” mold species are frequently present: *Acremonium* spp., *Aspergillus penicillioides*, *Aspergillus restrictus*, *Aspergillus versicolor*, *Aureobasidium pullulans*, *Chaetomium* spp., *Phialophora* spp., *Stachybotrys chartarum*, *Tritirachium* (*Engyodontium*) *album* and *Trichoderma* spp.

Although moulds are ubiquitous in the environment, their overall sensitisation rates as indoor or outdoor allergen are only near 5%. One possible reason are hydrophobins in the cell surface of the moulds which serve as a protect screen (Raulf-Heimsoth, 2011).

Industrial fungal enzymes

Green and Beezhold (2011) reviewed industrial fungal enzymes and found that in some occupations, workers are at an increased risk of for IgE-mediated disease and occupational asthma. This is especially the case for workers whose occupation requires debagging, sieving, weighing, dispensing, and mixing enzymes. In some countries, bakery exposures to enzymes are one of the leading causes of occupational allergy.

Fungal enzymes are used for a variety of purposes across many different industries, for example as purified preparations in baking, food, detergent, textile, and pharmaceutical industries. Many of these were produced by recombinant technology or had been genetically engineered. Exposure usually involves mixtures of many proteins. The most widely used enzymes of occupational importance are derived from the genus *Aspergillus* and include α-amylase, xylanase, and cellulase. Other enzymes are also utilized from rhizosphere fungal species belonging to the genera *Rhizopus* and *Humicola.* Lipase is a catalyst that digests water-insoluble lipids used in the manufacture of laundry detergents and in baking. *A. oryzae* and *R. oryzae* lipase are used because of low extraction costs, thermal and pH stability, substrate specificity, and activity in organic solvents. *Candida antarctica* lipase has been used as a biocatalyst for the biofuel industry. The aspartic proteases produced by *Rhizomucor miehei* and *Cryphonectria parasitica* are used in almost half of the cheese production operations throughout the world. *A. niger and R. oligosporus* produce phytase, which enhances phosphate bioavailability in the digestive tract and has been used in the animal feed industry, leading to allergic sensitisation in animal feed factory workers, which is highest at sites where phytase is handled in powdered form.

Fungal enzymes have a number of applications in healthcare. Fungal enzymes derived from *A. niger* are used in powdered form with other enzyme extracts by pharmacists to prepare digestive powders. Biodiastase and Flaviastase have been associated with sensitisation in hospital workers and pharmaceutical workers. Catalase, a fungal enzyme used in hygiene products, pharmaceuticals, and textiles, has been identified as an allergen in *Metarhizium anisopliae*. Pectinase is used in brewing and wine production, food processing, and paper industries and allergy to pectinase has been associated with occupational exposure. Esterase has been identified as an allergen in *Hevea brasiliensis* (natural rubber latex). Beta-glucanase is used to improve the nutritional yield of animal feeds. In the biotechnology and pharmaceutical industries, Glutathione-S-transferase has a number of applications. It has also been identified as a major *Alternaria alternata allergen* and is highly conserved across fungi([11]).

More than 250 high-molecular-weight allergens that induce occupational asthma have been identified. Green and Beezhold (2011) therefore recommended allergen avoidance strategies including personal protective equipment, engineering controls, protein encapsulation, and reduction of airborne enzyme concentrations.

Bacteria

Although both bacteria and fungi have been identified as causal agents of hypersensitivity pneumonitis, bacteria, particularly thermophilic actinomycetes such as *Saccharopolyspora rectivirgula* (Blais-Lecours et al., 2014; Cano-Jimenez et al., 2016), *Thermoactinomyces vulgaris*, *Thermoactinomyces viridis* and *Thermoactinomyces sacchari* (Cano-Jimenez et al., 2016), are reported as primary agents. Bacteria exposure inducing hypersensitivity pneumonitis is a risk in agriculture, food processing, the work of technicians (e.g. humidifier and ventilation system workers, machine operators), floristry and the detergent industry (Quirce et al., 2016)

Pantoea agglomerans should be regarded as one of the major causative agents of work-related diseases in the cotton industry, in the grain industry and in agriculture, caused by the adverse effects of protein allergens and endotoxin produced by this bacterium (Dutkiewicz et al. 2015 and 16).

Organic dust

Organic dust is a common cause of allergic respiratory diseases. For example, health statistics show that most of the occupational diseases of allergic origin reported in Polish farmers are caused by pathogens present in organic dust. In Poland, as in other countries, lung diseases are more common in farmers than in the rest of the population (Zukiewiciz-Sobczak et al., 2013b).

Organic dust, sometimes referred to as bioaerosols, is potentially harmful because of the huge variety of components it may include, such as plant proteins, animal proteins, bacteria and fungi, and their metabolites. Grain dust, for example, is a complex mixture of organic and inorganic materials, mainly cellulose-based seed coating and carbohydrate. It may also contain bacterial and fungal contamination, and the associated endotoxin and mycotoxin, mites, insects, and small amounts of crystalline silica. (Spankie and Cherrie, 2012). Exposure levels are set for some organic dusts such as grain dust, but the endotoxin levels are not correlated with the dust levels and therefore separate measures would be needed, and measures for, for example, mite allergens (Spankie and Cherrie, 2012).

Organic dust can lead to allergic diseases such as hypersensitivity pneumonitis, bronchial asthma, allergic rhinitis or allergic conjunctivitis and dermatitis. Components of dust can also cause the development of diseases with immunotoxic effects such as sick building syndrome, or cause ODTS, common in swine workers and people exposed to grain dust (Zukiewiciz-Sobczak et al., 2013b). Occupational rhinitis and asthma often coexist (up to 70% ofcases in asthma are due to laboratory animals) (Crivellaro et al., 2014; Stevens and Grammar, 2015). The main pathway leading to exposure is by inhalation of particles which reach the respiratory system. Particle deposition in lungs is closely related to their size. Many of the bioaerosol particles emitted by compost, for example, are very fine and can reach down the pulmonary alveoli. The size of spores of moulds colonizing compost (*Aspergillus*, *Penicillium*) is below 3 µm (and the one of thermophilic actinomycetes is around 1 µm (Wéry, 2014).

According to Montano (2014), bioaerosol exposure of veterinarians, farmers and agricultural labourers is related to hypersensitivity reactions, whereas farmers and workers in veterinary settings, workers in grain threshing and sieving, flax threshing, herb processing, composting and wood processing

([11]) In evolutionary biology, conserved sequences are identical or similar sequences in nucleic acids (DNA and RNA) or proteins across species.

(Zacharisen and Fink, 2011; Montano, 2014) and those handling silage have an increased risk of chronic respiratory disorders associated with intense exposure to allergenic microorganisms (e.g. bacteria and fungi) and related pathogenic and toxic substances (Alonso et al., 2013; Wéry, 2014). In a review by Samadi et al. (2013), however, it was concluded that there were indications that allergic respiratory symptoms were related to substantial exposure to inhalable dust, endotoxins and β(1→3)-glucans, but that evidence was lacking for sensitisation.

It is thought that archaea may be an emerging risk as immunogenic agents in bioaerosols in agriculture and wastewater treatment plants, although the role of archaea in the aetiology of respiratory illnesses remains to be determined (Blais-Lecours et al., 2014).

Textile dust related obstructive lung disease has characteristics of both asthma and COPD. The adverse respiratory effects of exposure to cotton, flax, and hemp dust in the textile industry was first described several centuries ago as a syndrome later called byssinosis. Significant progress has been made in the understanding of chronic lung disease due to organic dust exposure in textile workers. The mechanisms due to textile dust related endotoxin exposure linked to the development of persistent airway inflammation and associated airflow obstruction were described in a review by Lai et al (2014).

Mansour et al. (2014) assessed the health implications related to processing of natural wool insulation products. A wool insulation manufacturer would use cheaper, coarser wool than textile industries. The dust generated by different wool types and endotoxin content will vary depending on the wool quality.

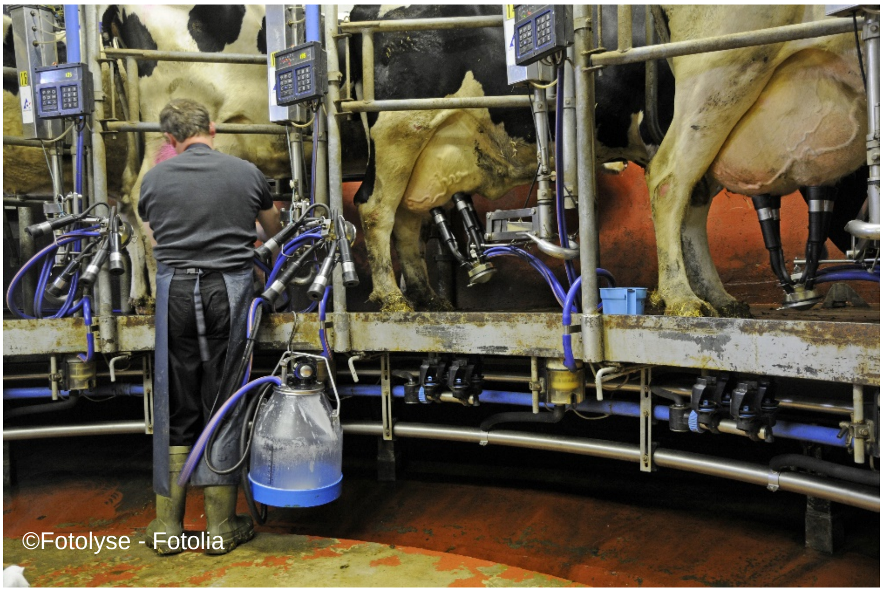
Similarly, Rohr et al, (2015) reviewed dust concentrations within biomass plants and found that they can be extremely variable, with peak levels in some areas exceeding occupational exposure limits for wood dust and general inhalable dust. Fungal spore types, identified as common environmental species, were higher than in outdoor air. They therefore concluded that measures needed to be taken and exposures further assessed. Biomass lacks the stability of traditional coal or petroleum fuels and has a tendency to decompose, create changing exposure scenarios and requiring different handling, transport, and storage considerations to minimise both microbial growth (e.g., spore formation, endotoxin release, etc.) and off-gassing of volatile organics or other gases (e.g., carbon monoxide).

Insects

Mites are considered biological agents under some definitions and are therefore included in this review. Mites are known to induce asthma and are often unavoidable in the home and in occupational settings. Sensitisation to dust mites and cockroach antigens has been found to be as high as 61 % and 41 % respectively in asthmatics (Gerardi, 2010). Moreover, proteins and glycoproteins from dust mites, rodents and cockroaches are also known to induce allergenic reactions. Mites are found in a range of different habitats.

Quirce and Diaz-Perales (2013) reported that, for bakers, in addition to flour, other allergen sources including arthropods should be considered. Exposure to grain mites, screw-worm flies, silkworm larvae, mealworm and insect larvae, and fruit flies and insect larvae have been linked with asthma in farmers and grain store workers, flight crews, sericulture workers, fish bait handlers and laboratory workers, respectively (Quirce and Bernstein, 2011).

Animals



It should be noted that, while animals are potent causes of allergy, respiratory diseases in animal farming environments are primarily non-allergic in nature. Nevertheless, large-animal farming is considered a strong risk factor for the development of occupational asthmatic diseases, although usually not involving IgE-related responses (i.e. not via an allergenic mechanism) (May et al., 2012). The primary allergens produced by animals relevant for Europe appear to be specific transport proteins called lipocalin proteins: Rat n 1, Mus n 1, Bos d 2 and Equ c 1 for rats, mice, cows and horses, respectively (Zahradnik and Raulf, 2014).. Reynolds et al. (2013) analysed the changes in dairy farming and their impact on workplace exposure. Dairy workers experience lung conditions such as asthma, chronic obstructive pulmonary disease, hypersensitivity pneumonitis, chronic bronchitis, and cancer. Pulmonary function studies have also identified obstructive lung changes among dairy farm workers. The increased scale of dairy production with significant changes in technology and work practices has modified inhalation exposure patterns among dairy workers. However, despite high levels of bovine allergens present in dairy farms, Nordgren et al (2016) found that sensitisation is generally low in farmers.

In work with laboratory animals, urine is the primary allergen (Westall et al., 2015; Feary and Cullinan, 2016; Raulf, 2016), resulting in hypersensitivity reactions including asthma and urticaria (Zacharisen and Fink, 2011; Tarlo and Lemiere, 2014; Westall et al., 2015; Zahradnik and Raulf, 2014; Feary and Cullinan, 2016), and hypersensitivity pneumonitis (Sennekamp, 2011; Quirce et al., 2016). It is considered that these allergies are primarily caused by lipocalin proteins in urine, as is the case in other animal-related occupations (Quirce and Bernstein, 2011; Feary and Cullinan, 2016; Raulf, 2016).

Biological agents and allergies in specific occupations

In this section, an overview is given of the known relations between exposures to biological agents and allergies in specific occupations and for specific groups of workers.

Indoor workers

Various types of biological agents have been identified as causing disease among indoor workers, but the literature on certain causative agents is ambiguous. For example, black fungi of the genus *Stachybotrys*, (*Stachybotrys atra* and *Stachybotrys alternans*), which grow on insulation material and fibreboard inside buildings (Gerardi, 2010), are purported to have adverse effects on humans, but extensive literature reviews have failed to establish *Stachybotrys* as a causative agent (Gerardi, 2010).

Similarly, *Histoplasma*, *Coccidioides*, *Cryptococcus* and *Blastomyces* are fungi that are known to infect immunocompetent individuals, whereas immunocompromised people are also susceptible to infection with *Candida* and *Aspergillus* (Gerardi, 2010), yet no association has been specifically established between immunocompetent individuals and occupational exposure (Gerardi, 2010). Moreover, a relationship between fungi, mycotoxins and human disease is limited to circumstantial evidence only (Gerardi, 2010). It is also known that fungal spores, which are particularly small, may easily penetrate the upper and lower respiratory tracts and are especially harmful to the lungs of the immunocompromised (Zukiewicz-Sobczak et al., 2013b). Exposure of indoor workers to the main indoor fungi or to fungal spores increases the risk of contracting hypersensitivity pneumonitis, allergic rhinitis and allergic asthma. Allergies specific to fungal spores include food allergies, contact allergies (skin reactions) and allergic reactions in response to fungal infection in the organism.

Other indoor occupations

In addition to the abovementioned occupations, fungi-related hypersensitivity pneumonitis and asthma are reported for a broad spectrum of indoor occupations, including workers in the pharmaceutical industry, construction workers, cotton workers, machine operators, horticultural workers, mushroom growers, woodworkers, wine growers, sewage workers, waste processing and management workers, biotechnological workers, automotive workers, workers in air-conditioned spaces, and operators of indoor fountains, humidifiers and air conditioners (Raulf-Heimsoth et al., 2011; Sennekamp, 2011; Liebers et al., 2012; Merget, 2011, 2012; Ochmann et al., 2012; Raulf-Heimsoth et al., 2012). Some of these occupations overlap with others discussed in this section.

According to Hox et al. (2015), repeated or long-term exposures to lower concentrations of irritants might also induce chronic rhinitis. For example, cleaners or swimming pool workers exposed to chlorination products suffer more from asthma and upper airway symptoms. Similar findings have been reported in beverage processing plant workers chronically exposed to low levels of hydrogen peroxide. These chemical factors may interact with biological factors to exacerbate the symptoms.

Agricultural workers and workers in related sectors

Farmer's lung disease, a form of hypersensitivity pneumonitis, is probably the most common allergic complication among agricultural workers. It is caused by the inhalation of microorganisms from hay or grain stored in conditions of high humidity (Cano-Jimenez et al., 2016). Nordgren and Bailey (2016) found that dense packing of hay in warm and humid climates correlated with an increased concentration of hypersensitivity pneumonitis-causing microorganisms such as *Absidia corymbifera*. Furthermore, heat and humidity have been identified as risk factors, making farmer's lung disease a more common occurrence in the south of Europe (Cano-Jimenez et al., 2016). Hypersensitivity pneumonitis has also been reported in the animal-breeding industry (in cattle, pig and poultry farmers) and in the bird-breeding industry, in relation to exposure to feed, bird serum, feather bloom and droppings (Sennekamp, 2011; Zacharisen and Fink, 2011).

Fungal agents implicated in hypersensitivity pneumonitis in agricultural settings (*Aspergillus* and *Penicillium*) are primarily related to the storage conditions of raw agricultural commodities or animal feed. This includes those present in hay/silage, grain, mouldy sugar cane, tobacco, mouldy grapes, mouldy onions, mouldy potatoes, peat moss and mushrooms (Alonso et al., 2013; Zacharisen and Fink, 2011), including shiitake mushroom spores (Nordgren and Bailey, 2016). The most common of these can be found growing on plants and are of the genera *Alternaria* and *Cladosporium*. Other researchers have corroborated the role of *Absidia corymbifera* in farmer's lung disease (Méheust et al., 2014), as well as naming other common causative fungal agents, notably *Eurotium amstelodami* and *Wallemia sebi* (Selman et al., 2010; Méheust et al., 2014), *Aspergillus fumigatus* and *Penicillium* (Selman et al., 2010; Cano-Jimenez et al., 2016), and *Alternaria* and *Botrytis* (Cano-Jimenez et al., 2016). Pigeon breeder's disease is the avian counterpart to farmer's lung disease, caused by *Saccharopolyspora rectivirgula* (Selman et al., 2010) and exposure to bird proteins.

In addition to the evidence supporting the role of bacteria and fungi in causing farmer's lung disease, Darby et al. (2011) have indicated that the cause may be pesticide exposure rather than biological agents. A combined effect cannot be ruled out. However, no publication among the studies that met the criteria for this review had investigated this possibility.

Finally, working in agriculture (greenhouse workers, gardeners) is a risk factor for occupational anaphylaxis (Moscato et al., 2014a), which can result from a range of allergenic agents associated with this sector.

According to Poole (2012) there is a protective effect of growing up on the farm from the subsequent development of IgE-mediated allergic disorders. Longer exposure to occupational farming is also associated with decreased asthma risk (Wunschel and Poole, 2015). However, upper and lower respiratory adverse health effects, particularly non-IgE mediated, are common to agriculture work and represent a substantial concern for farmers, workers, and their families. Farming exposure is heterogeneous and complex and regional and international variation in farming practice should be considered.

Food processing workers and workers in related trades

Bakers, pastry cooks and confectionery makers

According to Roberge et al. (2012) flour exposures in bakeries, seem to be lower than the reference values of 10 mg/m^3 for dusts not otherwise classified, but several are above concentrations that can cause lung sensitisation. Accordingly, among bakery workers, about 5-10 % suffer from asthma and 15-20 % from rhinitis. Baker's asthma is the most common type of occupational asthma in France, and the second most common in the UK and Norway. In these occupational settings, occupational asthma is mainly caused by inhalation of cereal flour or powder from wheat, rye, barley, maize or rice (Raulf-Heimsoth et al., 2012; Quirce and Diaz-Perales, 2013). Wheat, an allergen of plant origin, is a well-known cause of occupational asthma among bakers, confectioners, pastry factory workers, pasta workers, pizza workers, millers, farmers and cereal handlers (Moscato et al., 2011; Raulf-Heimsoth et al., 2011; Sennekamp, 2011; Raulf-Heimsoth et al., 2012; Sennekamp and Forster, 2012; Raulf, 2016). Several wheat proteins are thought to cause allergies by triggering an immune response. These suspected allergens are the α-amylase/trypsin inhibitor family, lipid transfer proteins, peroxidase, thioredoxin, serine proteinase inhibitors, thaumatin-like proteins and certain prolamins (Quirce and Diaz-Perales, 2013; Raulf, 2016). However, other allergens may also affect bakers, for example enzymes used as flour improvers, legumes, mites, arthropods and moulds (Quirce and Diaz-Perales, 2013).

Quirce and Sastre (2011) reported the first case of allergen-related occupational asthma caused by marigold flour, which is used in the food additive industry as a poultry feed colourant.

In addition to asthma, hypersensitivity pneumonitis has also been reported among bakers and flour producers, the prime allergenic source being flour. However, Quirce and Diaz-Perales (2013) and Quirce and Bernstein (2011) have reported that other sources, including fungal enzymes, moulds and arthropods, should also be considered.

Fishmongers and workers preparing related foods

Lucas et al. (2010) reported a 16 % prevalence of asthma among fishermen and one of 36-57 % among shrimp processing workers, whereas for seafood workers a prevalence of between 2 % and 36 % was found by Lopata and Jeebhay (2013). Dickel et al. (2014) noted that seafood allergy had been observed among young workers (cooks), with an early manifestation of the disease after a median employment period of 1.7 years. Onset was localised on the hands in all but one case (96.7 %). Most commonly documented were immediate sensitisations to cod, salmon, trout and herring. Emergency treatment for anaphylactic shock in the workplace had been administered to 16.7 %, whereas 90 % had had to discontinue their occupation at a median of 6.3 years.

Occupational asthma in the seafood processing industry (Raulf-Heimsoth et al., 2011; Sennekamp, 2011; Jeebhay and Lopata, 2012; Raulf-Heimsoth et al., 2012; Sennekamp and Forster, 2012; Tarlo and Lemiere, 2014) is generally the result of aerosol exposure arising from crustacea (crab and shrimp). However, it may also be caused by prawn, the hoya parasite in oysters, cuttlefish, salmon and red soft coral on lobster (Lucas et al., 2010; Quirce and Bernstein, 2011). It has also been associated with handling mealworm and insect larvae among fish bait handlers (Quirce and Bernstein, 2011).

According to Lopata and Jeebhay (2013), work processes that have been identified as generating excessive bioaerosols include butchering or grinding; degilling; ‘cracking’ and boiling crabs; cleaning and brushing crabs; ‘tailing’ lobsters; ‘blowing’ prawn meat through shells; washing or scrubbing shellfish; degutting, heading and cooking (particularly boiling) fish; mincing seafood; and cleaning the processing line or storage tanks with high-pressure hoses. Lucas et al. (2010) reported that the highest-risk tasks were the boiling and butchering of shellfish.

Processes that generate dry aerosol particulates through the use of compressed air, such as prawn blowing operations and fishmeal loading/bagging, generate higher levels of particulate than wet processes (e.g. prawn-blowing using water jets). These wet or dry aerosolised particles produced from seafood during processing operations are inhaled by workers (Lopata and Jeebhay, 2013). Major allergens reported are tropomyosin in crustaceans and molluscs, and parvalbumin in fish (Jeebhay and Lopata, 2012; Lopata and Jeebhay, 2013; Dickel et al., 2014). Minor allergens include arginine kinase, myosin light chains and sarcoplasmic calcium-binding protein in crustaceans, and collagen, vitellogenin, and glyceraldehyde-3-phosphate dehydrogenase in bony fish (Jeebhay and Lopata, 2012; Lopata and Jeebhay, 2013).

Cross-reactivity often occurs, probably because tropomyosin has a highly conserved amino acid sequence across crustaceans. However, workers sensitised to crustacean tropomyosin are not expected to react to mollusc tropomyosin. Moreover, crustacean and mollusc allergens do not cross-react with fish allergens (Jeebhay and Lopata, 2012).

Exposure to aerosols arising from arthropods (crab and shrimp) is associated with a higher prevalence of occupational asthma than exposure to those arising from molluscs and bony fish. Curiously, in some isolated case reports, such occupational asthma has been reported to transition into ingestion-related allergic symptoms. As previously noted, red coral in lobster and the hoya parasite in oysters has been linked to asthma (Lucas et al., 2010).

Quirce and Sastre (2011) and Quirce and Bernstein (2011) reported the first case of allergen-related occupational asthma caused by aerosolised octopus allergens and turbot in a seafood processing worker.

Occupational asthma among fishmongers, chicken farm workers who handle fish-based animal feed, and frozen fish processing workers has also been associated with *Anisakis simplex*, a parasitic nematode of certain ocean fish (Lucas et al., 2010; Lopata and Jeebhay, 2013).

Also common among this occupational group are contact urticaria, reportedly related to dermal contact with fish products, and protein contact dermatitis (Jeebhay and Lopata, 2012). However, it should be noted that most seafood dermatitis is due to irritants, not allergens (Jeebhay and Lopata, 2012).

Other occupations in the food industry

Allergic sensitivity is relevant to many other food industry occupations in addition to those mentioned above. Zacharisen and Fink (2011) reported occupational hypersensitivity pneumonitis related to exposure to dry sausage moulds, mouldy cheese, mouldy brewing mail and soy sauce production processes among sausage/salami makers, cheese makers, mill workers, malt workers and soy sauce brewing workers, respectively. Quirce and Sastre (2011) reported the first cases of allergen-related occupational asthma caused by *Chrysonilia sitophila*, which affects workers in the coffee industry, and by *Penicillium nalgiovensis* in a worker at a semi-industrial pork butcher. Moreover, new causes of occupational asthma have been reported, namely sausage mould among semi-industrial pork butchers and mushroom in groceries (Quirce and Bernstein, 2011).

Jewellery workers

Interestingly, although cases of hypersensitivity pneumonitis are considered rare in the seafood industry, they have been observed among workers in button manufacturing and jewellery production (clam shell dust), as a result of exposure to dust from molluscs (oysters, sea snails) (Sennekamp, 2011; Zacharisen and Fink, 2011; Jeebhay and Lopata, 2012), and they have also been reported among workers in the pearl and nacre industry (Quirce et al., 2016).

Metalworkers

Contamination of metalworking fluids with biological agents causes a new pattern of health problems and is examined in many articles. Occupational exposure to microorganisms in metalworking fluids, for instance in the metalworking industry, occurs mainly through direct contact with skin and inhalation, the latter indicating a possible relation with occupational asthma and hypersensitivity pneumonitis (Barber et al, 2012; Burton et al., 2012) and/or possibly sarcoidosis (Newman and Newman, 2012). The agents are most often Gram-negative bacteria, opportunistic mycobacteria, and fungi, growing in an antibiotic-resistant biofilm. Fast-growing mycobacteria such as *Mycobacterium immunogenum* or *Mycobacterium chelonae* are suspected to be the cause of hypersensitivity pneumonitis in the metalworking industry

(Darby and Fishwick, 2011; Trafny, 2013; Rosenman, 2015; Quirce et al., 2016). They are also implicated in hypersensitivity pneumonitis in machine operators (Zacharisen and Fink, 2011; Quirce et al., 2016). Hypersensitivity pneumonitis in metalworkers is also associated with exposure to *Pseudomonas* sp., *Acinetobacter* and *Ochrobactrum* (Darby and Fishwick, 2011). Rosenman (2015) reported that since 2005 the number of asthma cases related to metalworking fluids had been decreasing, possibly owing to the stricter air standard introduced in 1998 (from 5 mg/m^3 to 0.5 mg/m^3 of metalworking fluids in air), and the concurrent introduction of new equipment to meet this standard (Rosenman, 2015). Duchaine et al. (2012) evaluated bacteria as present in 44 machining sites in 25 Québec plants, but they found no evidence of respiratory and/or skin pathology attributable to the work environment of the workers, and nor did they detect *Mycobacterium immunogenum*.

Life science professionals and life science technicians

Laboratory workers who handle insects or laboratory animals are exposed to several allergenic agents, with the possibility of immediate onset of hypersensitivity reactions as a result of exposure to laboratory animals' urine, hair, dander and/or saliva (Corradi et al., 2012; Jones, 2015)., Roe deer have been reported as a new cause of occupational asthma among animal rehabilitation workers (Quirce and Bernstein, 2011). Gerbils have been reported as a new cause of occupational asthma among biologists (Quirce and Bernstein, 2011), whereas bird breeding has been associated with hypersensitivity pneumonitis (Selman et al., 2010).

Rodent allergy affects between 11 % and 44 % of exposed laboratory personnel, and can cause both acute and chronic symptoms, including contact urticaria, hypersensitivity pneumonitis, asthma and even anaphylaxis (Jeal and Jones, 2010; Nicholson et al., 2010; Quirce and Bernstein, 2011; Sennekamp, 2011; Zacharisen and Fink, 2011; Corradi et al., 2012; Tarlo and Lemiere, 2014; Westall et al., 2015; Zahradnik and Raulf, 2014; Feary and Cullinan, 2016; Quirce et al., 2016). However, driven by rapid changes in technology, such as the introduction of ventilated cages, exposures to laboratory animal allergens are decreasing; nonetheless, a recent study reported a 5-8 % prevalence in laboratory workers of sensitisation to laboratory mice (Feary and Cullinan, 2016).

Young workers are particularly susceptible: in a study evaluating work-related respiratory allergies among young workers, including laboratory animal personnel, Moscato et al. (2011) found that students starting their careers who were exposed to allergens had a substantially higher frequency of specific sensitisation to work-related allergens, which in turn was related to atopy and bronchial hyper-responsiveness during the first 2-3 years after exposure began. After this, however, sensitisation rate decreased.

The primary allergens are contained in the urine of laboratory animals (Westall et al., 2015; Feary and Cullinan, 2016; Raulf, 2016), with lipocalin proteins considered to be the major allergen (Jones, 2015; Feary and Cullinan, 2016; Raulf, 2016). Recent evidence suggests that lipocalins, such as Mus m 1 (prealbumin), which makes up more than half of urine-excreted proteins, could trigger the innate immune response. This is proposed as a new mechanism that could initiate laboratory animal allergy (Jones, 2015).

Although it may be considered counterintuitive, allergy or sensitisation to pet cats or dogs has not been found to be an independent risk factor for sensitisation to laboratory animals (Nicholson, 2010). In other words, being allergic to domestic cats or dogs does not imply that one will be allergic to rodents, and vice versa.

Laboratory work with insects (e.g. fruit flies, insect larvae, locusts) and insect-breeding (e.g. grasshoppers, tubifex, locust) is associated with occupational asthma (Quirce and Bernstein, 2011; Raulf-Heimsoth et al., 2011; Fishwick, 2012; Cartier, 2015), allergic rhinoconjunctivitis, bronchial hyperreactivity (Jensen-Jarolim et al., 2015) and anaphylaxis (Moscato et al., 2014a). Allergic prevalence is reported for laboratory insect handlers (26-35 %), field workers (0-6 %), laboratory scientists (7-13 %) and administrators (0-7 %) (Stanhope et al., 2015). In a review of risks to entomologists, Stanhope et al. (2015) reported that allergic reactions were associated with exposure to Coleoptera (beetles), Lepidoptera (including butterflies and moths), Araneae (spiders), Blattodea (including cockroaches and termites), Orthoptera (including grasshoppers, locusts and crickets), Diptera (flies), Hymenoptera (a large order of insects, comprising the sawflies, wasps, bees and ants), Ixodidae (hard or scale ticks), Trombidiformes (an order of mites), Hemiptera (true bugs, including cicadas, aphids, planthoppers, leafhoppers and shield bugs), Isoptera (termites), Neuroptera (net-winged insects), Sarcoptiformes (an order of mites and ticks) and Mesostigmata (an order of mites). They found that bites and stings from Hymenoptera, spiders and scorpions led to envenomation, which could result in pain, allergic reactions (including asthma and anaphylactic reactions) and even death. There were cases of entomologists being allergic to arthropod feed, in addition to cases of allergic reactions to the arthropods they were working with.

Pharmacologists

In the pharmaceutical industry, exposures to corn starch and gum arabic dust are related to asthma (Raulf-Heimsoth et al., 2012).

Archivists, librarians and other information professionals

Despite the uncertainties noted above, it has been established that, like workers in the agricultural and food industries, the staff of museums, libraries and archives, and art conservators, are exposed to the main indoor fungi: *Penicillium* spp. (Prester, 2011; Zukiewicz-Sobczak et al., 2013b) and *Alternaria* spp. (Prester, 2011). These occupational groups are believed to come into contact with fungi via ventilation and air-conditioning hoses, stock, settling dust and wooden shelves (Zukiewicz-Sobczak et al., 2013b).

Health professionals

Veterinarians

As previously noted, veterinarians are exposed to some of the same agents to which agricultural workers are exposed and may experience similar sensitivity reactions, including asthma and hypersensitivity pneumonitis. This includes exposure to domestic animals (cats, dogs, etc.), that is, their faeces, saliva, urine, serum, and lipocalin proteins in dander (shed fur, hair or feathers), which may induce allergic reactions in sensitised individuals. Occupational asthma and other allergic reactions are reported in agriculture (farmers), veterinary practices and laboratory work (Quirce and Bernstein, 2011; Raulf-Heimsoth et al., 2011; May et al., 2012; Raulf-Heimsoth et al., 2012; Tarlo and Lemiere, 2014; Quirce et al., 2016). Asthma in veterinarians and farmers related to lipocalin proteins from horses (e.g. in dander) and cattle, respectively, is reported by Zahradnik and Raulf (2014); a prevalence of 3.6-16.5 % is indicated for horse-related allergenic effects.

Healthcare workers

Latex glove exposure has been linked to asthma and anaphylaxis in dental technicians, healthcare workers and glove manufacturers (Moscato et al., 2011; Quirce and Bernstein, 2011; Raulf-Heimsoth et al., 2011; Raulf-Heimsoth et al., 2012; Moscato et al., 2014a; Raulf, 2016).

Rescue workers

In ‘healthy’ buildings, the indoor airborne fungi composition is similar to that of the outdoor fungi. However, certain circumstances may result in optimal conditions for fungal growth, resulting in a composition of fungi in buildings that could lead to ill health. For instance, in the aftermath of a natural disaster such as a tornado or flood, moulds have optimal conditions for growth. Rescue workers and medical personnel who are required to work under these conditions are at particular risk of an allergic response and protective measures should be taken (Johanning et al., 2014).

Domestic helpers and staff in offices, hotels and other establishments

Workers such as hotel and cinema staff (Macan et al., 2012) who are required to operate in dusty areas may be exposed to rodents, cockroaches or dust mites, which are highly allergenic, with specific sensitisation to dust mites and cockroach antigens being as high as 61 % and 41 %, respectively, in asthmatics (Gerardi, 2010). In a case reported by Cartier (2015), a van driver’s asthma was related to dust mite exposure due to contamination of the floor of his van, in which he transported dry-cured ham. Exposure to mites is often unavoidable, both at home and in occupational settings. The most common dust mites (hence the name ‘house dust mites’) are from the Pyroglyphidae family, the

Dermatophagoides genera (*D. pteronyssinus*, *D. farinae*). Allergy to these mites is common in people with asthma (45-90 % prevalence), indicating their high allergenic potential and the need to take such exposures into account in specific environments.

Miscellaneous occupations

The sections above highlight occupations that are particularly associated with allergenic reactions. However, new causes of occupational asthma have been reported for a range of occupations that may or may not fall within those occupational groups and which represent a diverse range of work sectors and occupational settings. These include plant breeders (cauliflower and broccoli pollen), herbal product traders (Korean ginseng and sanyak), florists (yarrow, ivy), carpenters (cedrorana, chengal wood), parquet floor layers (cabreuva wood), laboratory plant workers (*Arabidopsis thaliana*), tea-packing plant workers (chamomile), chemists (linseed oilcake), brush makers (tampico fibre), olive oil mill workers (olive fruit), machine operators at malt companies (malt), animal fodder factory workers (marigold flour), rice mill workers (rice), pharmaceutical workers (papain) and greenhouse workers (tomato) (Quirce and Bernstein, 2011).Noll et al. (2012) highlight risks to woodworkers (biomass) from pathogenic fungi (e.g. *Candida*, *Aspergillus*, *Mucoraceae*, *Geotrichum*) and bacteria (e.g. *Aeromonas*) in stored woody biomass (wood chips and tree logs), as well as Jacobsen et al. (2010).

The list goes on to include carpet manufacturers (guar), flight crews (screw-worm flies) and sericulturists (silkworm larvae) (Quirce and Bernstein, 2011). Quirce and Sastre (2011) reported the first cases of allergen-related occupational asthma caused by caddis flies in an engineer who worked for an electric power company and by the predatory mite *Amblyseius californicus* in greenhouse workers.

Overview of allergenic agents

In Table 20- Table 36, an overview of occupations, allergenic agents and related diseases is provided. The list is based on the biological agents causing occupational asthma as reported by Rosenman and Beckett (2015), complemented with information from the research carried out for this project'on occupational allergies induced by biological agents and animal- and plant-derived allergens (see Annex 5, Part B).

Table 20-Table 24 relate to microorganisms and biological agents in the narrow sense of the Biological Agents Directive.

Table 20: Overview of occupations, biological agents and related allergic diseases for the 'bacteria' category, by occupation

Occupation	Agent	Disease
Agriculture	*Saccharopolyspora rectivirgula* (previously known as *Micropolyspora faeni*), *Thermoactinomyces vulgaris*/*viridis*/*sacchari*	Hypersensitivity pneumonitis
Agriculture (bird breeder)	Bacteria	Hypersensitivity pneumonitis
Agriculture (farmer)	Bacteria Thermophilic actinomycetes	Hypersensitivity pneumonitis Asthma, hypersensitivity pneumonitis
Composting site worker	Actinomycetes	Hypersensitivity pneumonitis
Detergent industry	*Bacillus subtilis*	Asthma

Occupation	Agent	Disease
Factory worker	*Bacillus subtilis*	Asthma
Florist/floral worker	Bacteria	Hypersensitivity pneumonitis
Food processing	Bacteria *Thermoactinomyces sacchari*	Hypersensitivity pneumonitis
Indoor worker (air-conditioned spaces)	*Achromobacter* *Alcaligenes*, *Thermoactinomyces*	Hypersensitivity pneumonitis
Ironing worker	*Sphingobacterium spiritivorum*	Hypersensitivity pneumonitis
Machine operator	*Acinetobacter Iwoffii*	Hypersensitivity pneumonitis
	Bacteria	Hypersensitivity pneumonitis
	Mycobacterium immunogenum, *Pseudomonas fluorescens* and *aeruginosa*	Asthma, hypersensitivity pneumonitis
Metalworker	*Acinetobacter, Mycobacterium chelonae, Mycobacterium immunogenum*, *Ochrobactrum, Pseudomonas fluorescens* and *aeruginosa*	Asthma, hypersensitivity pneumonitis, sarcoidosis
Mushroom worker	Bacteria	Hypersensitivity pneumonitis
Stucco worker	Bacteria	Hypersensitivity pneumonitis
Waste worker	*Acinetobacter*	Hypersensitivity pneumonitis

Table 21: Overview of occupations, biological agents and related allergic diseases for the 'bacteria' category, by occupation

Agent	Occupation	Disease
Bacteria	Agriculture (bird breeder, farmer) Florist/floral worker Food processing Machine operator Mushroom worker Stucco worker	Hypersensitivity pneumonitis
Achromobacter	Indoor worker (air-conditioned spaces)	Hypersensitivity pneumonitis

Agent	Occupation	Disease
Acinetobacter	Waste worker	Hypersensitivity pneumonitis
Acinetobacter Iwoffii	Machine operator	Hypersensitivity pneumonitis
Actinomycetes	Composting site worker	Hypersensitivity pneumonitis
Alcaligenes, *Thermoactinomyces*	Indoor worker (air-conditioned spaces)	Hypersensitivity pneumonitis
Bacillus subtilis	Detergent industry Factory worker	Asthma
Mycobacterium immunogenum, *Pseudomonas fluorescens* and *aeruginosa*	Machine operator	Asthma, hypersensitivity pneumonitis
Mycobacterium immunogenum, *Mycobacterium chelonae*, *Pseudomonas fluorescens* and *aeruginosa*, *Acinetobacter*, *Ochrobactrum*	Metalworker	Asthma, hypersensitivity pneumonitis, sarcoidosis
Saccharopolyspora rectivirgula (previously known as *Micropolyspora faeni*), *Thermoactinomyces vulgaris*, *viridis* and *sacchari*	Agricultural worker	Hypersensitivity pneumonitis
Sphingobacterium spiritivorum	Ironing worker	Hypersensitivity pneumonitis
Thermoactinomyces sacchari	Food processing worker	Hypersensitivity pneumonitis
Thermophilic actinomycetes	Agriculture (farmer)	Asthma, hypersensitivity pneumonitis

Table 22: Overview of occupations, biological agents and related allergic diseases for the 'fungi/mushrooms' category, by occupation

Occupation	Agent	Disease/health effect
Fungi		
Agricultural worker	*Alternaria* *Aspergillus fumigatus* *Botrytis*	Hypersensitivity pneumonitis
Agriculture (farmer)	*Absidia corymbifera* (dense packing of hay), *Candida albicans*, *Eurotium*	Asthma, hypersensitivity pneumonitis

Occupation	Agent	Disease/health effect
	amstelodami, *Fusarium*, *Plasmopara viticola*, *Saccharomyces cerevisiae*, *Sporobolomyces*, *Sporothrix schenkii*, *Ustilago esculenta*, *Wallemia sebi*	
Animal worker	*Aspergillus fumigatus*	Hypersensitivity pneumonitis
Automotive worker	Moulds	Asthma
Bakery worker	*Alternaria* *Aspergillus*	Asthma
Beet sugar worker	*Aspergillus* (unspecified)	Asthma
Butcher (sausage)	*Penicillium nalgiovensis*	Asthma
Cheese production worker	*Penicillium*	Hypersensitivity pneumonitis
Chiropodist/pedicurist	*Penicillium brevicompactum*, *Candida albicans*, *Torulopsis glabrata*	Hypersensitivity pneumonitis
Coal miner	*Rhizopus nigricans*	Asthma
Coffee maker	*Chrysonilia sitophila*	Asthma
Construction worker	Airborne mould fragments and spores	Sensitisation
Cork worker	*Penicillium*	Hypersensitivity pneumonitis
Food processing	*Aspergillus niger*, shiitake mushroom (*Lentinula edodes*), sausage mould	Hypersensitivity pneumonitis
	Penicillium	Asthma
	Saccharomyces cerevisiae	Hypersensitivity pneumonitis
	Spores of *Aspergillus* and *Alternaria*	Asthma
Gardener	*Aureobasidium* (*Pullularia*), *Cephalosporium*, *Fusarium*, *Sporothrix schenkii*	Hypersensitivity pneumonitis
Horticulturist	Mould fragments and spores	Sensitisation
Indoor worker	*Aspergillus, Absidia corymbifera*, *Cladosporium, Cephalosporium, Eurotium*	Asthma, hypersensitivity pneumonitis

Occupation	Agent	Disease/health effect
	amstelodami, *Penicillium, Wallemia sebi*	
Indoor worker (air-conditioned spaces)	*Absidia corymbifera*, *Aspergillus*, *Aureobasidium* (*Pullularia*), *Candida albicans*, *Eurotium amstelodami*, *Fusarium*, *Penicillium*, *Sporothrix schenkii*	Hypersensitivity pneumonitis
Indoor worker (mouldy work environment)	*Epicoccum nigrum*, *Paecilomyces variotii/nivea, Pezizia domiciliana*, *Poria megalospora*, *Serpula lacrymans* (*Merulius lacrymans*)	Hypersensitivity pneumonitis
Labourer	Sooty moulds	Asthma
Logging worker	*Chrysonilia sitophila*	Asthma
Metalworker	Airborne mould fragments and spores *Aspergillus*	Sensitisation Hypersensitivity pneumonitis
Musician	*Candida albicans*, *Fusarium*, *Mycobacterium chelonae*	Hypersensitivity pneumonitis
Peat worker	*Penicillium*	Hypersensitivity pneumonitis
Plywood factory	*Neurospora*	Asthma
Pool attendant	*Aureobasidium, Exophiala jeanselmer*	Hypersensitivity pneumonitis
Sawmill worker	*Trichoderma koningii*	Asthma
Sorter (potato/onion)	*Fusarium*, *Penicillium*	Hypersensitivity pneumonitis
Stucco worker	*Mucor* spp.	Asthma
Technician	*Aspergillus niger* *Dictyostelium discoideum* (mould)	Asthma
Veterinarian	*Aspergillus fumigatus*	Hypersensitivity pneumonitis
Waste processing/recycling worker	Airborne mould fragments and spores	Sensitisation
Wine grower	*Botrytis*	Hypersensitivity pneumonitis

Occupation	Agent	Disease/health effect
Woodworker	*Alternaria alternata*, *Aspergillus*,*Acremonium strictum*, *Cryptostroma corticale*, *Graphium*, *Leucogyrophana pinastri*, *Mucores*, *Paecilomyces*, *Penicillium, Pullaria*, *Rhizopus nigricans*, *Sporothrix schenkii, Trichoderma koningii*	Asthma, hypersensitivity pneumonitis
Mushrooms		
Agricultural worker	*Agaricus bisporus*	Asthma
Bakery worker	Baker's yeast	Asthma
Mushroom worker	*Pleurotus*, shiitake, *Pholiota*, *Tricholoma*, bunashimeji, shimeji, *Strophariaceae*, champignon mushroom	Asthma, hypersensitivity pneumonitis
Mushroom worker (packager of dried mushrooms)	Shiitake (*Lentinus edodes*)	Asthma, hypersensitivity pneumonitis
Mushroom worker (soup processing)	Mushroom (unspecified)	Asthma
Office worker, cook, hotel manager	*Boletus edulis*	Asthma
Seller	*Pleurotus ostreatus*	Asthma

Table 23: Overview of occupations, biological agents and related diseases for the 'fungi/mushrooms' category, by agent

Agent	Occupation	Disease/health effect
Fungi		
Absidia corymbifera, *Aspergillus*, *Cephalosporium, Cladosporium*, *Eurotium amstelodami*, *Penicillium*, *Wallemia sebi*	Indoor worker	Asthma, hypersensitivity pneumonitis
Absidia corymbifera (dense packing of hay), *Candida albicans*, *Eurotium amstelodami*, *Fusarium*, *Saccharomyces cerevisiae, Sporobolomyces*, *Sporothrix schenkii*, *Ustilago esculenta*, *Wallemia sebi*	Agriculture (farmer)	Asthma, hypersensitivity pneumonitis

Agent	Occupation	Disease/health effect
Airborne mould fragments and spores	Construction worker Metalworker Waste processing/recycling	Sensitisation
Alternaria	Bakery worker	Asthma
Alternaria, *Aspergillus fumigatus*, *Botrytis*	Agricultural worker	Hypersensitivity pneumonitis
Alternaria alternata, *Rhizopus nigricans*, *Mucor*, *Acremonium strictum*, *Graphium*, *Leucogyrophana pinastri*, *Trichoderma koningii*, *Paecilomyces*, *Penicillium*, *Cryptostroma corticale*, *Pullaria*, *Aspergillus*, *Sporothrix schenkii*	Woodworker	Asthma, hypersensitivity pneumonitis
Aspergillus	Bakery worker Metalworker	Asthma Hypersensitivity pneumonitis
Aspergillus (unspecified)	Beet sugar worker	Asthma
Aspergillus, *Penicillium*, *Absidia corymbifera*, *Eurotium amstelodami*, *Aureobasidium* (*Pullularia*), *Fusarium*, *Sporothrix schenkii*, *Candida albicans*	Indoor worker (air-conditioned spaces)	Hypersensitivity pneumonitis
Aspergillus fumigatus	Animal worker Veterinarian	Hypersensitivity pneumonitis Hypersensitivity pneumonitis
Aspergillus niger	Technician	Asthma
Aspergillus niger, shiitake mushroom, sausage mould.	Food processing worker	Hypersensitivity pneumonitis
Botrytis	Wine grower	Hypersensitivity pneumonitis
Candida albicans, *Mycobacterium chelonae*, *Fusarium*	Musician	Hypersensitivity pneumonitis
Cephalosporium, *Aureobasidium* (*Pullularia*), *Fusarium*, *Sporothrix schenkii*	Gardener	Hypersensitivity pneumonitis
Chrysonilia sitophila	Coffee maker	Asthma

Agent	Occupation	Disease/health effect
	Logging worker	Asthma
Dictyostelium discoideum (mould)	Technician	Asthma
Exophiala jeanselmer, *Aureobasidium*	Pool attendant	Hypersensitivity pneumonitis
Fusarium, *Penicillium*	Sorter (potato/onion)	Hypersensitivity pneumonitis
Mould fragments and spores	Horticulturist	Sensitisation
Moulds	Automotive worker	Asthma
Mucor species	Stucco worker	Asthma
Neurospora	Plywood factory worker	Asthma
Penicillium	Cheese production worker Cork worker Food processing Peat worker	Hypersensitivity pneumonitis Hypersensitivity pneumonitis Asthma Hypersensitivity pneumonitis
Penicillium brevicompactum, *Candida albicans*, *Torulopsis glabrata*	Chiropodist/pedicurist	Hypersensitivity pneumonitis
Penicillium nalgiovensis	Butcher (sausage)	Asthma
Rhizopus nigricans	Coal miner	Asthma
Saccharomyces cerevisiae	Food processing worker	Hypersensitivity pneumonitis
Serpula lacrymans (*Merulius lacrymans*), *Epicoccum nigrum*, *Pezizia domiciliana*, *Poria megalospora*, *Paecilomyces variotii or nivea*	Indoor worker (mouldy work environment)	Hypersensitivity pneumonitis
Sooty moulds	Labourer	Asthma
Spores of *Aspergillus* and *Alternaria*	Food processing worker	Asthma
Trichoderma koningii	Sawmill worker	Asthma
Mushrooms		

Agent	Occupation	Disease/health effect
Agaricus bisporus	Agricultural worker	Asthma
Baker's yeast	Bakery worker	Asthma
Boletus edulis	Office worker, cook, hotel manager	Asthma
Mushroom (unspecified)	Mushroom worker (soup processing)	Asthma
Pleurotus, shiitake, *Pholiota*, *Tricholoma*, bunashimeji, shimeji, *Strophariaceae*, champignon mushroom	Mushroom worker	Asthma, hypersensitivity pneumonitis
Pleurotus ostreatus	Seller	Asthma
Shiitake (*Lentinus edodes*)	Mushroom worker (packager of dried mushrooms)	Asthma, hypersensitivity pneumonitis

Table 24: Overview of occupations, biological agents and related allergic diseases for the 'parasites' category, by agent

Agent	Occupation	Disease
Herring worm (*Anisakis simplex*)	Agriculture (animal worker/poultry farmer)	Asthma, hypersensitivity pneumonitis
	Fishmonger	Asthma
	Fish processing	Asthma
Protozoa	Indoor worker (air-conditioned spaces)	Hypersensitivity pneumonitis
Steinernema feltiae	Technician	Asthma

Table 25-Table 36 provide an overview of other allergens of a biological nature that may be addressed under biological agents regulations in some countries.

Table 25: Overview of occupations, biological agents and related allergic diseases for the 'algae' category, by occupation

Occupation	Agent	Disease
Pharmacist	*Chlorella*	Asthma
Thalassotherapist	Unspecified	Asthma

Table 26: Overview of occupations, biological agents and related allergic diseases for the ‘animal-derived antigens’ category, by occupation

Occupation	Agent	Disease/health effect
Agricultural worker	Cow dander	Asthma
Agriculture (animal worker/farmer)	Deer dander Mink urine	Asthma
Agriculture (animal worker/poultry)	Poultry, turkey, wild bird, pheasant (serum, droppings, feathers) Chicken	Hypersensitivity pneumonitis Asthma
Agriculture (bird breeder)	Bird serum, droppings, feathers (pigeon, parakeet, canary, zebra finch)	Hypersensitivity pneumonitis
Agriculture (farmer)	Livestock animals (hair, urine, saliva, dander and other inhalable components of farm animals such as cattle, horses, pigs, sheep and goats)	Asthma
Animal worker	Livestock animals (hair, urine, saliva, dander and other inhalable components of farm animals such as cattle, horses, pigs, sheep and goats) African penguin	Asthma
Bakery worker	Lactalbumin	Asthma
Bird dealer	Bird serum, droppings, feathers (pigeon, parakeet, canary, zebra finch)	Hypersensitivity pneumonitis
Bird photographer	Pigeon serum, droppings, feathers	Hypersensitivity pneumonitis
Butcher	Cow bone dust Goat dander Pig	Asthma
Butcher (pork production)	Pig gut (vapour from soaking water)	Asthma
Cheese production	Goat’s cheese (goat whey)	Asthma
Cook	Raw beef	Asthma
Dairy industry	Lactoserum	Asthma
Egg production	Egg protein	Asthma

Occupation	Agent	Disease/health effect
Food processing	Powder from animal products (milk, egg)	Asthma
Frog catcher	Frog	Asthma
Hairdresser	Sericin	Asthma
Ivory worker	Ivory dust	Asthma
Laboratory technician	Bovine serum albumin	Asthma
Laboratory worker	Laboratory animals (hair, urine, saliva, dander and other inhalable components of mouse, rat, gerbil; urinary — prealbumin and alpha-2u-globulin)	Asthma, immediate hypersensitivity, anaphylaxis, urticarial
	Monkey dander	Asthma, immediate hypersensitivity
Manufacturer of feather beds	Duck and goose serum/feathers	Asthma
Nacre industry	Animal proteins	Hypersensitivity pneumonitis
Nacre industry (buttons)	Nacre dust	Asthma
Pearl industry	Animal proteins	Hypersensitivity pneumonitis
Pharmacist	Endocrine glands	Asthma
Tanner	Casein (cow's milk)	Asthma
Textile industry	Animal proteins (fur, shell dust, silkworm larvae cocoon fluff)	Hypersensitivity pneumonitis
Various	Bat guano	Asthma
Veterinarian	Goat dander	Asthma
	Livestock animals (hair, urine, saliva, dander and other inhalable components of farm animals such as cattle, horses, pigs, sheep and goats)	Asthma
	Cats	Hypersensitivity pneumonitis
	Bird serum, droppings, feathers (pigeon, parakeet, canary, zebra finch)	Hypersensitivity pneumonitis

Occupation	Agent	Disease/health effect
Zookeeper	Birds	Asthma

Table 27: Overview of occupations, biological agents and related allergic diseases for the 'animal-derived antigens' category, by agent

Agent	Occupation	Disease/health effect
African penguin	Animal worker	Asthma
Animal proteins	Nacre industry Pearl industry	Hypersensitivity pneumonitis
Animal proteins (fur, shell dust, silkworm larvae cocoon fluff)	Textile industry	Hypersensitivity pneumonitis
Bat guano	Various	Asthma
Birds	Zookeeper	Asthma
Bird serum, droppings, feathers (pigeon, parakeet, canary, zebra finch)	Agriculture (bird breeder) Bird dealer Veterinarian	Hypersensitivity pneumonitis
Bovine serum albumin	Laboratory technician	Asthma
Casein (cow's milk)	Tanner	Asthma
Cats	Veterinarian	Hypersensitivity pneumonitis
Chicken	Agriculture (animal worker/poultry)	Asthma
Cow bone dust	Butcher	Asthma
Cow dander	Agriculture	Asthma
Deer dander	Agriculture (animal worker/farmer)	Asthma
Duck and goose serum/feathers	Manufacturer of feather beds	Asthma
Egg protein	Egg production	Asthma
Endocrine glands	Pharmacist	Asthma
Frog	Frog catcher	Asthma
Goat dander	Butcher, veterinarian	Asthma

Agent	Occupation	Disease/health effect
Goat's cheese (goat whey)	Cheese production	Asthma
Ivory dust	Ivory worker	Asthma
Laboratory animals (hair, urine, saliva, dander and other inhalable components of mouse, rat, gerbil; urinary prealbumin and alpha-2u-globulin)	Laboratory worker	Asthma, immediate hypersensitivity, anaphylaxis, urticaria
Lactalbumin	Bakery worker	Asthma
Lactoserum	Dairy industry	Asthma
Livestock animals (hair, urine, saliva, dander and other inhalable components of farm animals such as cattle, horses, pigs, sheep and goats)	Agriculture (farmer) Animal worker Veterinarian	Asthma
Mink urine	Agriculture (animal worker/farmer)	Asthma
Monkey dander	Laboratory worker	Asthma, immediate hypersensitivity
Nacre dust	Nacre industry (buttons)	Asthma
Powder from animal products (milk, egg)	Food processing	Asthma
Pig	Butcher	Asthma
Pig gut (vapour from soaking water)	Butcher (pork production)	Asthma
Pigeon serum, droppings, feathers	Bird photographer	Hypersensitivity pneumonitis
Poultry, turkey, wild bird, pheasant (serum, droppings, feathers)	Agriculture (animal worker/poultry)	Hypersensitivity pneumonitis
Raw beef	Cook	Asthma
Sericin	Hairdresser	Asthma

Table 28: Overview of occupations, biological agents and related allergic diseases for the 'Annelida' agent category

Occupation	Agent	Disease
Fish food producer	*Tubifex*	Asthma

Table 29: Overview of occupations, biological agents and related allergic diseases for the category 'arthropods', by occupation

Occupation	Agent	Disease/health effect
Agriculture (animal worker/poultry)	Fowl mite	Asthma
Agriculture (farmer)	Dust mite, citrus red mite, barn mite Grain mite Grain pests (*Eurygaster* and *Pyrale*) Housefly Two-spotted spider mite	Asthma
Agronomist	*Bruchus lentis*	Asthma
Angler	Green bottle fly larvae (*Lucilla caesar*)	Asthma
Apple grower	Fruit tree red spider (*Panonychus ulmi*)	Asthma
Aquarist, fish food handler	Chironomid midges (*Psychoda alternata*)	Asthma
Aviation personnel	Screw-worm fly	Asthma
Bakery worker	Mites, beetles, cockroaches, weevils	Asthma
Bottling plant worker	Ground bug	Asthma
Car driver	Dust mite Insect stings and bites	Asthma Immediate hypersensitivity, anaphylaxis
Carpenter (working close to a granary)	*Liposcelis decolor*	Asthma
Cinema employee	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma

Occupation	Agent	Disease/health effect
Citrus farmer	Citrus red mite	Asthma
Construction worker	Insect stings and bites	Immediate hypersensitivity, anaphylaxis
Day-care worker	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Engineer at electric power plant	Caddis flies	Asthma
Entomologist	Coleoptera, Lepidoptera, Araneae, Blattodea, Orthoptera, Diptera, Hymenoptera, Ixodidae, Trombidiformes, Hemiptera, Isoptera, Neuroptera, Sarcoptiformes, Mesostigmata	Asthma, anaphylactic shock
	Mealworm	Asthma
	Moth, butterfly	Asthma
Fish bait breeder/farmer	Insect larvae *Galleria mellonella*	Asthma
Fish bait handler	Mealworm larvae	Asthma
Fish food store worker	Daphnia	Asthma
Fish food handler	Fish-feed *Echinodorus* larvae (*Echinodorus plasmosus*)	Asthma
Flight crew	Screw-worm fly	Asthma
Flour handler	Mites and parasites	Asthma
Food processing worker	*Harmonia axyridis* Two-spotted spider mite Wheat weevils, flour beetles, meal moths, cake cockroaches, mites	Asthma
Fruit grower	Chlorophyll-eating spider mites, predator mites	Asthma
Gardener	Chlorophyll-eating spider mites, predator mites Insect stings and bites	Asthma Immediate hypersensitivity, anaphylaxis
Grain store worker	Grain mite	Asthma

Occupation	Agent	Disease/health effect
Greenhouse worker	Chlorophyll-eating spider mites, predator mites	Asthma
	Insect stings and bites	Immediate hypersensitivity, anaphylaxis
Honey processing worker	Honeybee	Asthma
Horticulturist	*Amblyseius cucumeris*	Asthma
Hotel chambermaid	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Indoor worker	Mites	Asthma, hypersensitivity pneumonitis
Insect breeder	Grasshopper	Allergic rhinoconjunctivitis, bronchial hyperreactivity, asthma
	Insect stings and bites	Immediate hypersensitivity, anaphylaxis
	Locust	Asthma
Laboratory worker	Cricket	Asthma
	Fruit fly	Asthma
	Grasshopper	Asthma, allergic rhinoconjunctivitis, bronchial hyperreactivity
	Insect stings and bites	Immediate hypersensitivity, anaphylaxis
	Locust	Asthma
Library personnel	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Mechanics in a rye plant	Confused flour beetle	Asthma
Miller	Grain weevils	Asthma
	Mites	Asthma
Museum curator	Beetles (Coleoptera)	Asthma
Producer of flies	Mediterranean fruit fly	Asthma
Public transportation worker	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Seed house worker	Mexican bean weevil (*Zabrotes subfasciatus* (Boh.))	Asthma

Occupation	Agent	Disease/health effect
Sericulturist	Silkworm larvae	Asthma, hypersensitivity pneumonitis
Sewage plant worker	Sewer fly	Asthma
Silk worker	Silkworm	Asthma
Snake breeder	Insect stings and bites	Immediate hypersensitivity, anaphylaxis
Submarine personnel	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Teacher	Pyroglyphid mites	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Technician	Arthropods (*Chrysoperla carnea*, *Leptinotarsa decemlineata*, *Ostrinia nubilalis*, *Ephestia kuehniella*) Sheep blowfly (*Lucilia cuprina*)	Asthma
Wool worker	*Dermestidae* spp.	Asthma

Table 30: Overview of occupations, biological agents and related allergic diseases for the category 'arthropods', by agent

Agent	Occupation	Disease/health effect
Amblyseius cucumeris	Horticulturist	Asthma
Arthropods (*Chrysoperla carnea*, *Leptinotarsa decemlineata*, *Ostrinia nubilalis*, *Ephestia kuehniella*)	Technician	Asthma
Beetles (Coleoptera)	Museum curator	Asthma
Bruchus lentis	Agronomist	Asthma
Caddis flies	Engineer at electric power plant	Asthma
Chironomid midges (*Psychoda alternata*)	Aquarist, fish food handler	Asthma
Chlorophyll-eating spider mites, predator mites	Fruit grower Gardener Greenhouse worker	Asthma Asthma Asthma

Agent	Occupation	Disease/health effect
Citrus red mite	Citrus farmer	Asthma
Coleoptera, Lepidoptera, Araneae, Blattodea, Orthoptera, Diptera, Hymenoptera, Ixodidae, Trombidiformes, Hemiptera, Isoptera, Neuroptera, Sarcoptiformes, Mesostigmata	Entomologist	Asthma, anaphylactic shock
Confused flour beetle	Mechanic in a rye plant	Asthma
Cricket	Laboratory worker	Asthma
Daphnia	Fish food store	Asthma
Dermestidae spp.	Wool worker	Asthma
Dust mite	Car driver	Asthma
Dust mite, citrus red mite, barn mite	Agriculture (farmer)	Asthma
Echinodorus larvae (*Echinodorus plasmosus*)	Fish food handler	Asthma
Fowl mite	Agriculture (animal worker/poultry)	Asthma
Fruit fly	Laboratory worker	Asthma
Fruit tree red spider (*Panonychus ulmi*)	Apple grower	Asthma
Harmonia axyridis	Food processing worker	Asthma
Housefly	Agriculture (farmer)	Asthma
Galleria mellonella	Fish bait breeder/farmer	Asthma
Grain mite	Agriculture (farmer) Grain store worker	Asthma
Grain pests (*Eurygaster* and *Pyrale*)	Agriculture (farmer)	Asthma
Grain weevils	Miller	Asthma

Agent	Occupation	Disease/health effect
Grasshopper	Insect breeder Laboratory worker	Asthma, allergic rhinoconjunctivitis, bronchial hyperreactivity
Green bottle fly larvae (*Lucilla caesar*)	Angler	Asthma
Ground bug	Bottling plant worker	Asthma
Honeybee	Honey processing worker	Asthma
Insect larvae	Fish bait breeder/farmer	Asthma
Insect stings and bites	Car driver Construction worker Gardener Greenhouse worker Insect breeder Laboratory worker Snake breeder	Immediate hypersensitivity, anaphylaxis
Liposcelis decolor	Carpenter (working close to a granary)	Asthma
Locust	Insect breeder Laboratory worker	Asthma
Moth, butterfly	Entomologist	Asthma
Mealworm	Entomologist	Asthma
Mealworm larvae	Fish bait handler	Asthma
Mediterranean fruit fly	Producer of flies	Asthma
Mexican bean weevil (*Zabrotes subfasciatus* (Boh.))	Seed house worker	Asthma
Mites	Indoor worker Miller	Asthma, hypersensitivity pneumonitis Asthma
Mites and parasites	Flour handler	Asthma
Mites, beetles, cockroaches, weevils	Bakery worker	Asthma

Agent	Occupation	Disease/health effect
Pyroglyphid mites	Cinema employee Day-care worker Hotel chambermaid Library personnel Public transportation worker Submarine personnel Teacher	Atopic rhinitis, conjunctivitis, dermatitis, asthma
Screw-worm fly	Aviation personnel Flight crew	Asthma
Sewer fly	Sewage plant worker	Asthma
Sheep blowfly (*Lucilia cuprina*)	Technician	Asthma
Silkworm	Silk worker	Asthma
Silkworm larvae	Sericulturist	Asthma, hypersensitivity pneumonitis
Two-spotted spider mite	Agriculture (farmer) Food processing worker	Asthma
Wheat weevils, flour beetles, meal moths, cake cockroaches, mites	Food processing worker	Asthma

Table 31: Overview of occupations, biological agents and related allergic diseases for the 'enzymes' category, by occupation

Occupation	Agent	Disease
Animal feed production worker	Phytase from *Aspergillus* or *Trichoderma*	Hypersensitivity pneumonitis
Bakery worker	Fungal amylases, xylanases, cellulases Lipase from *Rhizopus oryzae* Fungal amyloglucosidase and hemicellulase	Asthma
Cheese production worker	Various enzymes in rennet production (proteases, pepsin, chymosin)	Asthma
Detergent industry worker	Esperase Fungal amylases, xylanases, cellulases	Asthma

Occupation	Agent	Disease
	Lipase from *Rhizopus oryzae*	
Florist/floral worker	Enzymes	Hypersensitivity pneumonitis
Fruit processing worker	Pectinase and glucanase	Asthma
Hospital personnel	Empynase (pronase B)	Asthma
Laboratory worker	Xylanase	Asthma
Pharmaceutical worker	Bromelin Egg lysozyme Flaviastase Lactase Lipase from *Rhizopus oryzae* Pancreatin Papain Phytase from *Aspergillus niger* Serratial peptidase and lysozyme chloride Trypsin	Asthma
Plastic industry worker	Trypsin	Asthma
Technician	Phytase from *Aspergillus niger*	Asthma
Textile industry worker	Fungal amylases, xylanases, cellulases Lipase from *Rhizopus oryzae*	Asthma
Wine cellar worker	Lallzyme EX-V (from *Aspergillus niger*)	Asthma

Table 32: Overview of occupations, biological agents and related allergic diseases for the ‘enzymes’ category, by agent

Agent	Occupation	Disease
Bromelin	Pharmaceutical worker	Asthma
Egg lysozyme	Pharmaceutical worker	Asthma
Empynase (pronase B)	Hospital personnel	Asthma
Enzymes	Florist/floral worker	Hypersensitivity pneumonitis
Esperase	Detergent industry worker	Asthma

Agent	Occupation	Disease
Flaviastase	Pharmaceutical worker	Asthma
Fungal amylases, xylanases, cellulases	Bakery worker Detergent industry worker Textile industry worker	Asthma
Fungal amyloglucosidase and hemicellulase	Bakery worker	Asthma
Lactase	Pharmaceutical worker	Asthma
Lallzyme EX-V (from *Aspergillus niger*)	Wine cellar worker	Asthma
Lipase from *Rhizopus oryzae*	Bakery worker Detergent industry worker Pharmaceutical worker Textile industry worker	Asthma
Pancreatin	Pharmaceutical worker	Asthma
Papain	Pharmaceutical worker	Asthma
Pectinase and glucanase	Fruit processing worker	Asthma
Phytase from *Aspergillus niger*	Pharmaceutical worker Technician	Asthma
Phytase from *Aspergillus* or *Trichoderma*	Animal feed production worker	Hypersensitivity pneumonitis
Serratial peptidase and lysozyme chloride	Pharmaceutical worker	Asthma
Trypsin	Pharmaceutical worker Plastic industry worker	Asthma
Various enzymes in rennet production (proteases, pepsin, chymosin)	Cheese production worker	Asthma
Xylanase	Laboratory worker	Asthma

Table 33: Overview of occupations, biological agents and related allergic diseases for the 'plant material/plant-derived natural products' category, by occupation

Occupation/exposed group	Agent	Disease/health effect
Agriculture	Melons, oranges	Asthma
Agriculture (farmer)	Vetch (*Vicia sativa*)	Asthma
Animal fodder worker	Marigold flour (*Tagetes erecta*)	Asthma
Bakery worker	Amaranth, buckwheat, lupine Buckwheat flour Flours (wheat, rye, soya, barley) Gluten Grain dust Sesame seed Soybean lecithin	Asthma
Brewery chemist	Hops	Asthma
Brush maker	Tampico fibre in agave leaves	Asthma
Butcher	Aromatic herbs	Asthma
Cake processor	Lima bean	Asthma
Carpet manufacturing worker	Guar	Asthma
Chemist's spouse	Linseed oilcake *Voacanga africana* seed dust	Asthma
Christmas candy maker	Pectin	Asthma
Construction worker	Plant proteins	Hypersensitivity pneumonitis
Cook	Carrot	Asthma
Cosmetics factory worker	Argan Dust from seeds from sacha inchi (*Plukenetia volubilis*) *Moringa oleifera* seed	Asthma
Cosmetician	Chamomile (unspecified)	Asthma
Decorator	Cocoon seed	Asthma
Dental hygienist	Gutta-percha	Asthma

Occupation/exposed group	Agent	Disease/health effect
	Latex	
Factory worker	Peach	Asthma
Fish food producer	Fish food	Hypersensitivity pneumonitis
Fishmonger	Fish food	Hypersensitivity pneumonitis
Florist/floral worker	Baby's breath (*Gypsophila*)	Asthma
	Cyclamen	Asthma
	Chrysanthemum, marguerite, dahlia, tulip, Peruvian lily, poison ivy, primula	Asthma
	Decorative flowers	Asthma
	Ivy (*Hedera helix*)	Asthma
	Safflower and yarrow	Asthma
	Spathe flower	Asthma
	Statice (*Limonium tataricum*)	Contact dermatitis
Flour handler	Konjac flour White pea flour (*Lathyrus sativus*)	Asthma
Flower industry	Flowers (various)	Asthma
Food industry	Aniseed Fenugreek	Asthma
Food packaging	Food components and additives (e.g. flaxseed, cinnamon) Garlic dust	Asthma
Food processing	Asparagus	Asthma
	Dust from dry spices (chili peppers, garlic, onion powder)	Asthma
	Food components and additives (e.g. flaxseed, cinnamon)	Asthma
	Green coffee dust, castor bean dust, chicory dust	Asthma
	Sinapsis alba pollen, bell pepper pollen	Asthma

Occupation/exposed group	Agent	Disease/health effect
	Spinach powder	Hypersensitivity pneumonitis
	Soybean proteins, *Artemia*, konjac glucomannan, gum arabic	Asthma
	Vegetables, fruit and other food (lettuce, endive, chicory, artichoke, garlic, citrus fruit, mango, carrot, black mustard, cauliflower, caperbush)	Contact dermatitis
	Wheat, rye and barley flour, amaranth, buckwheat, lupine and soya flour	Asthma
	White upin flour (*Lupinus albus*)	Asthma
Food processing (emptying, roastery)	Coffee bean	Asthma
Food transport	Food components and additives (e.g. flaxseed, cinnamon)	Asthma
Fruit grower	Green coffee dust, castor bean dust, chicory dust	Asthma
	Peach leaf	Asthma
	Pollen from flowers and crops	Asthma, pollen allergy, rhinitis, conjunctivitis
Fruit warehouse	Courgette	Asthma
Gardener	Canary Island date palm (*Phoenix canariensis*)	Asthma
	Copperleaf	Asthma
	Grass juice	Asthma
	Green coffee dust, castor bean dust, chicory dust	Asthma
	Pollen from flowers and crops	Asthma, pollen allergy, rhinitis, conjunctivitis
Gardener (landscape)	Umbrella tree (*Schefflera*)	Asthma
Glove manufacturer	Latex	Asthma
Grain elevator worker	Grain dust	Asthma
Greenhouse worker	Amaryllis	Asthma
	Bell pepper pollen	Asthma

Occupation/exposed group	Agent	Disease/health effect
	Aubergine (*Solanum melongena*)	Asthma
	Chrysanthemum	Asthma
	Green coffee dust, castor bean dust, chicory dust	Asthma
	Madagascar jasmine sap	Asthma
	Pollen from flowers and crops	Asthma, pollen allergy, rhinitis, conjunctivitis
	Sea lavender	Asthma
	Spores of white spongy rot, sweet pea (*Lathyrus odoratus*)	Asthma
Gum importer	Tragacanth	Asthma
Hairdresser	Henna Hydrolysed wheat protein Karaya (vegetable gum)	Asthma
Healthcare worker	Latex Pharmaceutical plants	Asthma
Herb manufacturing worker	Yuan Zhi (*Polygala tenuifolia*)	Asthma
Herbal product merchant	Sanyak and Korean ginseng	Asthma
Herbal tea processor Herbal tea worker Herbal worker	Herbal tea Sarsaparilla root Herb material	Asthma
Herbalist	Liquorice root	Asthma
Homemaker	Green bean Onion	Asthma
Horticulturist	Freesia and paprika Bells of Ireland	Asthma
Jam factory worker	Carob bean	Asthma
Laboratory technician	Alginate	Hypersensitivity pneumonitis
Laboratory worker	Latex	Asthma
	Sunflower (*Helianthus* spp.)	Asthma

Occupation/exposed group	Agent	Disease/health effect
Laboratory worker (animal feed)	Soy flour dust	Asthma
Labourer (handling fruit)	Citrus fruits	Asthma
Medicinal plant processor	Brazilian ginseng	Asthma
Miller	Flours (wheat, rye, soya)	Asthma
Oil industry worker	Castor bean Olive oilcake	Asthma
Olive farmer	White mustard (*Sinapis alba*)	Asthma
Pasta factory worker	Amaranth, buckwheat, lupine Flours (wheat, rye, soya) Spinach powder	Asthma
Pest control worker	Pyrethrum	Hypersensitivity pneumonitis
Pharmaceutical worker	Corn starch, gum arabic dust Passion flower and cascara sagrada (*Rhamnus purshiana*) Rosehip	Asthma Asthma Asthma
Plant keeper	Weeping fig	Asthma
Preservative maker	*Lycopodium* powder	Asthma
Printer	Acacia (vegetable gum)	Asthma
Processing worker	*Glycine maxima* Sunflower (Helianthus annuus)	Asthma Asthma
Research student	*Arabidopsis thaliana*	Asthma
Restaurant worker	Cauliflower and cabbage	Asthma
Rice mill worker	Rice	Asthma
Rose extraction worker	Rose oil	Asthma
Rose grower	Rose	Asthma
Saffron processing worker	Saffron	Asthma
Sausage processing worker	Fennel seed	Asthma
Seed packaging worker	Onion seeds	Asthma

Occupation/exposed group	Agent	Disease/health effect
Sewer worker	Kapok	Asthma
Sheller	Almond shell dust	Asthma
Soybean processing worker	Soybean	Asthma
Spice processing worker	Spices	Asthma
Stucco handler	Esparto	Asthma
Stucco worker	Plant proteins	Hypersensitivity pneumonitis
Tea processing worker	Tea plant dust (*Camellia sinensis* containing epigallocatechin gallate)	Asthma
Tea packing worker	Chamomile (unspecified)	Asthma
Technician	Miracle tree	Asthma
Tobacco manufacturing worker	Tobacco leaf	Asthma
Vegetable plant worker	*Brassica oleracea* pollen (cauliflower and broccoli)	Asthma
Vegetable wholesaler	Chicory	Asthma
Woodworker	Wood dust (abachi, robine, needle wood, sequoia, mahogany, cedar, ramin, pine, cabreuva, red cedar, limba, oak, African zebra wood, spindle tree, pau marfim, cherry, ash, South American timbers, cedro rana)	Asthma

Table 34: Overview of occupations, biological agents and related allergic diseases for the 'plant material/plant-derived natural products' category, by agent

Agent	Occupation/exposed group	Disease/health effect
Alginate	Laboratory technician	Hypersensitivity pneumonitis
Almond shell dust	Sheller	Asthma
Amaranth, buckwheat, lupine	Bakery worker Pasta factory worker	Asthma
Amaryllis	Greenhouse worker	Asthma

Agent	Occupation/exposed group	Disease/health effect
Aniseed	Food industry	Asthma
(*Arabidopsis thaliana*)	Research student	Asthma
Argan	Cosmetics factory	Asthma
Aromatic herbs	Butcher	Asthma
Asparagus	Food processing	Asthma
Aubergine (*Solanum melongena*)	Greenhouse worker	Asthma
Baby's breath (*Gypsophila*)	Florist/floral worker	Asthma
Bell pepper pollen	Greenhouse worker	Asthma
Bells of Ireland	Grower	Asthma
Brazilian ginseng	Medicinal plant processor	Asthma
Buckwheat flour	Bakery worker	Asthma
Canary Island date palm (*Phoenix canariensis*)	Gardener	Asthma
Carob bean	Jam factory worker	Asthma
Carrot	Cook	Asthma
Castor bean	Oil industry worker	Asthma
Cauliflower and broccoli (*Brassica oleracea*) pollen	Vegetable plant worker	Asthma
Cauliflower and cabbage	Restaurant worker	Asthma
Chamomile (unspecified)	Cosmetician Tea packing worker	Asthma
Chicory	Vegetable wholesaler	Asthma
Chrysanthemum	Greenhouse worker	Asthma
Chrysanthemum, marguerite, dahlia, tulip, Peruvian lily, poison ivy, primula	Florist/floral worker	Contact dermatitis
Citrus fruits	Labourer (handling fruit)	Asthma
Cocoon seed	Decorator	Asthma

Agent	Occupation/exposed group	Disease/health effect
Coffee bean	Food processing (emptying, roastery)	Asthma
Copperleaf	Gardener	Asthma
Corn starch, gum arabic dust	Pharmaceutical worker	Asthma
Courgette	Fruit warehouse	Asthma
Cyclamen	Florist/floral worker	Asthma
Decorative flowers	Florist/floral worker	Asthma
Dust from dry spices (chili peppers, garlic, onion powder)	Food processing	Asthma
Dust from seeds from sacha inchi	Cosmetics factory	Asthma
Esparto	Stucco handler	Asthma
Fennel seed	Sausage processing worker	Asthma
Fenugreek	Food industry	Asthma
Fish food	Fish food producer Fishmonger	Hypersensitivity pneumonitis
Flours (wheat, rye, soy)	Pasta factory worker Miller	Asthma
Flours (wheat, rye, soy, barley)	Bakery worker	Asthma
Flowers (various)	Flower industry	Asthma
Food components and additives (e.g. flaxseed, cinnamon)	Food packaging Food processing Food transport	Asthma
Freesia and paprika	Horticulture	Asthma
Garlic dust	Food packaging	Asthma
Gluten	Bakery worker	Asthma
Grain dust	Bakery worker Grain elevator worker	Asthma
Grass juice	Gardener	Asthma

Agent	Occupation/exposed group	Disease/health effect
Green bean	Homemaker	Asthma
Green coffee dust, castor bean dust, chicory dust	Food processing Fruit grower Gardener Greenhouse worker	Asthma
Glycine maxima	Processing worker	Asthma
Henna	Hairdresser	Asthma
Herb material	Herbal worker	Asthma
Herbal tea	Herbal tea processor	Asthma
Hops	Brewery chemist	Asthma
Hydrolysed wheat protein	Hairdresser	Asthma
Ivy (*Hedera helix*)	Florist/floral worker	Asthma
Kapok	Sewer worker	Asthma
Konjac flour	Flour handler	Asthma
Latex	Dental hygienist Glove manufacturer Healthcare worker Laboratory worker	Asthma
Lima bean	Cake processor	Asthma
Linseed oilcake	Chemist’s spouse	Asthma
Liquorice root	Herbalist	Asthma
Lycopodium powder	Preservative maker	Asthma
Madagascar jasmine sap	Greenhouse worker	Asthma
Marigold flour (*Tagetes erecta*)	Animal fodder worker	Asthma
Melons, oranges	Agriculture	Asthma
Miracle tree	Technician	Asthma
(Moringa oleifera) seed	Cosmetics factory	Asthma
Olive oilcake	Oil industry worker	Asthma

Agent	Occupation/exposed group	Disease/health effect
Onion	Homemaker	Asthma
Onion seeds	Seed packaging worker	Asthma
Passion flower and cascara sagrada (*Rhamnus purshiana*)	Pharmaceutical worker	Asthma
Peach	Factory worker	Asthma
Peach leaf	Fruit grower	Asthma
Pectin	Christmas candy maker	Asthma
Pharmaceutical plants	Healthcare worker	Asthma
Plant proteins	Construction worker Stucco worker	Hypersensitivity pneumonitis
Pollen from flowers and crops	Fruit grower Gardener Greenhouse worker	Asthma, pollen allergy, rhinitis, conjunctivitis
Pyrethrum	Pest control worker	Hypersensitivity pneumonitis
Rice	Rice mill worker	Asthma
Rose	Rose grower	Asthma
Rose oil	Rose extraction worker	Asthma
Rosehip	Pharmaceutical worker	Asthma
Safflower and yarrow	Florist/floral worker	Asthma
Saffron	Saffron processor	Asthma
Sanyak and Korean ginseng	Herbal product merchant	Asthma
Sarsaparilla root	Herbal tea worker	Asthma
Sea lavender	Greenhouse worker	Asthma
Sesame seed	Bakery worker	Asthma
Sinapsis alba pollen, bell pepper pollen	Food processing	Asthma
Soybean	Soybean processing worker	Asthma
Soybean lecithin	Bakery worker	Asthma

Agent	Occupation/exposed group	Disease/health effect
Soybean proteins, *Artemia*, konjac glucomannan, gum arabic	Food processing	Asthma
Soy flour dust	Laboratory worker (animal feed)	Asthma
Spathe flower	Florist/floral worker	Asthma
Spices	Spice processing worker	Asthma
Spinach powder	Food processing Pasta factory worker	Hypersensitivity pneumonitis Asthma
(Spores of white spongy rot), sweet pea (*Lathyrus odoratus*)	Greenhouse worker	Asthma
Statice (*Limonium tataricum*)	Florist/floral worker	Asthma
Sunflower (*Helianthus* spp.) Sunflower (*Helianthus annuus*)	Laboratory worker Processing worker	Asthma
Tampico fibre in agave leaves	Brush maker	Asthma
Tea plant dust (*Camellia sinensis* containing epigallocatechin gallate)	Tea processing worker	Asthma
Tobacco leaf	Tobacco manufacturing worker	Asthma
Umbrella tree (*Schefflera*)	Gardener (landscape)	Asthma
Vegetables, fruit and other food (lettuce, endive, chicory, artichoke, garlic, citrus fruit, mango, carrot, black mustard, cauliflower, capers bush)	Food processing	Contact dermatitis
Vetch (*Vicia sativa*)	Agriculture (farmer)	Asthma
Voacanga Africana seed dust	Chemist's spouse	Asthma
Weeping fig	Plant keeper	Asthma
Wheat, rye and barley flour, amaranth, buckwheat, lupine and soya flour	Food processing	Asthma
White lupin flour (*Lupinus albus*)	Food processing	Asthma

Agent	Occupation/exposed group	Disease/health effect
White mustard (*Sinapis alba*)	Olive farmer	Asthma
White pea flour (*Lathyrus sativus*)	Flour handler	Asthma
Wood dust (abachi, robine, needle wood, sequoia, mahogany, cedar, ramin, pine, cabreuva, red cedar, limba, oak, African zebra wood, spindle tree, pau marfim, cherry, ash, South American timbers, cedro rana)	Woodworker	Asthma
Yuan Zhi (*Polygala tenuifolia*)	Herb manufacturing worker	Asthma
Vegetable gums		
Acacia	Printer	Asthma
Guar	Carpet manufacturing worker	Asthma
Gutta-percha	Dental hygienist	Asthma
Karaya	Hairdresser	Asthma
Tragacanth	Gum importer	Asthma

Table 35: Overview of occupations, biological agents and related allergic diseases for the 'seafood' ([a]) category, by occupation

Occupation	Agent	Disease/health effect
Canning factory worker	Octopus	Asthma
Cook	Cod, salmon, trout, herring	Sensitisation, anaphylaxis
Deep-sea fisherman	Cuttlefish	Asthma
Dietetic product worker	Shark cartilage	Asthma
Fish farm worker	Turbot	Asthma
Fish food factory worker	*Gammarus* shrimp	Asthma
Fish processing worker	Crab, prawn, hoya, cuttlefish, salmon, red soft coral	Asthma
	Fish flour	Hypersensitivity pneumonitis
	Various fish	Asthma

Occupation	Agent	Disease/health effect
Fisherman	Fish, shellfish and crustaceans Red soft coral	Asthma
Fishmonger's shop worker	Lobster and shrimp	Asthma
Food processing worker	Clam and shrimp	Asthma
Jewellery polisher	Cuttlefish bone	Asthma
Laboratory grinder	Marine sponge	Asthma
Prawn processing worker	Hoya (oyster prawn or sea-squirt) Prawn	Asthma
Processing plant worker	Salmon	Asthma
Restaurant worker (seafood handler)	Scallop and shrimp	Asthma
Scallop plant processor	King and queen scallop	Asthma
Seafood production worker	Fish, shellfish and crustaceans	Asthma
	Fish, octopus, shellfish and crustaceans (tropomyosin and parvalbumin)	Asthma, contact dermatitis
	Hoya	Asthma
	Squid (*Loligo vulgaris*)	Asthma
Shellfish processing worker (jewellery, ornaments)	Oyster, snail and clam shell dust	Hypersensitivity pneumonitis
Snow crab processing	Crab	Asthma
Technician	Shrimp meal (*Artemia salina*)	Asthma
Trout processing worker	Trout	Asthma
Worker on factory ships	Alaska pollock and yellowfin sole	Asthma
Restaurant worker	Alaska pollock and yellowfin sole	Asthma

([a]) Lobster, shrimp and crab, for instance, are arthropods, squid are molluscs and hoya is a chordate.

Table 36: Overview of occupations, biological agents and related allergic diseases for the 'seafood' ([a]) category, by agent

Agent	Occupation	Disease/health effect
Alaska pollock and yellowfin sole	Worker on factory ships, restaurant worker	Asthma
Clam and shrimp	Food processing worker	Asthma
Cod, salmon, trout, herring	Cook	Sensitisation, anaphylaxis
Crab	Snow-crab processing	Asthma
Crab, prawn, hoya, cuttlefish, salmon, red soft coral	Fish processing worker	Asthma
Cuttlefish	Deep-sea fisherman	Asthma
Cuttlefish bone	Jewellery polisher	Asthma
Fish, octopus, shellfish and crustaceans (tropomyosin and parvalbumin)	Seafood production worker	Asthma, contact dermatitis
Fish, shellfish and crustaceans	Fisherman Seafood production worker	Asthma
Fish flour	Fish processing worker	Hypersensitivity pneumonitis
Gammarus shrimp	Fish food factory worker	Asthma
Hoya (oyster prawn or sea-squirt)	Prawn processing worker Seafood production worker	Asthma
King and queen scallop	Scallop plant processor	Asthma
Lobster and shrimp	Fishmonger's shop worker	Asthma
Marine sponge	Laboratory grinder	Asthma
Octopus	Canning factory worker	Asthma
Oyster, snail, clam shell dust	Shellfish processing worker (jewellery, ornaments)	Hypersensitivity pneumonitis
Prawn	Prawn processing worker	Asthma
Red soft coral	Fisherman	Asthma
Salmon	Processing plant worker	Asthma

Agent	Occupation	Disease/health effect
Scallop and shrimp	Restaurant worker (seafood handler)	Asthma
Shark cartilage	Dietetic product worker	Asthma
Shrimp meal (*Artemia salina*)	Technician	Asthma
Squid (*Loligo vulgaris*)	Seafood production worker	Asthma
Trout	Trout processing worker	Asthma
Turbot	Fish farm worker	Asthma
Various fish	Fish processing worker	Asthma

([a]) Lobster, shrimp and crab, for instance, are arthropods, squid are molluscs and hoya is a chordate.

4.4 Questionnaire — biological agents and related health effects in the occupational context

Of the 62 respondents, 28 from 17 countries indicated that they were familiar with one or more existing (major) published national reports on exposure to biological agents and/or on work-related diseases due to exposure to biological agents, or with currently ongoing projects that focused on this subject (Question 14). An overview of the individual responses is given in Annex 4, Table A4-9, and certain characteristics of the reports are summarised in Table 37.

Most of the 45 reports focused on a specific agent or disease; for example, the Greek report, by the Hellenic Centre for Disease Control and Prevention, is on the national epidemiological situation with regard to brucellosis, and the report by the Norwegian Institute of Public Health provides guidelines on MRSA. A few countries also mentioned reports on HIV (Portugal, the UK, Denmark) and fungal agents (Finland, Portugal, Norway). The specific topics mentioned were exposure assessment (e.g. a summary assessment of the annual data on occupational diseases and cases of increased exposures, published in a peer-reviewed journal, identified by a Hungarian participant), diagnosis, needlestick injuries and epidemiology. Specific sectors or jobs mentioned were, for example indoor environments, healthcare, wastewater treatment and the pig farming industry. Most reports on exposure to biological agents are publicly available (n = 30 of 45 reports).

Respondents provided a reference and/or link for 34 out of the 45 major national reports identified.

Table 37: Overview of reported (major) national reports or ongoing projects on exposure to biological agents and/or related work-related diseases (Question 14), by type of report/project

Type of report/ project	Type of organisation involved	Publicly available?	Agent/disease	Specific topic/ exposure	Sector/job
Guidelines (3)	National association of occupational hygiene/medicine (1) National institute for occupational/environmental health (2)	Yes (3)	MRSA (1) General (2)	Technical guide for prevention and evaluation of risks (1)	General (1)

Type of report/ project	Type of organisation involved	Publicly available?	Agent/disease	Specific topic/ exposure	Sector/job
List of recognised occupational diseases (1)	National institute for occupational/environmental health (1)	Yes (1)	General (1)		
Publication in journal (1)		Yes (1)	Fungi (1)	Exposure assessment (1)	Indoor environments (1)
Report ([a]) (24)	Centre for occupational diseases (2) Labour inspectorate (2) Ministry (1) National institute/authority on public health (2) National institute for occupational/environmental health (12) Occupational health services (1) Various experts (1)	Yes (20) No (4)	Allergens (1) Bloodborne viruses (1) HIV/AIDS (1) Infectious disease (2) *Legionella* (1) Particles/fungi (1) General (7)	Diagnosis (2) Epidemiology (1) Exposure (2) Needlestick injuries (1) Occupational diseases (3) Prevention (1) Risk assessment (1)	Accidents at laboratory (1) Bakeries (1) Fish processing (1) Healthcare (2) Labour inspectorate (1) Sewer workers (1) Wastewater treatment (1) General (7)
Statistics on website (2)		Yes (2)			
Summary assessment of annual data on occupational diseases and cases of increased exposures (2)	National institute for occupational/environmental health (2)	Yes (2)	Carcinogens (1) Unknown (1)		
Thesis (1)	University (1)	No (1)		Exposure (1)	Veterinarians caring for pets (1)
Unknown (11)	Labour inspectorate (1) National institute for occupational/environmental health (9) Unknown (1)	Yes (6) No (4) Unknown (1)	Antibiotics (1) Bioaerosols/ inflammation (1) Brucellosis (1) Chemical and biological agents (1)	Epidemiology (1) Exposure (2) Unknown (8)	Facilities that clean and recover waste from oil drilling (1) Greenhouse workers (1)

Type of report/ project	Type of organisation involved	Publicly available?	Agent/disease	Specific topic/ exposure	Sector/job
			Fungi, mycotoxins, endotoxins (1) Gastroenteritis (1) MRSA (1) General (1) Unknown (3)		Pig farming (1) Wastewater workers (1) General (1) Unknown (6)
Website (1)	National institute for occupational/environmental health (1)				
Total 45 reports/projects, divided over nine categories					

Note: The numbers in brackets indicate the frequency with which respondents reported the particular categories.

([a]) Various types of reports are collated in this category (annual reports, statistical reports, progress reports, reviews, knowledge dossiers and study reports).

In response to Question 15, ‘Are you aware of reported cases with regard to work-related diseases due to exposure to biological agents?’, 28 of the 62 respondents from 17 countries indicated that they were familiar with one or more cases, and 12 respondents reported 3 or more cases. An overview of the individual responses of the respondents who indicated that they were familiar with one or more cases is given in Annex 4, Table A4-10, of which Table 38 is a slightly modified version (alphabetically ordered by biological agent/disease).

The biological agents or diseases mentioned in the cases varied widely, with only a few being mentioned more than once (e.g. brucellosis, hepatitis C, legionellosis, leptospirosis, measles, MRSA, mycobacteriosis and Q fever). The number of cases per subject per respondent varied considerably. Most respondents mentioned one case, while some described outbreaks concerning ≥ 20 cases (n = 3). It was not always clear how many cases were involved, since some respondents specified a group of cases as one case, while others indicated a number, ‘several’ or ‘epidemic’. Most reported cases or outbreaks were in the healthcare sector (13), followed by agriculture (10), in particular animal farming, and slaughterhouses, as well as other professions that involve contact with animals.

No clear pattern between reported cases of specific agents or diseases in relation to sector or activity was observed. In addition, no regional patterns were observed. For example, legionellosis was reported in both Spain and Sweden (Table 38). Some diseases were reported in one country only (e.g. Ebola in Spain and several cases of ornithosis in Hungary) while others were reported by experts in several countries (e.g. MRSA was reported in Denmark, Norway and Sweden).

Although some respondents gave generic descriptions of the biological agents, stating simply that exposure was to air contaminants (e.g. in Germany) or biological agents (the UK), in most cases the specific biological agent and/or relevant disease was named.

Table 38: Reported cases of work-related disease due to exposure to biological agents (Question 15), organised by biological agent/disease

Biological agent/disease ([a])	Country	Sector	Case report descriptions
Air contaminants	DE	Agriculture, farmers	Air contaminants in various European farming environments
Allergic alveolitis	NO	Wood product processing	Cluster of allergic alveolitis in sawmill workers
Allergic alveolitis/ *Thermoactinomyces*, from mushroom/ mushroom compost dust and fungal spores	IE	No further details	No further details
Biological agents	UK	Metalworking	Exposure to biological agents from contaminated metalworking fluids in an engineering workshop
Brucellosis	PT	Animal care	One case of brucellosis (animal care) in 2015
Brucellosis	ES	Abattoirs (slaughterhouses)	Brucellosis in slaughterhouses
Brucellosis	ES	Animal care	**Case(s):** three outbreaks in 2011 **Infected person(s):** animal care workers **Exposure:** outbreaks of brucellosis are primarily associated with rural areas and livestock. The 2011 outbreak was associated with occupational contact with sick animals **Current status:** its incidence has declined significantly in recent years due to sanitation campaigns
Chrysonilia sitophila/ asthma	FR	Maintenance of coffee machines	Asthma in maintenance staff working on coffee machines and exposed to *Chrysonilia sitophila*
Cotton dust	BG	No further details	No further details
Dermatitis, eczema, allergy	LV	Food industry (processing)	A confectioner working with flour, preparing confectionery by hand **Occupational disease:** skin and tissue disorders, dermatitis, eczema, allergy (2014).
Ebola	ES	Healthcare	Ebola in a healthcare worker
Enteric pathogens (e.g. *E. coli*, *Shigella*)	UK	No further details	Laboratory-acquired infections involving enteric pathogens (e.g. *E. coli*, *Shigella*)
Hepatitis A virus	BG	No further details	No further details

Biological agent/disease ([a])	Country	Sector	Case report descriptions
Hepatitis C virus	EE	Healthcare	Needlestick injury of a nurse in an emergency department and a nurse in a prison environment
Hypersensitivity pneumonitis	DE	No further details	Farmer's lung case after bullectomy
Hypersensitivity pneumonitis	LV	Agriculture, animal breeders	Cattle breeder taking care of cattle; hypersensitivity pneumonitis caused by organic dust (2015)
Hypersensitivity pneumonitis	DE	Waste workers	Hypersensitivity pneumonitis in waste workers
Legionellosis (34)	ES	Healthcare	**Case(s):** outbreak that affected 27 people and killed 7 **Infected person(s):** healthcare workers and patients **Exposure:** infection came from hospital's cooling towers **Comment:** legionellosis is a notifiable disease in Spain, although it is suspected of being under-reported and therefore under-diagnosed. Spain is one of the countries with the most reported cases in Europe
Legionellosis (5)	SE	Paper product manufacturing	**Case(s):** five cases of legionellosis in a coastal county in the middle of Sweden in 2010 **Infected person(s):** two of the five were maintenance workers **Exposure:** the maintenance workers had conducted maintenance work at an industrial biological treatment plant (BTP) at a paper mill, by cleaning one aeration and two sedimentation ponds with a high-pressure washer **Official response:** environmental sampling 2 weeks after confirmed legionellosis diagnosis showed 3.200 000 000 cfu/l of *Legionella pneumophila* SG 1 in the aeration pond **Comment:** this was the third time cases had been associated with a BTP in Sweden
Leptospirosis (43)	HU	Agriculture, field crop growers	**Case(s):** 43 cases in 2014 **Infected person(s):** workers in a maize field **Exposure:** workers in the field were exposed to puddles and soil contaminated with animal urine

Biological agent/disease ([a])	Country	Sector	Case report descriptions
Leptospirosis (voles) (several)	HU	Agriculture, field crop growers	**Case(s)**: an epidemic of leptospirosis was detected in a county **Infected person(s):** workers working barefoot in maize fields **Exposure:** owing to rainfall, the soil was soaked and muddy and the population of common voles was increasing **Official response:** The public health authority investigated and forwarded the cases to the labour inspection but in most cases the employer could not be identified (black labour)did not initiate reporting to the occupational disease system. **Follow-up and current status:** After almost two years, the Only four cases weare still not officially regis-tered as occupational diseases: those who were employed by the local gov-ernment in the public employement scheme. The employment status of the victims is unclear. **Comment:** The case draws attention to the lack of cooperation between public health and labour inspection bodies, which reside in the same local government office. Furthermore, it highlights the legal difficulties arising from seasonal, informal (atypical) employment, and sub-contracting, which are common in agriculture in poor regions.
Measles	ES	Healthcare	Measles outbreaks in the healthcare sector
Measles (> 40)	IT	Healthcare	Measles outbreak in a hospital in southern Sardinia, with more than 40 nosocomial transmissions
Measles (5)	IT	Healthcare	Measles outbreak in five healthcare workers in a hospital in northern Sardinia
MRSA (several)	DK	Agriculture, livestock farmers	**Case(s):** several cases of MRSA infection of workers on pig farms; increase in infected farms since first case identification in 2006
MRSA	DK	Agriculture, farmers	MRSA-positive farmers reporting to hospital
MRSA	NO	Healthcare	**Case(s):** a nurse who worked in intensive care or with premature babies became a carrier of MRSA **Risk factors:** possible causes and risk factors pointed out by the nurse included: - high workload; - many of the children had been treated with

Biological agent/disease ([a])	Country	Sector	Case report descriptions
			antibiotics; - high turnover of staff; - a shortage of nurses; - the premises were cramped, run down and not suitable for the intensive care of children **Official response:** she was withdrawn from the department and worried about her ability to continue working in intensive care and her economic future
MRSA	SE	Healthcare	MRSA in healthcare workers
Mycobacterium bovis infection	UK	Abattoirs (slaughterhouses)	*Mycobacterium bovis* infection of an abattoir worker
Nephritis (22)	FI	Agriculture, farmers	22 cases in 2012
Non-tuberculous mycobacteriosis	FR	House painting	Case of atypical mycobacteriosis in an exposed house painter.
ODTS	DK	No further details	ODTS associated with exposure to high concentrations of bioaerosols as a result of handling grass seeds
ODTS	DK	No further details	ODTS associated with handling fish meal
Ornithosis (several)	HU	Abattoirs (slaughterhouses)	**Case(s):** repeated ornithosis cases over the past few years (thus pre-2016). **Infected person(s):** workers in a large poultry slaughterhouse and processing plant **Official response:** substantial investment in the ventilation system (plus training, provision of PPE) **Follow-up and current status:** despite the control measures described, the disease appeared again (2016). A peculiar pattern: the most recent victims were newly hired white-collar workers. The exposure of white-collar workers is substantially lower than that of those working on the line. Owing to the awareness of general practitioners, cases were identified in time and serious complications were avoided
Pseudopox virus infection	IT	Agriculture, farm workers	Pseudopox virus infection in a cow milker
Q fever	ES	Not clear	Q fever cluster in waste processers (details on the specific waste stream were not given)
Q fever	UK	Abattoirs (slaughterhouses)	Q fever infection in abattoir workers in Scotland

Biological agent/disease ([a])	Country	Sector	Case report descriptions
Q fever (dozens)	HU	Agriculture (sheep breeding), spread to park maintenance staff, drivers and general public	**Case(s):** dozens of Q fever cases. **Infected person(s):** citizens of a small region; cases not only among sheep tenders but also among park maintenance staff in a nearby village and coach drivers who drove through the area **Exposure source:** an infected sheep flock whose manure was not properly treated. Owing to dry weather, the wind dispersed the biological agent **Comment:** the case illustrates the risk that this kind of zoonosis could emerge and spread widely
Respiratory infections	FR	No further details	Occupational respiratory infectious risk in workers already taking inhaled steroids for asthma
Tinea	IE	No further details	Tinea infection
Toxoplasma	IE	No further details	*Toxoplasma*
Tuberculosis	BG	No further details	No further details
Tuberculosis	EE	Healthcare	Tuberculosis infection in a nurse in an emergency department
Tuberculosis	ES	Healthcare	Tuberculosis cases reported among auxiliary nursing staff in healthcare settings
Tuberculosis	PT	Healthcare	Occupational tuberculosis outbreak in health sector workers
Tuberculosis (4)	FI	No further details	Four cases in 2012
Tuberculosis, scabies	LUX	Healthcare	Needlestick injuries, tuberculosis, scabies among nurses
Tularaemia (5)	FI	Agriculture, farmers	Five cases in 2012
Varicella zoster virus	PT	Healthcare	One case of varicella zoster (in a doctor) in 2015

([a]) If more than one case was reported, the number of cases is indicated in brackets.

Questions 16-18 of the questionnaire were intended to gather information to supplement the information that was gathered by means of the scientific literature search. The questions were about the topics within the field of biological agents that the respondents considered important, and specific cases they were familiar with.

In Question 16, respondents were presented with a list comprising 14 areas of work from which to choose those they considered of concern with respect to emerging risks, and a free-text field for any items that were not included in the list.

On the basis of the number of respondents who indicated a particular area (i.e. a workplace sector, industry or occupation) as facing an emerging risk of which awareness should be raised (Question 16), the five top areas of concern were identified. These were waste treatment (including composting) (*n* = 36), the agriculture and healthcare sectors (both *n* = 30), workers travelling to other countries (*n* = 25) and wastewater treatment (including sewage) (*n* = 25). These were followed by biotechnology (*n* = 19), laboratories (*n* = 18) and food processing (*n* = 16). The least selected were the detergent industry (*n* = 3), education (schools) (*n* = 5) and woodworking (*n* = 6). A few additional areas that were mentioned by one or two respondents were famers, the bioindustry, green energy and GMOs (Table 39).

Table 39: Workplace sectors, industries or occupations considered by respondents to be of concern with respect to emerging risks of which more awareness should be generated (Question 16).

Sectors, industries or occupations	Yes	No	No answer
Waste treatment (including composting)	36	17	9
Agriculture	30	23	9
Healthcare (human and veterinary)	30	23	9
Wastewater treatment (including sewage)	25	28	9
Workers travelling to other countries as part of work	25	28	9
Biotechnology	19	34	9
Laboratories (including laboratory animal workers)	18	35	9
Food processing	16	37	9
Childcare/day care	9	44	9
Education (schools)	5	48	9
Metalworkers (metalworking fluids)	7	46	9
Outdoor workers	7	46	9
Wood industry	6	47	9
Detergent industry	3	50	9
Not applicable	4	49	9
Other, namely: ▪ farming ▪ bioindustry ▪ GMOs ▪ green energy ▪ recycling	 2 1 1 1 1		

Sectors, industries or occupations	Yes	No	No answer
▪ points for registration of refugees	1		
▪ sex industry	1		
▪ slaughterhouses	1		

Questions 17 and 18 were open questions. The responses represent the (subjective) opinions of the respondents.

Of the 62 respondents, 32 answered Question 17, which asked respondents to indicate which biological agent (or agents) they considered most important and should therefore be taken into account in specific campaigns on this subject in the (near) future, and why. Three respondents mentioned up to seven biological agents that they considered important. However, some respondents reported the corresponding diseases rather than the biological agents that cause them. As shown in Table 40, the kind of biological agents that the respondents indicated varied significantly; altogether, 40 unique biological agents (or diseases caused by a biological agent) were named. Some of the biological agents (or diseases) were mentioned by several respondents (e.g. *Borrelia*, hepatitis B and MRSA), with high incidence rates and increasing risk or occurrence often stated as the reason the agent required more attention. Less frequently named reasons for increased attention were antibiotic resistance, severity, poor means of control and lack of knowledge regarding the agent. No clear pattern between specific biological agents and reasons for more attention was observed, and the reported biological agents were not usually linked to a specific sector.

Table 40: Overview of biological agents that respondents considered to be most important (Question 17)

Biological agent	Sector/measure	Reason
Actinomycetes (1)		
Agents with antibiotic resistance (3)	Healthcare (1)	Antibiotic resistance (1) Inappropriate use (1)
Agents with dual-use potential (1)		Future potential (1)
Aspergillus (2)	Green waste recycling (1)	Increasing occurrence (1) Poor means of control (1)
Avian influenza/retroviruses (3)		Possible carcinogenicity (1)
Bacterial agents of gastroenteritis (1)		Poor means of control (1)
Bioaerosols (1)		Lack of knowledge (1)
Borrelia (5)		Climate change (2) Increasing risk/occurrence (1) Working outdoors (1)
BRMO ([a]) (1)		Antibiotic resistance (1)

Biological agent	Sector/measure	Reason
Brucella melitensis (1)		Case reports (1)
Chlamydia (1)		High incidence rates (needlestick injuries) (1)
Ebola (2)		
Endotoxins (1)		High incidence rates, underestimation of effect (1)
Fungi (1)		High incidence rates, underestimation of effect (1)
Gram-negative bacteria (1)		Food transmission
Hanta virus (1)		
Hepatitis virus (1)		High risk of complication (1) Increasing occurrence (1) Poor means of control (1)
Hepatitis B virus (6)	Healthcare (1)	Needlestick injuries (2) High number of exposed workers (1) High risk of incidence (1) Poor means of control (1)
Hepatitis C virus (6)		Needlestick injuries (2) High number of exposed workers (1) High risk of incidence (1) No vaccination available (1)
Hepatitis E virus (1)		Lack of knowledge (1)
HIV (2)		Lifestyle issues (1)
Infectious agents (1)		Increasing risk/occurrence (1)
Influenza virus (2)		High burden (1) High incidence rates, antibiotic resistance (1)
Legionella (2)		Lack of knowledge (1) Poor identification (1)

Biological agent	Sector/measure	Reason
Leptospira (1)		Climate change, zoonosis occurrence (1)
Measles (2)		Large outbreaks, high risk of complication (1) Poor means of control (1)
Moulds (2)		Causes asthma (1)
MRSA (6)	Healthcare (1)	Increasing occurrence (3) Increasing/high risk (2) Antibiotic resistance (1) Severity (1)
Nanoparticles (1)		Lack of knowledge (1)
New viruses (1)		Globalisation (1) High incidence rates (1)
Plasmodium malaria (1)		Increasing occurrence (1)
Rubella (1)		Large outbreaks (1)
Staphylococcus aureus (1)		Global threat (1) High incidence rates (1)
Tick-borne encephalitis/diseases (3)		Increasing occurrence (2) Increasing risk (1) Working outdoors (1)
Tropical agents (1)		Globalisation (1) Increasing occurrence (1)
Tuberculosis (*Mycobacterium*) (10)	Animal breeding (1)	Increasing occurrence (4) (Increasing) migration (2) Antibiotic resistance (1) Easily transmissible (1) High incidence rates (1) High risk of complication (1) Higher risk of immune system suppression (1) Poor means of control (1)
Varicella (1)		Large outbreaks (1)

Biological agent	Sector/measure	Reason
Vector-borne diseases (3)		Global threat (1) High incidence rates (1) Severity (1)
Zika virus (1)		Lack of knowledge (1)
Zoonoses (2)		Increasing incidence/ occurrence (1)

Note: The numbers in brackets indicate the frequency with which respondents cited a particular agent, sector or measure, or reason.

([a]) BRMO, Bijzonder resistente micro-organismen, i.e. particularly resistant microorganisms; among these are Enterobacteriaceae (*E. coli* and *Klebsiella*), *Acinetobacter* spp., *Stenotrophomonas maltophili*, *Pseudomonas aeruginosa*, *Enterococcus faecium*, *Streptococcus pneumoniae* and *Staphylococcus aureus*.

Of the 62 respondents, 33 did not answer Question 18 (work-related disease (or diseases) caused by a biological agent considered most im-portant (and therefore for instance to be taken into account in specific campaigns on this subject in the (near) future)); the other 29 respondents mentioned one to three (*n* = 21), four (*n* = 3), five (*n* = 1) or more than five (*n* = 4) work-related diseases that they considered to be most important and that therefore should be taken into account in, for instance, specific campaigns on the subject in the (near) future. However, some respondents named the biological agents that cause the diseases rather than the work-related diseases themselves.

As shown in Table 41, the types of work-related diseases that respondents thought required more attention in the near future were varied. This was also observed with regard to the biological agents that the respondents considered important. Although most of the work-related diseases (or biological agents) were mentioned only once, some of them were mentioned by several respondents, such as hepatitis B, MRSA and tuberculosis. In most cases, the biological agents cited were not linked to a specific sector. In addition, the reasons why more attention was required were more or less the same as those mentioned with regard to important biological agents and included high incidence rates and increasing risk or occurrence. A notable reason given for more attention being required was climate change, but other interesting issues include viruses linked to travelling, allergic diseases and tuberculosis (which seems to be re-emerging).

As respondents did not always seem to distinguish between agent and disease, this may have led to similar answers to Question 17 (important biological agents) and Question 18 (important work-related diseases). It is also very probable that the respondents considered important the diseases caused by the biological agents that they considered important.

Table 41: Overview of work-related diseases/health problems that respondents considered to be most important (Question 18)

Work-related disease/health problem	Agent	Sector/job	Reason for importance
Allergic reaction (1)			Unpredictability in humans (1)

Work-related disease/health problem	Agent	Sector/job	Reason for importance
Alveolitis from metal cutting fluids (1)			Unknown (1)
Antibiotic resistance (2)	Resistant bacteria (2)		Increasing occurrence (1) Resistance (1)
Asthma (4)			High/increasing occurrence (2) Unknown (2)
Avian influenza (1)			Lack of knowledge (1)
BRMO ([a]) (1)			Antibiotic misuse
Cancer (1)	Hardwood dust (1)		Lack of knowledge (1)
COPD (3)			Poor means of control (1) Proven dose-response relationship (1)
Ebola (1)			Need for information (1)
Extrinsic allergic alveolitis (1)	Biological agents in metalworking fluids (1)		
Fungal infections (1)			Severity (1)
Hepatitis (1)			Widespread, severity, not preventable (1)
Hepatitis B (4)		Healthcare (2)	High risk of occurrence (2) Low level of awareness (1) Poor means of control (1) Severity (1)
Hepatitis C (5)		Healthcare (2)	High risk of occurrence (2) Low level of awareness (1) Severity (1)
Hypersensitivity pneumonitis (1)	Antigens of moulds and bacteria (1)		High occurrence rates (1)
Infectious diseases (3)	Blood-borne pathogens (hepatitis B, hepatitis C, HIV) (1)	Healthcare (1)	High/increasing occurrence (3) Severity (1)

Work-related disease/health problem	Agent	Sector/job	Reason for importance
		Immuno-compromised workers (1)	
Influenza (1)			Economic issue (1) Severity (1)
Leptospirosis (1)			Low level of awareness (1)
Livestock-associated MRSA infection	Livestock-associated MRSA		Increasing occurrence (1) Novelty (1)
Lung diseases (1)			High occurrence rates (1) Severity (1)
Lyme disease (1)		Outdoor workers	High risk of occurrence (1)
Measles (1)			Severity (1)
MRSA-induced health effects (3)	MRSA (3)		Increasing occurrence (2) Antibiotic resistance (1)
New virus infection (1)	New virus (1)		
Rubella (1)			Severity (1)
Skin infections (1)			Antibiotic resistance (1)
Tetanus (1)			High risk (1) Poor means of control (1)
Tick-borne encephalitis/diseases (2)		Outdoor workers (1)	High risk of occurrence (1)
Tuberculosis (9)		Healthcare (2)	High/increasing occurrence (6) Antibiotic resistance (1) Low level of awareness (1) Migration (1) Poor means of control (1)
Unknown (1)	Fish, shellfish (1)		
Varicella (1)			Severity (1)

Work-related disease/health problem	Agent	Sector/job	Reason for importance
Vector-borne diseases (2)			Climate change (1) Lack of knowledge (1)
Zika fever/Guillain-Barré syndrome (1)	Zika virus (1)		
Zoonotic diseases (3)	Zoonoses (3)		Economic issue (1) Increasing occurrence (1) Low level of awareness (1)

Note: The numbers in brackets indicate the frequency with which respondents cited a particular disease/problem, agent, sector/job or reason.

BRMO, Bijzonder resistente micro-organismen, i.e. particularly resistant microorganisms; among these are Enterobacteriaceae (*E. coli* and *Klebsiella*), *Acinetobacter* spp., *Stenotrophomonas maltophili*, *Pseudomonas aeruginosa*, *Enterococcus faecium*, *Streptococcus pneumoniae* and *Staphylococcus aureus*.

As can be seen from the information provided in the questionnaire, a lot of the issues raised coincide with those identified in the literature survey. A number of outbreaks were mentioned, which shows that prevention is still not systematically implemented in workplaces, and the experts highlighted the lack of awareness and the lack of systematic prevention. Another issue that was cause for concern is the rapid spread of some diseases beyond workplaces, and the need for a coordinated approach between public health authorities and those responsible for the implementation of OSH legislation in workplaces. The case of a zoonotic epidemic (Q fever) spread through a flock of sheep illustrates very well how animal breeding requirements linked to animal welfare and food safety are intertwined with public health requirements and occupational health. A failure in animal care led to an epidemic that not only reached workplaces but also put the general population at risk.

The experts aimed to raise awareness of the importance of addressing workplaces where exposure to biological agents is prevalent. They also mentioned a few issues in addition to those identified in the literature review, such as the resurgence of tuberculosis, linked, inter alia, to migration of people from outside the EU; the wider spread of vector-borne diseases and leptospirosis, linked to climate change; and the issue of new viruses. The Zika virus was one that has recently caused concern, and which was nonetheless not prominent in the literature search. In addition to these issues, the experts highlighted the resurgence of common childhood diseases, the unpredictability of allergic reactions and the importance of addressing antibiotic resistance. The risks posed by globalisation and changes in travelling patterns were other issues raised by the experts. Finally, GMOs and tetanus were two issues that were not identified in the literature survey either.

4.5 Information on monitoring systems and databases

In this section, the information from the specific searches carried out in relation to monitoring systems and databases are summarised.

Literature review — monitoring systems

For the purpose of this review, the monitoring systems of interest are those that record work-related diseases linked to exposure to biological agents. An ideal monitoring system should:

- record a disease
- record exposure (the cause of the disease)
    a. to (a) biological agent(s)
    b. in an occupational setting
- be able to link the exposure to the disease.

Following the literature search and preliminary screening, 15 articles were retained for full evaluation.

Concise information on the publications selected for full evaluation is given in Annex 5, Part C. Table 42 includes only articles that were found to contain relevant information on monitoring systems.

Table 42: Overview of literature evaluated and considered to contain relevant information on monitoring systems

Reference	Monitoring system(s)	Biological agent(s)	Occupational disease(s)	Limitations/remarks
Cheng et al., 2011a	No monitoring system for occupational disease; monitoring system in question concerns proper hand hygiene	N/A	N/A	N/A
Biradavolu et al., 2015	Monitoring system in question concerns the distribution of condoms and prevention of HIV, not registration of occupational disease	HIV virus	HIV infection, other sexually transmissible infections	The system is experimental, and some of the sex workers recruited into the initiative made human errors in documentation
EU-OSHA, 2014a	Various (national) registers and databases (see p. 14) are mentioned as covering carcinogens in general, presumably including biological agents	Various viruses, bacteria, fungi, bacterial and fungal toxins, particularly in the food industry and waste management	Cancer	Awareness and knowledge of (physical and) biological factors are considered very poor

Reference	Monitoring system(s)	Biological agent(s)	Occupational disease(s)	Limitations/remarks
Flynn and Reid, 2012	An Irish hospital registers occupational blood exposure among healthcare workers and documents the incidence of seroconversion	Blood-borne pathogens	Miscellaneous pathogens, HIV, hepatitis B	Specialised (prophylactic) protocols for blood exposure may not be representative. The human element was identified as a critical limitation. The study was sometimes unable to identify the biological agent owing to patient unavailability, lack of patient ability or lack of/incomplete documentation. The authors speculate about issues of worker error (unexpected exposure due to non-compliance with safety standards, under-reporting, incomplete recall of details due to blood exposure stress)
Gurung et al., 2011	A monitoring system run by Avahan is mentioned, but, as it concerns sexually transmissible infections, the system monitors people, not their exposure	Sexually transmissible infections	Primarily HIV	No information provided on the specifics of the monitoring system. The diseases described in this article would not be considered ‘occupational’ (except possibly those among sex workers)
Kuhar et al., 2013	NaSH (the US National Surveillance System for Health Workers) is mentioned briefly, but only as a source of data	Blood-borne pathogens, body fluids, transferable via needlestick/sharps injury	HIV	N/A
Lewis and Fishwick, 2013	The subject of the article is the detection of respiratory disease in individuals; the	N/A	Respiratory disease	The monitoring system is intended to detect a disease on the basis of an individual’s lung function, rather than to connect the disease to

Reference	Monitoring system(s)	Biological agent(s)	Occupational disease(s)	Limitations/remarks
	causal biological agent is not part of the monitoring system			the biological agent responsible
MacCannell et al., 2010	EPINet (the Exposure Prevention Information Network), NHSC (the US National Healthcare Safety Network), NaSH, the Massachusetts Department of Public Health's: Massachusetts Sharps Injury Surveillance and Prevention Project and the Boston Occupational Health Surveillance Program	Blood-borne pathogens, body fluids, transferable via needlestick/sharps injury	Primarily hepatitis B and C	Participation in the study reported on was voluntary and therefore limited. The article does not discuss monitoring systems in depth
Mehta et al., 2010	An Indian hospital registers possible exposure through needlestick injuries among healthcare workers and documents the incidence of seroconversion	Blood-borne pathogens, body fluids, transferable via needlestick injury	Risks are posed by miscellaneous pathogens, HIV, hepatitis B; owing to 'universally successful' prophylaxis, no occupational disease was found	The monitoring system is on a small scale (covering a single hospital); monitoring is combined with pre- and post-exposure prophylaxis
Sabatini et al., 2013	The monitoring system monitors the emissions in the air, not human health; the researchers observed no occupational disease	Emphasis is mainly on chemical pollutants; biological agents mentioned are primarily bacterial and fungal bioaerosols	N/A	N/A

Reference	Monitoring system(s)	Biological agent(s)	Occupational disease(s)	Limitations/remarks
Serdar et al., 2013	A Croatian hospital registers possible exposure through needlestick and sharps injuries in healthcare workers and documents the incidence of seroconversion	Blood-borne pathogens, body fluids, transferable via needlestick/sharps injury	Primarily HIV, hepatitis B and C	The monitoring system is on a small scale (covering a single hospital); monitoring is combined with pre- and post-exposure prophylaxis

Note: N/A, no information available.

Upon full evaluation of the articles retrieved, some were deemed not relevant due to the absence of a recognisable monitoring system (Lehman et al., 2012; Labrèche et al., 2014; Moscato et al., 2014b; Yacisin et al., 2015). Others described a monitoring system that either did not monitor biological agents or lacked disease data (Cheng et al., 2011a; Gurung et al., 2011; Kuhar et al., 2013; Lewis and Fishwick, 2013; Sabatini et al., 2013; EU-OSHA, 2014a,b; Biradavolu et al., 2015). Among the articles that were identified as (potentially) useful for the purpose of this review, two types could be distinguished: those in which monitoring systems were explicitly explained and/or reviewed, and those in which monitoring systems were merely mentioned.

The former type covered mostly small-scale monitoring systems, usually reporting on a single study or project that was conducted over a certain period of time. Mehta et al. (2010), Serdar et al. (2013) and Flynn and Reid (2012) all describe monitoring systems as registers for documenting the incidence of seroconversion from needlestick injuries among healthcare workers in hospitals, where healthcare workers may be exposed to the (blood-borne) diseases in patients. It should be noted that actual seroconversion in the reported cases did not occur, possibly due to successful prophylaxis. The most obvious limitation is the small scale of the registers; furthermore, they are not publicly accessible, and no national register is available. Because hospital monitoring is to some degree voluntary, such systems may not be structured in the same way and/or may not register the same aspects. Moreover, the articles described the outcome of an evaluation of the data in these registers and not the registers themselves. In addition, because these monitoring systems are not just passive registers of data but have the explicit purpose of reducing disease among healthcare workers, prophylaxis is an inextricable part of the system. While this is beneficial in preventing disease, these hospitals may not be representative of hospitals in general.

Another important limitation is mentioned by Lehman et al. (2012), namely that the data fed into the systems may be incomplete, as a patient can refuse to be examined or to have their data recorded, which means their biological (infection) status remains unknown. In addition, healthcare workers must be able to accurately document their exposure; under-reporting, incomplete recall due to stressful situations and non-compliance with protocol are all referred to in the articles and are noteworthy complications.

The second type of articles merely mentions a monitoring system, possibly as a source of data. Unfortunately, limitations in these systems cannot be identified from the literature retrieved alone without in-depth information on these systems.

In their review on occupational hepatitis, MacCannell et al. (2010) mention several monitoring systems concerning healthcare workers:

- the Exposure Prevention Information Network (EPINet) maintained by the International Healthcare Worker Safety Centre;
- the defunct National Surveillance System for Health Workers (NaSH) and its successor, the National Healthcare Safety Network (NHSC), maintained by the US Centers for Disease Control and Prevention;
- local monitoring systems such as the Massachusetts Sharps Injury Surveillance and Prevention Project (MSISPP) and the Boston Occupational Health Surveillance Program (BOHSP).

The literature retrieved yielded no information about large-scale monitoring systems that met the criteria. Those that did meet the criteria were both small in scale and narrow in scope. This suggests, based on the search performed, that systems with a wider scope may be difficult to establish, most likely because, compared with chemical agents, exposure to biological agents is a relatively difficult and therefore unexplored field of study. However, systems that record diseases caused by biological agents at work may feed into registers of work-related diseases or occupational diseases, and measurement data on biological agents may be included in other measurement databases, for example on chemicals. The search failed to retrieve literature assessing the data in these systems, which may reflect the availability of and access to data as well as missing data. Both options are possible, and, furthermore, the search strategy may have failed to retrieve available data.

Moreover, in relation to the selection criteria for monitoring systems of interest, preference was given to the linking of exposure data to a work-related disease, which would involve two different fields of study or monitoring that are not often combined. Exposure data and disease prevalence seem to be reported together only in small-scale registers in hospitals (Mehta et al., 2010; Flynn and Reid, 2012; Serdar et al., 2013). This may be because, in general, occupational disease registers have no detailed measurement data on exposure levels and substances/agents, and vice versa; exposure monitoring databases have only very general data on health effects (if any), although detailed information on both the exposure and the health effect are necessary to draw the right conclusions with regard to the relationship between the two, and the relationship with the workplace.

Based on the evaluation, some hospital registers that document the incidence of seroconversion following needlestick injuries in healthcare workers were identified, although the articles focused on the data in the registers, and information on the registers as such was not provided. Other monitoring systems also covered healthcare workers (EPINet, NaSH, MSISPP and BOHSP), but no information on the monitoring systems as such was provided. Apart from these healthcare-related registers and monitoring systems, the search did not identify in the public literature any articles describing monitoring systems for biological systems that met the relevant criteria. The data available were insufficient to derive conclusive information on the strengths and weaknesses of the systems and/or specific groups such as vulnerable workers.

Literature review — databases

A literature search was conducted to retrieve from public sources information on existing databases on biological agents and risks to workers. The databases were required to connect biological agents to specific risks to workers or to connect occupational disease to biological agents.

A total of 39 articles were considered of potential relevance after a preliminary screening and retrieved for full evaluation. Three articles were eliminated from the evaluation, as they were not available in a language eligible for this project. That left 35 articles to review.

Concise information on the publications retrieved for full evaluation are given in Annex 5, Part D. Table 43 includes only articles that were found to contain relevant information on existing databases.

Table 43: Overview of literature evaluated and considered to contain relevant information on existing databases

Reference	Database(s)	Biological agent(s)	Occupational disease(s)
Bonneterre et al., 2010	The French rnv3p database	Not specified in the publication, possibly available in the database	All
Camacho-Ortiz et al., 2013	Hospital database, records the type of exposure event (retrospective review of all reported occupational exposures), and in some cases the exposing agent (serological tests are carried out following exposure events)	Various blood-borne pathogens (HIV, hepatitis B virus, hepatitis C virus were mentioned)	Various (hepatitis B, hepatitis C and HIV were mentioned)
Courandier and Pradier, 2010	Health hazard list was mentioned, article did not provide detail	Various	Various
Crewe et al., 2016	SABRE: voluntary registration of occupational asthma in Australia, small scale	Publication mentions various agents that may cause asthma, but this information is not necessarily included in the SABRE database	Asthma
De Moraes et al., 2013	None mentioned; the databases referred to are probably national disease registers	*Bordetella pertussis*	Pertussis
Dulon et al., 2015 (in German)	Data on cases of occupational infectious diseases in healthcare workers were taken from the database of the German Institution for Statutory Accident Insurance and Prevention in the Health and Welfare Services (BGW) (it is assumed that the database contains information on all registered occupational diseases in the healthcare sector that are covered by this insurance association)	N/A	Occupational infectious diseases (code BK 3101), including tuberculosis, hepatitis B and C, and scabies)
Eskandarani et al., 2014	Hospital database	Various blood-borne pathogens	Various
Haamann et al., 2011a and 2011b (in German)	Data on cases of MRSA in healthcare workers were taken from the database of the BGW (it is assumed that the database contains information on all registered occupational diseases in the	MRSA	MRSA

Reference	Database(s)	Biological agent(s)	Occupational disease(s)
	healthcare sector that are covered by this insurance association)		
Honda et al., 2012	Hospital database records occupational health	Influenza	Influenza
Kakar et al., 2010	Clinic databases	Publication does not provide detail	STDs
Myong et al., 2013	KCOMWEL: registers compensation for confirmed occupational diseases	Various biological pathogens, primarily those with which healthcare workers are in contact	Various
Patrician et al., 2011	MilNOD: database of adverse events occurring to nurses	Various	Various
Rajaram et al., 2014	Private data	HIV, STDs	HIV, STDs
Rosenman and Beckett, 2015	AOEC: an online list of substances and agents that sensitise or irritate, related to asthma	Organic material is included in the list; publication does not provide detail	Asthma
Stocks et al., 2016	Various mentioned, none examined closely; main databases mentioned are THOR, rnv3p, Eurostat EODS and SHIELD	Not specified in the publication; an example given is work with laboratory animals	Allergy, asthma
Tang et al., 2013	Clinic database	Various STDs	Various STDs
Walters et al., 2013	SHIELD: voluntary registration of occupational asthma by UK physicians, small scale	Not specified in the publication, possibly available in the database.	Asthma
Walters et al., 2015	SHIELD: voluntary registration of occupational asthma by UK physicians, small scale.	Not specified in the publication; an example given is work with laboratory animals	Asthma
	Clinic databases	STDs	STDs

Reference	Database(s)	Biological agent(s)	Occupational disease(s)
Wang et al., 2014	NHIRD: Taiwan's National Health Insurance Research Database	Not specified in the publication; presumably various	Presumably various
Wu et al., 2010	NHIRD: Taiwan's National Health Insurance Research Database	Not specified in the publication; presumably various	Presumably various
Zhang et al., 2013	NCAIDS: Chinese national HIV/STDs surveillance database	HIV, STDs	HIV, STDs

Note: N/A, no information available; STD, sexually transmissible disease.

Following an in-depth examination of the articles selected for full evaluation, several were discarded as they lacked relevant information on existing databases (Alavian et al., 2010; Lollis et al., 2010; Wariki et al., 2012; Ghonim et al., 2013; Koehoorn et al., 2013; Edison et al., 2014), lacked information on an agent-disease link (Leedom Larson et al., 2010; Te Beest et al., 2010; Cadeddu et al., 2011; Holden et al., 2011; Chai et al., 2013) or did not concern *work-related* diseases (Fähnrich et al., 2015). It should be noted that some of the databases mentioned in the remaining articles were only presumed to include biological agents; confirming this would require access to and exploration of these databases. Of the databases identified in the remaining articles, the rnv3p database, a database attached to a French work-related disease monitoring system, seems to be most relevant, as it includes exposures to 'certain infections and parasitic diseases' (Bonneterre et al., 2010). Unfortunately, the article by Bonneterre et al. (2010) does not mention specific biological agents included in this database. Specific topics such as occupational asthma, blood-borne diseases among healthcare workers and, to a lesser extent, sexually transmissible diseases among sex workers were covered by several articles (see Table 43), but, based on the articles evaluated for this project, no specific databases could be identified. It seems that the datasets in question are not publicly available, and the underlying databases cannot be publicly accessed. The articles focused on evaluations of the data from the databases, and information on the databases as such was not provided, or the database was only mentioned in the text. Unfortunately, this demonstrates a limitation of scientific literature research: publications detailing the governmental surveillance mandatory in Europe are apparently limited in number and scope, rnv3p being the exception, and it appears that the relevant databases are not public.

Broadly, the databases identified by the search strategy applied can be sorted into two groups: large-scale (government) surveillance (e.g. rnv3p), and small-scale databases set up by, for example, specific clinics, hospitals, companies or humanitarian initiatives. However, both groups are under-represented in the scientific literature, possibly because such databases are rarely described in *scientific* journals. Unfortunately, annual reports based on the databases, for instance, were not covered by the literature search performed. Therefore, the literature search provided no, or only limited, information on the databases referred to in the articles.

Questionnaire — monitoring systems

Of the 62 respondents from 26 countries, 48 indicated that they were aware of a national monitoring system (or systems) for work-related diseases or accidents, which (also) covered work-related diseases caused by biological agents (Question 7). An overview of the individual responses that indicated the existence of at least one system is given in Annex 4, Table A4-2. The national monitoring systems mentioned were organised/operated by public health agencies, occupational and environmental health agencies, a social security body or the labour inspectorate (see Table 44). Several of the 81 monitoring systems mentioned a publication (41) or the system could be accessed via a website (52) that contained additional information. In general, information regarding these systems was provided in the language of the relevant country; for around 20 of the monitoring systems mentioned, at least some of the information was available in English. The systems were national systems meant either specifically for the obligatory notification of occupational diseases to the labour inspectorate (e.g. those named by the Cypriot and Estonian respondents) or for mandatory registration of mortality and morbidity due to exposure to biological agents in general (e.g. those mentioned by the Greek and Italian respondents). In the latter case, work-related exposure to biological agents and related diseases were covered incidentally, as these systems did not specifically focus on the work environment. These examples also illustrate the diverse purposes of the systems. However, the purposes most often mentioned were 'for use as an input for policy-making', 'for research purposes' (e.g. Estonia, Spain), 'as a source of information during workplace risk assessments following an incident' (e.g. Cyprus) and to provide input into prevention programmes (e.g. Cyprus, Greece, Spain). Several of the systems mentioned were intended for surveillance, one of was specifically intended to gather information on blood-borne pathogens among healthcare workers. Furthermore, three of the respondents mentioned being aware of a system that focused on a specific work-related disease (i.e. legionellosis, brucellosis or MRSA).

Table 44: Summary of reported national monitoring systems on work-related diseases or accidents, in which work-related diseases caused by biological agents are covered (Question 7), organised by type of system

Type of system	System organised by	Used as input for									
		Prevention programmes	Policy-making	Research	Compensation	Inspection	Enforcement	Surveillance	Diagnostics/cure	Education	Information/warning/ control system
Register of occupational diseases (39)	National institute for occupational/ environmental health (13) Labour inspectorate (6) Centre for occupational diseases (5) Workers' compensation board (4) Social security/insurance association (3) University epidemiology department (3) National environmental authority (1)	21	25	18	7	3	5	5	4	4	4

Type of system	System organised by	Used as input for									
		Prevention programmes	Policy-making	Research	Compensation	Inspection	Enforcement	Surveillance	Diagnostics/cure	Education	Information/warning/ control system
	National institute for public health (1) OSH authority (1) University hospital (1)										
Register of occupational accidents (7)	Social security/insurance association (4) National board for injuries/accidents (1) National environmental authority (1)	1	2		1			1			
Register of infectious diseases (5)	Centre for disease control (2) National institute for public health (1) National institute for occupational/ environmental health (1)	3	2	1		1		1	1		2
Surveillance system ([a]) (5)	National institute for occupational/ environmental health (4) National institute for public health (1)	2	2	3				1			
Information system ([b]) (4)	Centre for occupational diseases (1) Labour inspectorate (1) National institute for Occupational/ environmental health (1)	1	1	2		1					1

Type of system	System organised by	Used as input for									
		Prevention programmes	Policy-making	Research	Compensation	Inspection	Enforcement	Surveillance	Diagnostics/cure	Education	Information/warning/ control system
Focusing on a specific agent (3)	Ministry (1) National institute for public health (1)	1	3								
Labour inspection system (3)	Labour inspectorate (3)	3	2			1					1
Fund for occupational diseases (2)	Compensation fund for Occupational Diseases (2)										
Diagnostic centre for occupational diseases (1)	National institute for occupational/ environmental health (1)								1		
Health insurance system (1)	National institute for occupational/ environmental health (1)	1									
Total: 81 individual systems, over 11 categories		**33**	**37**	**24**	**8**	**6**	**5**	**8**	**6**	**4**	**4**

Note: The numbers in brackets indicate the frequency with which respondents cited a particular type of system or organiser.

([a]) A surveillance study or programme means that some type of monitoring (through visits, questionnaire surveys, measurements, etc) is performed in a sector/industry/group of workers, aiming to collect certain information. A periodic health survey is also a type of surveillance programme.

([b]) A system intended to collect, classify and/or categorise information.

In response to Question 8, concerning awareness of a national monitoring system (or systems) on worker exposure, which covers occupational exposure to biological agents, 30 respondents representing 20 countries indicated that they were familiar with one or more such systems. They were allowed to mention up to three systems. For more information on the methodology, please refer to Section 3.2.1. An overview of the individual responses is given in Annex 4, Table A4-3.

The systems referred to by the respondents from Hungary, Ireland, Slovakia and Poland represent the different types of systems typically indicated by respondents. The Irish respondent described the system recording each ‘notification to the authority where there has been an uncontrolled or accidental release or the escape of any substance or pathogen from any apparatus, equipment, pipework, pipe-line, process plant, storage vessel, tank, in-works conveyance tanker, land-fill site, or exploratory land-drilling site, which, having regard to the nature of the substance or pathogen and the extent and location of the release or escape, might have been liable to cause serious injury to any person’. Similarly, both the Polish and Hungarian respondents described systems that particularly targeted biological agents as part of larger systems for mandatory reporting, with the Hungarian system focusing on employers’ registration of activities involving group 2-4 microorganisms. In some cases, such as in the response from Slovakia, no particular mention was made of biological agents, but reference was made to a ‘Central register of risk works’, which presumably covers biological agents.

Most monitoring systems were organised by a national institute for occupational and/or environmental health (*n* = 19), with the next largest number organised by the labour inspectorate (*n* = 3) (see Table 45). The national board for accident insurance and a national institute for public health were mentioned twice. Furthermore, the following organisational bodies were mentioned once: a centre for occupational disease, a university epidemiology department, the health ministry, the labour ministry, the national authority for health and safety, a national board for injuries and accidents, a statistical institute and a website on occupational disease. For about half of the monitoring systems, a publication was cited, and/or a reference was made to a website containing additional information. In general, information on these systems was provided in the language of the relevant country; for around 15 of the monitoring systems mentioned, at least some of the information was also available in English.

The type of information provided by the systems varied considerably among countries. Most frequently mentioned were registration systems for exposures (*n* = 5) and for surveillance (to study/monitor a specific topic in a specific group) (*n* = 5), followed by information systems (to collect/categorise/classify information) (*n* = 4). However, of the 59 systems named, only 4 were actual systems the sole purpose of which was to collect exposure assessment data. This is not surprising given that collection of exposure data on biological agents is not mandatory under the Biological Agents Directive, although it would provide useful information for the mitigation and control of work-related diseases (see Table 45). As could be observed from the responses to Question 7, the outputs from the monitoring systems were mostly reported as being used for policy-making (*n* = 21), prevention programmes (*n* = 18) and research (*n* = 12), although the responses may be partly a result of suggestive questioning. Furthermore, no obvious relation was observed between the kind of system and how the information generated is used.

Table 45: Summary of reported national monitoring systems on worker exposure that cover occupational exposure to biological agents (Question 8), organised by type of system

Type of system	System organised by	Used as an input for									
		Prevention programmes	Policy-making	Research	Risk assessment	Inspection	Surveillance	Diagnostics/cure	Education	Information/warning/ control system	Unknown
Database on an	National institute for occupational/			1					1		

Type of system	System organised by	Used as an input for									
		Prevention programmes	Policy-making	Research	Risk assessment	Inspection	Surveillance	Diagnostics/cure	Education	Information/warning/ control system	Unknown
occupational health network (1)	environmental health (1)										
Database on biological agents (1)	National institute for accident insurance (1)	1									1
Exposure assessment system (4)	National institute for occupational/ environmental health (2) National board for accident insurance (2)		2	1	1						
Health insurance system (1)	National institute for occupational/ environmental health (1)	1	1								
Information system (4)	National institute for occupational/ environmental health (2) Ministry of labour (1) Website on occupational disease (1)	2	3		3			1		1	
Labour inspection system (3)	Labour inspectorate (3)	1	2	1							1
Notification system (3)	National institute for occupational/	1	1	1							1

Type of system	System organised by	Used as an input for									
		Prevention programmes	Policy-making	Research	Risk assessment	Inspection	Surveillance	Diagnostics/cure	Education	Information/warning/ control system	Unknown
	environmental health (2) Labour inspectorate (1)										
Register of exposure risk (5)	Labour inspectorate (1) National authority on health and safety (1) National environmental authority (1) National institute for occupational/ environmental health (1) National institute for public health (1)	3	2	1		1	1			2	
Register of job categorisa-tions (1)	Ministry of health (1)	1									
Register of occupational accidents/ diseases (3)	National institute for occupational/ environmental health (2) Labour inspectorate (1)	1	2	1		2					
Register of occupational diseases (2)	Centre for occupational disease (1) National institute on occupational/	2	1	1						1	

Type of system	**System organised by**	**Used as an input for**									
		Prevention programmes	**Policy-making**	**Research**	**Risk assessment**	**Inspection**	**Surveillance**	**Diagnostics/cure**	**Education**	**Information/warning/ control system**	**Unknown**
	environmental health (1)										
Research network (1)	University epidemiology department (1)							1			
Surveillance system (5)	National institute for occupational/ environmental health (3) Labour inspectorate (1) National institute for public health (1)	3	3	2		1	1				
Not specified (4)	National institute for occupational/ environmental health (3) Statistical institute (1)	2	4	3							
Total: 59 individual systems, divided over 14 categories		**18**	**21**	**12**	**4**	**4**	**2**	**2**	**1**	**4**	**3**

Note: The numbers in brackets indicate the frequency with which respondents cited a particular type of system or organiser.

Responses to Question 9, which concerned awareness of sentinel/alert systems, revealed that respondents from 26 of the 29 countries were aware of some form of sentinel/alert system in their country. In Annex 4, Table A4-4, an overview of the individual responses that indicated that the respondent was familiar with one or more sentinel or alert system is given. Most of the systems mentioned (*n* = 24) were not specifically for biological agent-related diseases. Among the more pertinent systems mentioned was one of three systems cited by the Spanish respondent — a sentinel clinical observation system on occupational diseases. The other two systems mentioned by the Spanish correspondent were cancERT (a specific register on occupational cancer) and a regional occupational health surveillance system. The Spanish respondent was one of a handful of that listed more than one different system, with most naming just one (usually mandatory) system for reporting or notification of occupational diseases. Systems that were explicitly concerned with biological agents included one named by a Hungarian respondent as the 'Mandatory reporting system of infectious diseases …', Portugal's system SINAVE (Sistema Nacional de Vigilância Epidemiológica (a national surveillance system for obligatory notifiable infectious diseases), Slovakia's national epidemiological system (EPIS) for surveillance of infectious diseases classified according to the International Classification of Diseases (ICD) and Norway's Meldingssystem for Smittsomme Sykdommer (MSIS), the Norwegian surveillance system for communicable diseases. One of the Norwegian respondents also mentioned an emergency response centre for acute/critical threats regarding chemical, biological, radiological, nuclear and explosive (CBRNE) materials. Sentinel or alert systems were most frequently reported as being used as to provide input into prevention programmes, policy-making and research (see Table 46), although this may be partly a result of suggestive questioning. Overall, the variety of purposes for which information generated from the systems is used is wide, and often the responses did not specify exactly how the information was used.

For 24 of the sentinel or alert systems mentioned, 16 respondents provided a reference and/or referred to a website where additional information could be found.

Table 46: Summary of reported sentinel or alert systems in which biological agents and/or work-related diseases due to biological agents are covered (Question 9), organised by type of system

Type of system	System organised by	Agent/ disease	Used as input for							
			Prevention programmes	Policy-making	Research	Surveillance	Diagnostics/cure	Information/warning/control system	Classification of biological agents	Unknown/not further specified
Advisory committee (1)	Institute/ network/ centre for occupational health/ epidemiology (1)	Dangerous pathogens (1)	1	1	1				1	
Clinical watch system (regional) (1)	Institute/ network/ centre for occupational health/ epidemiology (1)		1	1	1					

Type of system	System organised by	Agent/ disease	Used as input for							
			Prevention programmes	Policy-making	Research	Surveillance	Diagnostics/cure	Information/warning/control system	Classification of biological agents	Unknown/not further specified
Database (1)			1							
Emergency response centre (1)	National strategy for chemical, biological, radiological, nuclear, and explosives (1)	CBRNE materials (1)						1		
Epidemiolo-gical system (1)	National institute for public health (1)	Infectious diseases (1)				1				
Evaluation system/ register of occupational diseases (1)	Institute/ network/ centre for occupational health/ epidemiology (1)	Cancer (1)	1	1	1					
Food safety authority system (1)	Food safety authority (1)	Food safety (1)								
Labour inspection system (2)	Labour inspectorate (2)			1						
National contact centre on	Institute/ network/ centre for occupational health/	Infectious disease (2)								

Type of system	System organised by	Agent/ disease	Used as input for							
			Prevention programmes	Policy-making	Research	Surveillance	Diagnostics/cure	Information/warning/control system	Classification of biological agents	Unknown/not further specified
infectious diseases (2)	epidemiology (1) Unknown (1)									
Register of occupational diseases (4)	Institute/ network/ centre for occupational health/ epidemiology (3)	General (4)	3	1	3		1	1		
Reporting system (1)	Institute/ network/ centre for occupational health/ epidemiology (1)	General (1)					1			
Reporting system for occupational accidents/ disease (1)	Institute/ network/ centre for occupational health/ epidemiology (1)	General (1)								1
Sentinel system (3)	Centre for occupational diseases, university (1) Institute/ network/ centre for occupational	Influenza (1) General (1)	2	1	1	1	1			

Type of system	System organised by	Agent/ disease	Used as input for							
			Prevention programmes	Policy-making	Research	Surveillance	Diagnostics/cure	Information/warning/control system	Classification of biological agents	Unknown/not further specified
	health/ epidemiology (1) National institute for public health (1)									
Surveillance system (4)	National institute for public health (3)	Infectious disease (1)	2	1	1	1		1		
Not specified (6)	Institute/ network/ centre for occupational health/ epidemiology (3) National risk observatory (1)		1	2	3	1				
Total: 24 individual systems, divided over 15 categories			**12**	**9**	**11**	**4**	**3**	**3**	**1**	**1**

Note: The numbers in brackets indicate the frequency with which respondents cited a particular type of system, type of organiser or agent/disease.

In considering the responses to Questions 7, 8 and 9, it became clear that respondents had probably found it difficult to distinguish monitoring systems focusing on work-related diseases, those focusing on work-related exposures, and sentinel or alert systems, as several respondents repeatedly named the same system for each of the questions. This may have been due to the similarity in wording of the questions, resulting in respondents missing the subtle differences in what was being asked. However, given that steps were taken to clarify precisely what was meant by each question, for instance by including definitions, and by piloting the questionnaire before disseminating it to participants, this was unexpected. It should be noted, however, that there are countries where the same system serves more than one of these functions, in which case the respondent would have been correct in naming the same system in response to the different questions. Notwithstanding this issue, valuable information on the range of different types of systems across the Member States was gathered.

With respect to Question 10, 39 of the 62 respondents, representing 21 out of 29 countries, indicated that they were familiar with one or more national public health provisions that focus on or cover biological agents in the workplace; they could name a maximum of three. These included health surveillance systems gathering data on individual workers, especially for (groups of) workers who are likely to be exposed to biological agents; guidelines for vulnerable (groups of) workers; and preventive measures such as mandatory or voluntary vaccination programmes for (groups of) workers (e.g. hepatitis B vaccination for laboratory workers or healthcare workers). In Annex 4, Table A4-5, an overview of the individual responses that indicated familiarity with one or more provisions is given.

The types of national public health provisions mentioned varied significantly (see Table 47). Most provisions (*n* = 7) concerned vaccination programmes (e.g. Austria and Bulgaria provide free hepatitis B vaccinations), four out of seven of which were related to the healthcare sector. Public health provisions were mainly mentioned in relation to the healthcare sector when a specific sector was mentioned at all (*n* = 8), for example in the case of Italy's voluntary hepatitis B vaccination programme, Lithuania's guidelines on healthcare-associated infections and Malta's infection control unit, which provides vaccination programmes for hospital healthcare and laboratory workers.

Overall, the variety of uses of the information collected through the national public health provisions is considerable. Generally, information generated by means of public health provision systems seems to be primarily used as input for prevention programs (*n* = 22) and policy-making (*n* = 11), although this may be partly due to suggestive questioning.

For 50 of the reported public health provisions, 25 respondents provided a reference and/or website link.

Table 47: Summary of reported national public health provisions that focus on or cover biological agents in the workplace (Question 10), organised by type of provision

Type of provision	Sector/ specific topic	Specific agent or disease	Used as input for										
			Prevention programmes	Policy-making	Research	Risk assessment	Surveillance	Diagnostics/cure	Information/warning	Records purposes	Inspection	Case evaluation	Unknown
Accident insurance (1)													1
Guidance/ guidelines (51)	Healthcare (2) Vaccination (1)	General (1)	2	1				1					2

Type of provision	Sector/ specific topic	Specific agent or disease	Used as input for										
			Prevention programmes	Policy-making	Research	Risk assessment	Surveillance	Diagnostics/cure	Information/warning	Records purposes	Inspection	Case evaluation	Unknown
Health protection agency (1)				1	1								
Health statistics/ research (1)			1	1	1								
Infection control unit (1)	Healthcare, vaccination (1)		1							1			
Labour inspectorate (6)	General (1) Unknown (5)		2	1				1					
Occupational healthcare (10)	Medical surveillance/examination (5) Vaccination (1)		4	2	2			2			1		
Occupational health research (1)		General (1)											1
Occupational health services (1)									1				
Prevention programme (3)	Committee (1) Healthcare (1)	Hepatitis B (1) General (2)	3										
Registration of infectious diseases (1)	Notification/ registration system (1)	Infections (1)		1									

Type of provision	Sector/ specific topic	Specific agent or disease	Used as input for										
			Prevention programmes	Policy-making	Research	Risk assessment	Surveillance	Diagnostics/cure	Information/warning	Records purposes	Inspection	Case evaluation	Unknown
Regulation (2)	Vaccination (1)	Unknown (2)	1								1		1
Surveillance studies (4)	Medical surveillance system (2)	Needle-stick injuries/ hepatitis B (1)	1	1			1	2					
Vaccination programmes (10)	Vaccination (9) Healthcare (3) Farmers, veterinarians fire workers (1) Vaccination/ immunisation (1)	Hepatitis B (3) Influenza (1)	5	2	1	1						1	
Not specified (7)	Vaccination (1) Maternity protection (1)	Hepatitis B (1) MRSA (1)	2	1									5
Total: 57 provisions, divided over 15 categories			**22**	**11**	**5**	**1**	**1**	**6**	**1**	**1**	**2**	**1**	**10**

Note: The numbers in brackets indicate the frequency with which respondents cited a particular kind of provision, sector or agent/disease.

4.6 Information on Directive 2000/54/EC

Literature review — Directive 2000/54/EC

EU Directive 2000/54/EC aims to minimise the health risks arising from biological agents in the workplace. The provisions of the directive include special measures such as containment categories for laboratory work and industrial processes, and particular attention for healthcare and veterinary care facilities. In addition, the directive provides an indicative list of activities that entail exposure to biological agents. Furthermore, requirements for notification of particular activities to the authorities are laid down. For workers likely to be exposed to certain biological agents, employers have to keep records, including information about exposure and health surveillance. These provisions are minimum requirements and have been implemented through national legislation.

A literature search, following the process described in section 3.1 and Annex 1, Part D, was conducted to retrieve publications concerning Directive 2000/54/EC. The idea was that these would provide an insight into the success of the directive — that is, make it possible to assess the directive's impact on morbidity due to occupational exposure to biological agents since its implementation in 2000. Of secondary interest were possible complications encountered in the directive's implementation, and areas where further improvement may still be possible.

The literature search identified 10 publications considered of potential relevance after the preliminary screening, which were retrieved for full evaluation. Concise information on the publications retrieved for full evaluation is given in Annex 5, Part E. Table 48 presents only publications that were considered to contain relevant information with regard to Directive 2000/54/EC.

Table 48: Overview of literature evaluated and considered to contain relevant information on Directive 2000/54/EC

Author(s)	Title	Context	Relevant information	Remarks
Brewczyńska et al., 2015	'The influence of the workplace-related biological agents on the immune systems of emergency medical personnel'	Review of the effect of biological agents on medical personnel	Directive 2000/54/EC is mentioned mainly in the context of being inflexible	Review concerns itself with a situation in which Directive 2000/54/EC cannot be reliably adhered to. While preventive measures are easy to ensure in a controlled environment such as a laboratory, jobs in which emergencies are expected do not have this opportunity
EU-OSHA, 2009b	*Biological agents and pandemics: Review of the literature and national policies*	Policy review; Directive 2000/54/EC is mentioned only briefly	The directive is potentially difficult to adhere to; risk assessment is considered difficult, and good practices are not always developed	No specific information with regard to the topic
EU-OSHA, 2011a	Legionella *and Legionnaires' disease: A policy overview*	Policy overview concerning *Legionella*-related diseases	Directive 2000/54/EC is said to lack specific instructions regarding *Legionella*	Overview, not review; puts forward no opinion on Directive 2000/54/EC
EU-OSHA, 2011b	'Factsheet 100 — *Legionella* and	Concise factsheet		

Author(s)	Title	Context	Relevant information	Remarks
	legionnaires' disease: European policies and good practices'			
EU-OSHA, 2013a and 2013b	*Green jobs and occupational safety and health: Foresight on new and emerging risks associated with new technologies by 2020* (main report and summary)	Predictive report concerning green jobs and OSH	Owing to the prospective nature of the report, there is no review of the directive or its implications	The article stresses risk assessment associated with green jobs; technically, it implies the insufficiency of the directive, although risk assessment is an obvious course of action to recommend
EU-OSHA, 2013c and 2014	*Priorities for occupational safety and health research in Europe: 2013-2020* (main report and summary)	Report on possible focuses of health research in the coming decade	Directive 2000/54/EC is mentioned in the context of being insufficient protection alone	This article suggests that in-depth study of individual biohazards is required. The implication is that rough classification is insufficient, nothing more specific is said about the directive
Hofmann, 2010	'Biological hazards in working life'	Describes the classification of microbiological agents, the relevance of infectious diseases in working life and different methods of prevention in general in view of the current national and European regulations	The German and Austrian *Biostoffverordnung* are said to be derived from a European directive. No direct mention is made of Directive 2000/54/EC; there is merely a summary of existing knowledge. No statements are made with regard to the current regulations	The article contains a description of the evolution of various biological agents and infectious diseases. There are no reliable data on the epidemiology of occupational infectious diseases in Germany, since the statutory accident insurance system is severely fragmented. In the case of tuberculosis and hepatitis B, a significant number of cases (10-17 %) of these infectious diseases are considered to be occupational. With

Author(s)	Title	Context	Relevant information	Remarks
				regard to control measures, prevention of accidents involving sharp objects and use of PPE are mentioned
Lessmann et al., 2011	‘Classification of skin sensitizing substances: A comparison between approaches used by the DFG-MAK Commission and the European Union legislation’	Comparison of German and European approaches to classifying skin-sensitising substances	No direct mention of Directive 2000/54/EC	Directive 2000/54/EC takes a relatively generalised approach to risk management; substances are broadly classified, and this article raises the point that such classification is not without complications

The primary information retrieved from this selection of literature appears to be the identification of two possible shortcomings in the directive, namely:

- The broad classification of biological agents according to level of risk: reliable classification requires research and subsequently risk assessment for each individual biological agent, research that for some biological agents is simply unavailable. Furthermore, classification into broad categories requires generalisation, and therefore the risk management measures related to those categories are also generalised. Consequently, the directive is considered to be too general for biological agents that require specialised precautions (Lessman et al., 2011; EU-OSHA, 2013c, 2014).
- In certain occupational situations, such as medical emergencies, it is not possible to adhere to the directive (Brewczyńska et al., 2015).

Both points can be summarised as follows: occupational exposures and biological agents are immensely variable, and a generalised directive cannot be expected to cover all possible permutations.

Several articles passed the initial literature screening but, upon closer perusal, did not provide information relevant to Directive 2000/54/EC. Articles that explicitly or even implicitly reviewed the directive were not found. This implies that such articles either do not exist or do exist and were not found by the literature search. For the purpose of verification, a brief additional manual search was conducted. The search seemed to substantiate the unavailability of data pertaining specifically to Directive 2000/54/EC. Three articles were found that were potentially useful concerning the directive (Swords, 2011; Hottes et al., 2012; Bielecka and Mohammadi, 2014). This verification process was conducted only because of the unexpected dearth of data and should be considered non-standard for the purposes of this project.

Bielecka and Mohammadi (2014) published a review on national legislation with regard to biosafety and biosecurity in the wider sense of the term, including issues related to bioterrorism and the use of genetically modified microorganisms. These are generally covered independently in national laws, procedures and on technical and physical measures related to human, plant and animal pathogens. They conclude that risk management is better documented for GMOs than for native pathogens, also indicating that, in processes in which handling biological agents is part of the primary process, the level of control is much higher than when workers have to deal with naturally occurring biological agents. They mention that there is lack of legislative consistency on GMOs and pathogenic agents, indicating a need for worldwide cooperation on more consistent national regulations on biological agents, biosafety and biosecurity.

Hottes et al. (2012) reported on an international workshop that examined issues related to the design, construction, and operation of high-containment biological laboratories, i.e. safety 3 or 4 level labs. Although these laboratories are needed to isolate some highly dangerous pathogens and they play an important role in human and animal disease diagnostics, they are complex systems with inherent risks. Accidental pathogen releases could occur and have serious consequences. Accidents could, for example, include a worker developing a laboratory-acquired infection and then inadvertently exposing the communityg or improper maintenance leading to environmental contamination. Regardless of the accidental or intentional nature of a release, the result can be expensive both in terms of loss of life, economic losses, and erosion of public confidence in those conducting important research for the purpose of protecting humans, animals, and plants from infectious diseases.

In addition, in a review of established European practice in relation to biohazards associated with waste and waste-related biofuels (Swords, 2011), it is stated that, although in general the relevant control measures to prevent exposure are known (and can be related to relatively simple hygiene and housekeeping, such as the avoidance of power-hosing to clean surfaces in order to prevent the formation of aerosols), the implementation of these control measures has to be engineered on a step-by-step basis to reduce exposure pathways (e.g. a change in equipment surfaces may be needed to facilitate alternative cleaning methods). However, the skills necessary for this may not exist within many companies already engaged in the waste sector, and for a gap analysis of their needs they may need to turn to specialists with the necessary experience gained in the process industries. The same is probably true of other sectors as well, and, owing to the wide variety of sectors/industries in which biological agents pose a potential risk to workers, a 'one size fits all' solution is not very likely to be found.

It might be possible to indirectly evaluate the impact of Directive 2000/54/EC by, for example, assessing how occupational morbidity has changed since its implementation, but such an assessment would be largely speculative, as there is no means of determining the directive's specific contribution.

Questionnaire — EU Directive 2000/54/EC

Of the 62 respondents, 43 representing 22 (out of a total of 29) countries indicated that they were familiar with one or more national policies with regard to biological agents that went beyond the minimum regulations in Directive 2000/54/EC (Question 11). Annex 4, Table A4-6, gives an overview of the individual responses.

As shown in Table 49, the kinds of policies mentioned are most generally described and categorised as 'regulation', 'legislation' or 'legislation/regulation' (in total, n = 19); the next most frequently mentioned type are guidance/guidelines (n = 8). For example, of the three policies mentioned by the Austrian respondent, two were guidance documents: one offered guidance on evaluating workplaces with regard to biological agents and the other on waste treatment.

Most policies mentioned by the respondents were aimed at the healthcare sector (n = 14), some of them specifically in relation to needlestick injuries (n = 6). Two policies concerned regulations on disinfection of hands. The Austrian respondent indicated that an decree on disinfection of hands was one of Austria's three key policies, and the only national policy referred to by the Macedonian respondent was on this subject. With regard to the other policies mentioned, no specific topic was indicated.

Several of the policies mentioned focus on a specific biological agent, disease or group of diseases, such as *Legionella*, tuberculosis or spongiform encephalopathies. However, most policies concerned regulations or legislation on biological agents in general.

Table 49: Summary of reported national policies with regard to biological agents (Question 11), organised by type of policy

Type of policy	Biological agent/disease	Aim of policy	Specific topic	Sector
Classification of biological agents (1)	General (1)	Classification (1)		
Code of practice (2)	General (1)		Needlestick injury (1)	Healthcare (1)
Control system (1)				
Decree (5)	General (4)	Classification (1)		
Framework agreement (1)	General (1)		Needlestick injury (1)	Healthcare (1)
Guidance/guidelines (8)	Viruses (2) General (1)	Prevention (1) Prevention/control (1) Vaccination (1)	Needlestick injury (1)	Healthcare (1) Waste treatment (1)
Information (5)	General (2) *Legionella* (1) Unknown (2)			Laboratories (1)
Inspection (2)	General (1)	Inspection/control (2)		
Legislation/regulation (9)	General (3)	Protection, promotion and development of public health/ prevention (1)	Disinfection of hands (1) Technical information (1)	
Publications/technical regulations (1)	General (1)			
Regulation (10)	General (4) *Legionella* (1) Spongiform encephalopathies (1) Viruses (1)	Vaccination (1)	Needlestick injury (1)	Laboratories (1) Medical assessment (1)
Surveillance (1)	Tuberculosis (1)			
Technical regulations (2)	General (2)			

Type of policy	Biological agent/disease	Aim of policy	Specific topic	Sector
Not specified (7)	Hepatitis (1)	Disinfection of workwear (1) Prevention (1)		Healthcare (1)

Total: 55 policies, divided over 14 categories

Note: The numbers in brackets indicate the frequency with which respondents cited a particular kind of policy, agent/disease, aim, topic or sector.

Of the 62 respondents, 22 indicated that they were not aware of national or local campaigns/strategies which a focus on biological agents at work, and 11 respondents did not respond. However, 19 respondents indicated that they were familiar with 1 campaign, 4 respondents that they were familiar with 2 campaigns and 6 respondents that they were familiar with 3 campaigns. Respondents were limited to naming a maximum of 3. The 29 respondents represented 16 (out of a total of 29) countries. Annex 4, Table A4-3, gives an overview of the individual responses of the respondents who indicated that they were familiar with one or more policies.

As shown in Table 50, the types of campaigns mentioned by the respondents could generally be described and categorised as (workplace) inspections (n = 14), unknown (n = 7) or campaigns (n = 6). Unlike the health provisions (Question 10), alert systems (Question 9) and policies (Question 11), the campaigns seem largely to focus on a specific agent or disease, for instance influenza or *Legionella* (as indicated by the Irish respondent), with the latter campaign focusing particularly on the accommodation sector. Where specific sectors or jobs were mentioned, these mainly concerned the healthcare sector (n = 10), with respondents from Hungary and Spain referring to sharps injuries in hospitals and needlestick accidents in healthcare, and the Irish respondent mentioning increased flu vaccination in healthcare workers. Furthermore, the following sectors or workplace settings were mentioned once: abattoirs, education, healthcare, childcare, agriculture, biosafety, laboratories and reception centres. Where specific topics were mentioned, these mainly concerned needlestick injuries (n = 12).

For 28 of the national or local campaigns mentioned, 24 respondents cited a publication and/or referred to a website where additional information could be found.

Table 50: Summary of reported national or local campaigns/strategies that focus on the risks of biological agents at work (Question 12), organised by type of campaign/strategy

Type of campaign/strategy	Agent/disease	Specific topic	Sector/profession
Campaign (6)	Bird flu (1) Lyme disease (1) HIV (1)	Equipment (1) Hand washing (1)	Healthcare (1)
Conference (1)	General (1)		
Control programme (1)	*Mycobacterium bovis* (1)		Abattoirs (1)

Type of campaign/strategy	Agent/disease	Specific topic	Sector/profession
Educational initiative (1)	General (1)		Education (1)
Guidelines (1)	Unknown (1)		Healthcare (1)
Inspection programme (6)	General (2) *Legionella*, general (1)	Needlestick injuries (4)	Healthcare (2) Healthcare, accommodation (1)
Intervention programme (2)	*Legionella* (1) General (1)		Biosafety, laboratories (1)
National strategy (1)	General (1)		
Prevention strategy (2)	Hepatitis B (1) Tuberculosis (1)		Health professionals (1)
Safety briefings for workers (1)	General (1)		General (1)
Seminar/conference (1)	General (3)		
Vaccination (3)	Flu (2) Hepatitis, FSME, tetanus (1)		Healthcare (2)
Workplace inspection (8)	General (2) Infections (1) *Legionella* (1) Sharps (1)	Needlestick/sharp objects (4) Exposure (1) Management (1)	Healthcare (3) Accommodation (1) Waste (including composting) and the cleaning sector (1)
Workplace inspection/prevention (1)	General (1)	Needlestick injuries (1)	Healthcare (1)
Not specified (7)	Ebola (1) HIV (1) Infections (1) Livestock-associated MRSA, MRSA (1) *Legionella* (1) Vector-borne diseases (1)	Needlestick injuries (3)	Healthcare (2) Healthcare, childcare, agriculture (1) Reception centres (1)

Type of campaign/strategy	Agent/disease	Specific topic	Sector/profession
Total: 42 campaigns/strategies, divided over 15 categories			

Note: The numbers in brackets indicate the frequency with which respondents cited a particular type of campaign/strategy, agent/disease, topic or sector/profession.

Of the 62 respondents, 26 indicated that they were familiar with one or more expert networks that pay attention specifically to exposure to biological agents in the workplace and/or work-related diseases due to exposure to biological agents (Question 13); those 26 respondents represent 14 countries (out of a total of 29). Annex 4, Table A4-8, gives an overview of the individual responses of the respondents that indicated to be familiar with one or more expert networks. Of the 26 respondents, 22 cited a publication and/or referred to a website where additional information could be found

As shown in Table 51, the expert networks mentioned by the respondents could generally be described and categorised as organisations of occupational physicians or hygienists (n = 8). This is exemplified by organisations such as the British Occupational Hygiene Society or Denmark's conglomerate of occupational physicians employed at seven different hospital departments across the country but working together as the Scientific Society for Occupational and Environmental Medicine. Other expert groups may also include occupational physicians or hygienists but can be categorised more specifically, for instance as a national association. However, a relatively large number of the expert networks cited could not be categorised because the description of the network was not detailed enough (n = 11).

Most expert groups did not focus on a specific sector and/or agent/disease. However, where a sector focus was mentioned, it was most frequently the healthcare sector (n = 8), and one group focused specifically on MRSA in pig farms.

Table 51: Summary of reported expert networks that pay attention specifically to exposure to biological agents in the workplace and/or work-related diseases due to exposure to biological agents (Question 13), organised by the type of organisation/structure of the expert network

Type of organisation/structure	Specific topic/aim	Agent/disease	Sector
Committee (1)			Healthcare (1)
Committee of experts from different organisations (2)	Advising the Federal Ministry of Labour and Social Affairs regarding occupational safety in operations with biological agents (2)	General (2)	
Collaboration between institutes (2)	MRSA (1)	MRSA (1)	Pig farms (1)
Inspectorate (2)	Workplace inspection (2)		
Knowledge network (website) (1)	Work-related infectious diseases (1)		

Type of organisation/structure	Specific topic/aim	Agent/disease	Sector
National association for occupational medicine/hygiene (3)		General (1)	
Network of biosafety officers; network of occupational hygienists between hospitals; national association for occupational medicine/hygiene (1)	Spreading/sharing information (1)	General (1)	Healthcare (1)
Network of experts with various areas of expertise within a (national) institute (2)	The insurance system (2)		
Network of occupational physicians/hygienists (8)	Spreading/sharing information (4) Registration of occupational diseases (1)	Work-related infectious diseases (2) General (2)	Healthcare, childcare, agriculture (1) Healthcare, public health, epidemiology, clinical toxicology (1) Healthcare (1)
Network within a ministry (2)	Workers' health surveillance (1)	General (1)	
Network within/created by a (national) institute (6)	Epidemiology (1) Prevention of exposure, risk assessment (1) Risk prevention (1)	General (2)	Epidemiology in general (2)
Occupational physicians operating in several hospitals (1)			Healthcare (1)
Tripartite committee (1)	Occupational diseases (1)		
Not specified (11)	MRSA (1) Needlestick injury prevention; development of standards (1) Prevention (1) Spreading/sharing information (1) The insurance system (1)	General (4) MRSA (1) Needlestick injuries/sharp objects (1) Tuberculosis (1)	Healthcare (2)

Type of organisation/structure	Specific topic/aim	Agent/disease	Sector
Total: 43 expert networks, divided among 14 categories			

Note: The numbers in brackets indicate the frequency with which respondents cited a particular type of organisation/structure, topic/aim, agent/disease or sector.

5 Exploring and comparing monitoring systems

This chapter presents selected monitoring systems for occupational diseases and occupational exposures operating in the Netherlands, the UK, Germany, France, Denmark and Finland. Each system is described, and examples of their outputs and an overview of their benefits and limitations given. The systems were selected from those mentioned in response to the questionnaire and with the help of the research consortium.

5.1 Registration of occupational diseases in the Netherlands

Description of the system

As prescribed in the Working Conditions Act (Arbeidsomstandighedenwet, Section 9, paragraph 3) and the Working Conditions Regulation (Arbeidsomstandighedenregeling, Section 1.11, paragraph 2), occupational physicians (company doctors) or certified health and safety service providers (*Arbodiensten*) are obliged to notify occupational diseases to the Dutch Centre for Occupational Diseases (Nederlands Centrum voor Beroepsziekten, NCvB). This obligation in principle covers all occupational diseases and all sectors. An occupational disease is defined in this context as a disease or condition resulting from an exposure that has occurred predominantly in an occupational situation. Suspicion of occupational diseases can also be notified. This notification duty also covers the aggravation of existing diseases and diseases that manifested themselves during a previous job or in previous employment. For other physicians, such as general practitioners, registration of occupational diseases is voluntary.

Registration of occupational accidents is not part of this system. Registration of occupational diseases is not linked to compensation of workers, since in the Netherlands no distinction is made between occupational diseases and occupational accidents (*risque professionel*) and conditions that are not work-related (*risque social*) (for more detail, see Section 5.1.3).

The NCvB registers and reports on occupational diseases via the national notification and registration system (based on reports from occupational physicians) and three specific surveillance projects that register reports of occupational skin diseases by dermatologists (the ADS project), occupational lung diseases by lung specialists (the PAL project) and cases of chronic toxic encephalopathy by the two solvent teams operating in the Netherlands (in Amsterdam and Enschede).

The main purpose of registration is to improve knowledge of and insight into the occurrence and prevention of occupational diseases. Although the employer is not obliged to notify occupational diseases, the employer has a duty to keep a register of occupational diseases as part of risk identification and evaluation (RI&E) ([12]) and must map, document, estimate and address all risks in the areas of safety, health and welfare (for more detail, see Section 5.1.3).

Notification of occupational diseases by physicians

For occupational physicians who suspect an occupational disease, the NCvB provides a step-by-step plan (called 'the six-step plan') to systematically investigate a number of important aspects, in order to determine whether the disease is actually an occupational disease, that is, a clinically observable disease or disorder due to an exposure that predominantly (> 50 %) occurred at work or under working conditions:

Step 1: determination of disorder/disease;

Step 2: determination of relation with work;

([12]) According to the Dutch Occupational Health and Safety Act, companies based in the Netherlands are required to perform RI&E, also known as hazard identification and risk assessment (HIRA). Through RI&E, all risks in the areas of safety, health and welfare are mapped and documented, after which they are evaluated to estimate the level of risk and prioritise the risks. After this, an action plan is formulated to address these risks (who does what and when).

Step 3: determination of nature and level of causal exposure;

Step 4: check of other possible explanations and the role of individual susceptibility;

Step 5: drawing of conclusions and registration;

Step 6: preventive measures and implementation and evaluation of interventions (following the Biological Occupational Hygiene (BAH) principle (an occupational hygiene strategy that is tailored to the characteristics of biological agents)).

The notification of an occupational disease should contain at least the following information, presented in such a way that the identity of the individual concerned cannot be deduced:

1. diagnosis;
2. worker's gender and year of birth;
3. nature and extent of stress(or) at work/as part of working conditions;
4. nature of work when occupational disease manifested/emerged;
5. worker's profession at time of exposure
6. worker's economic activity at time of exposure.

As mentioned above, the registration system in principle covers all occupational diseases that fit the description, all possible exposures and all industries; no exceptions are made. In addition to the registration of specific information based on predefined categories, as described below, the registrant is asked to include a more detailed description in free-text fields.

From the national registration system, for which an online standardised registration form as well as instructions and help with regard to the electronic notification system (including tables outlining all the categories for the different parameters) are available, it is possible to gather information on:

- health and safety service provider;
- year of birth;
- gender;
- diagnosis/clinical description based on a coding system with fixed categories (Classification for Health and Safety and Social Insurance (Classificatie voor Arbo en Sociale verzekering, CAS) codes), and a detailed description of the disorder/disease;
- cause/exposure, based on a coding system with fixed categories of work-related factors taken from a European list, and a detailed description of the cause/exposure, with the possibility of identifying the main cause/exposure and one or two other causes/exposures, the categories for biological agents being the following (since 1 January 2016):
    - bacteria — *Leptospira*
    - bacteria — *Mycobacterium*
    - bacteria — *Rickettsia*
    - bacteria — *Salmonella*
    - bacteria — *Staphylococcus aureus*
    - bacteria — *Streptococcus*
    - bacteria — other
    - fungi — *Aspergillus fumigatus*
    - fungi — *Candida albicans*
    - fungi — *Trichophyton*
    - fungi — other
    - parasites
    - viruses — hepatitis A virus — picornaviruses
    - viruses — hepatitis B virus
    - viruses — hepatitis C virus
    - viruses — hepatitis E virus
    - viruses — hepatitis virus (other)

  - o viruses — HIV
  - o viruses — other
  - o plants/vegetable-based products
  - o animals — insects
  - o animals — mites
  - o animals — ticks/harvest mites (*Ixodes*)
  - o animals — birds
  - o animals — mammals
  - o animals — other
  - o other biological agents;
- occupation/job based on a coding system (the International Standard Classification of Occupations (ISCO), ISCO-08), and a detailed description of the occupation/job;
- economic sector/industry based on a coding system (the Standard Business Indicator (SBI) codes of the Central Bureau of Statistics), and a detailed description of the company;
- seriousness of the disorder/disease;
- if the worker's personal characteristics or pre-existing conditions have predominantly contributed to the manifestation of this disease/disorder (yes/no);
- means of tracking the occupational disease (from a list of set answers);
- what advice has been given (to the employer and/or the worker) and/or which control measures have been implemented (maximum four answers);
- who has been informed of the occupational disease (maximum four answers).

For each of the six steps, guidance is available to lead the occupational physician through the determination process. Furthermore, the NCvB has a helpdesk that can be contacted, and one of the NCvB team members specialises in biological agents and related diseases.

Occupational diseases are (mostly) notified by occupational physicians in accordance with the NCvB guidelines, which describe the clinical picture and the minimum exposure criteria. The NCvB produces registration guidelines and information notices. These registration guidelines are developed by the NCvB on the basis of international scientific literature about occupational diseases (described in a background document) and are considered to be the leading information sources with regard to the registration process. The EU information notices offer additional information on registration with regard to exposure to chemical and physical factors (European Commission, 2009). With regard to biological agents, the following guidelines and information notices are applicable:

A) <u>Registration guidelines/directives</u>

In relation to risk factors for occupational diseases caused by chemical agents:

- toxic inhalation fever.

In relation to occupational diseases due to biological agents:

- zoonoses (outdated);
- tuberculosis (outdated);
- hepatitis A, B, C, and E.

In relation to skin diseases:

- occupational contact dermatoses.

In relation to conditions of the lungs and airways:

- work-related asthma;
- toxic effects on the airways;
- work-related rhinitis;
- toxic inhalation fever.

B) Information notices

In relation to occupational diseases due to biological agents:

- infectious or parasitic diseases transmitted to humans by animals or remains of animals;
- tetanus;
- brucellosis;
- viral hepatitis;
- tuberculosis;
- amoebiasis;
- other infectious diseases caused by work in disease prevention, healthcare, domiciliary assistance and other comparable activities for which a risk of infection has been proven.

In relation to conditions of the lungs and airways:

- extrinsic allergic alveolitis;
- lung diseases caused by the inhalation of dusts and fibres from cotton, flax, hemp, jute, sisal and bagasse;
- respiratory ailments caused by the inhalation of dust from cobalt, tin, barium and graphite;
- allergic asthma caused by the inhalation of substances consistently recognised as causing allergies and inherent to the type of work;
- allergic rhinitis caused by the inhalation of substances consistently recognised as causing allergies and inherent to the type of work.

SIGNAAL

When an occupational physician suspects a new combination of health effect(s), exposure and work situation, for which the relationship is not (yet) well established, the case can be submitted to a panel of Dutch and Belgian occupational disease specialists from the NCvB, the Catholic University of Leuven and IDEWE (an external service for prevention and control in the workplace) via an online system called SIGNAAL (Signalering Nieuwe Arbeidsgerelateerde Aandoeningen Loket; www.signaal.info); the panel will then assist in determining whether the case is indeed a new occupational disease. SIGNAAL is a pilot project initiated by the Dutch Ministry of Social Affairs and Employment. In principle, this system covers all economic sectors and all workers (no exceptions), and as is the case with regard to the registration of occupational diseases, SIGNAAL is not linked to worker compensation. The resulting information is shared with a broader audience through newsletters and scientific publications. Of the 17 cases that were reported on the website from July 2013 (when the system was put in place) to April 2017, at least 4 related to biological agents:

- endotoxin fever after spray-cleaning a contaminated waste pipe (not new but not yet described for this work situation);
- repeated airway infections when frequently passing through time zones when flying (not completely new but not yet reported);
- immune-mediated pathology in a sewage treatment station after accidental bacterial excess mortality (not new but relatively unknown);
- extrinsic allergic alveolitis among workers in a metalworking company (metalworking fluids) (not new but not reported before in the Netherlands).

OSIRIS

According to the Public Health Act (Wet Publieke Gezondheid), in addition to the national registration of occupational diseases, all regional health authorities (Gemeentelijke Geneeskundige Dienst), doctors and microbiological laboratories are obliged to register certain infectious diseases with the National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu, RIVM) by means of the national registration system, OSIRIS (https://osiris.rivm.nl/sniv/).

Examples of reports from the system

Every year, key figures concerning registration are published (in Dutch) by the NCvB by order of the Ministry of Social Affairs and Employment (http://www.beroepsziekten.nl/kerncijfers). These reports give an overview of the number and nature of registered occupational diseases, and their distribution over sectors and occupations in the Netherlands. They also present some information on scientific and social developments with regard to occupational diseases. In addition to these reports, overview tables of reported occupational diseases per diagnosis group, occupation/industry and cause group are presented annually on the website (www.beroepsziekten.nl/statistiek-introductie/ncvb-statistiek-nationale-registratie-beroepsziekten). These reports on key figures are meant for organisations that operate in the field of policy on the prevention of occupational diseases, such as the government, employers' and workers' organisations, health and safety service providers, and healthcare providers and (para)medical professionals operating in the field of OSH. However, in what way this information is actually used to target preventive measures, for instance by the Ministry or health and safety services, has not been systematically evaluated. The information generated by the NCvB can be used as input into enterprises' RI&E and to analyse sickness absence to determine which negative health effects caused by work can be prevented.

Apart from the reports on key figures described above, which are promoted by means of newsletters, the NCvB reports on an annual basis to:

- health and safety services, for example on the top 10 reported occupational diseases over the past year, the number of occupational diseases reported by each health and safety service, and the occupational physicians within the health and safety services that have reported occupational diseases;
- independent occupational physicians;
- Eurostat.

In addition to the provisions of these reports, the database is also publicly accessible (https://ncvb.amc.nl/NCVB-MenR/dyn/draaitabellen/selecteerArgumenten). Statistics for several parameters (e.g. diagnosis, cause, economic sectors and occupations) can be generated for periods from 1997 onwards. However, these statistics are generally presented at the level of larger categories (e.g. the categories bacteria/viruses/parasites/fungi as a cause), and thus little detail is given. Furthermore, statistics can be generated for only one or two parameters at the same time, and the output is for a maximum of five consecutive years.

Table 52 provides an overview of the occupational diseases reported over the period 2011-2015 with biological agents indicated as the cause of the disease (based on output from the public database). In Annex 6, Table A6-1, a further distinction is made with regard to the diagnosis of the occupational diseases. Although occupational diseases due to exposure to biological agents account for only a relatively small percentage of all reported occupational diseases, they are reported, and, like the overall number of reported occupational diseases, their number is steadily increasing over time. In general, occupational diseases due to bacteria and parasites are most frequently reported. As shown in Annex 6, Table A6-1, for some of the diagnosed occupational diseases, biological agents are indicated as the major cause of the disease (e.g. zoonoses, infectious diseases and hypersensitivity pneumonitis), while for other diseases — for instance occupational asthma, asthma aggravated by work and contact dermatitis — half or less of the reported cases are related to biological agents.

Table 52: Overview of occupational diseases reported over the period 2011-2015 in the Netherlands for which biological agents were indicated as the cause of the disease

Year	2011		2012		2013		2014		2015	
Cause	Number of diseases	% of total	Number of diseases	% of total	Number of diseases	% of total	Number of diseases	% of total	Number of diseases	% of total
All diseases	6,989	100 %	6,451	100 %	6,391	100 %	8,513	100 %	8,073	100 %
Bacteria	33	< 1 %	46	1 %	38	1 %	54	1 %	66	1 %
Viruses	29	< 1 %	10	< 1 %	14	< 1 %	18	< 1 %	17	< 1 %
Parasites	45	1 %	8	< 1 %	13	< 1 %	11	< 1 %	45	1 %
Fungi	4	< 1 %	7	< 1 %	7	< 1 %	11	< 1 %	8	< 1 %
Plants/ vegetable-based products (e.g. flour, wood dust)	22	< 1 %	14	< 1 %	34	1 %	33	< 1 %	12	< 1 %
Animals	6	< 1 %	3	< 1 %	9	< 1 %	10	< 1 %	5	< 1 %
Other biological agents	7	< 1 %	4	< 1 %	5	< 1 %	16	< 1 %	11	< 1 %

Source: output from public database (https://ncvb.amc.nl/NCVB-MenR/dyn/draaitabellen/selecteerArgumenten) generated on 7 June 2016).

Based on the information available from the yearly reports and the online database, various types of overviews of outputs relevant to biological agents can be generated from the system, from either an exposure/agent or a disease perspective. These are presented in Table 52-Table 54. In the NCvB's latest official report (van der Molen et al., 2015), one of the relevant sections is a summary of reported occupational diseases due to biological agents, as presented in Table 53, along with figures from the NCvB's annual statistical reports for 2010-2014. The main focus is on occupational infectious diseases, and thus the table does not cover all types of occupational diseases that can be related to exposure to biological agents. In 2014, 115 occupational infectious diseases were reported, which was a 37 % increase on 2013. In 2014, the occupational sectors with the highest numbers of reports of occupational infectious diseases were curative healthcare (24 %), aviation/air transport (14 %) and the construction industry (11 %). Skin conditions were reported most frequently (of which almost half were caused by a fungal infection), followed by airway symptoms and Lyme disease. In 2015, a further increase in the number of reported diseases due to biological agents was observed.

Table 53: Reports of occupational diseases due to biological agents over the period 2010-2015 in the Netherlands (by total number over 2010-2015)

Condition	2010	2011	2012	2013	2014	2015 ([a])	2010-2015
Skin conditions ([b])	12	47	6	14	25	47	**151**
Airway	3	4	4	13	18	41	**83**
Intestinal	20	21	2	5	9	13	**70**
Lyme disease	6	12	13	15	16	0	**62**
Tuberculosis ([f])	18	13	12	9	8	1	**61**
Zoonoses ([h])	15	1	2	2	3	31	**54**
Travel-related	0	4	11	5	9	0	**29**
Other infections						16	**16**
Malaria	4	4	3	2	7	0	**20**
RVP ([g])	0	3	0	3	4	0	**10**
Q fever	4	1	2	2	0	0	**9**
Legionellosis	0	1	3	0	2	0	**6**
Hepatitis B	1	1	0	0	0	0	**2**
Hepatitis C	0	0	0	0	1	0	**1**
Hepatitis E	1	0	0	0	0	0	**1**
Parvovirus	0	1	0	1	0	0	**2**
HIV	0	0	0	0	0	0	**0**
Other ([i])	5	28	15	13	12	4	**77**
Total	**89**	**141**	**73**	**84**	**115**	**153**	**654**

([a]) Not based on formal report; based on yearly statistical overview (and therefore the categorisation of conditions may be different from that used in previous reports).
([b]) Various skin conditions, such as fungal infections, inflammation, allergies or irritated skin condition due to biological agents, parasite, scabies.
([c]) Various airway symptoms, such as asthma (allergic, fungi-related), influenza A, pneumonia, allergic rhinitis, chronic bronchitis, others (infections, allergies).
([d]) Various gastrointestinal infections, such as those caused by norovirus, *Campylobacter* and *Salmonella*.
([e]) Travel-related conditions: shigella, dengue fever, chikungunya, giardiasis, parasite infection, rickettsioses.
([f]) Latent and active tuberculosis.
([g]) Pertussis and measles.
([h]) Zoonoses such as leptospirosis, other.
([i]) Various: MRSA, ‘general’ infection, coxsackie virus, foot-and-mouth disease.

Sources: van der Molen et al. (2015) and the annual statistical report for 2015 (http://www.beroepsziekten.nl/datafiles/statistics/ncvb-statistics/NCvB-Statistiek-2015.pdf).

Another relevant category of reported occupational diseases presented by van der Molen et al. (2015) are conditions of the lungs and airways. Table 54 presents an overview of all reported lung and airway conditions over the period 2010-2014; these also show a more or less steady increase over the years.

Table 54: Overview of reported lung and airway conditions over the period 2010-2014 in the Netherlands (alphabetically)

Condition	2010	2011	2012	2013	2014
(Occupational) asthma	22	47	21	41	78
Cancer (e.g. lung cancer, throat cancer, nasal cancer)	2	3	3	3	1
Chronic airway obstruction	13	18	7	14	30
Dust lungs	11	5	12	6	13
Extrinsic allergic alveolitis	1	5	2	2	1
Mesothelioma	5	7	5	5	9
Symptoms of the upper airways	15	31	27	23	35
Toxic inhalation fever/alveolitis	0	0	2	3	0
Tuberculosis	18	13	12	9	8
Other lung and airway infections	9	7	5	19	16
Other symptoms of the lungs and airways	20	9	11	13	11
Total	**116**	**145**	**107**	**138**	**202**

Source: van der Molen et al. (2015).

Not all of these lung and airway conditions are caused by biological agents: in general for around 30 % of these reported cases biological agents were indicated as the cause of the condition, with plants/vegetable-based products and bacteria most frequently reported as causes (Table 55).

Table 55: Overview of reported occupational lung and airway conditions with biological agents indicated as the main cause in the Netherlands 2012-2014

Cause	2012	2013	2014
Biological agents	**34 (31.8 %)**	**52 (37.7 %)**	**58 (28.7 %)**
Bacteria	16	16	15
Fungi	5	4	5
Viruses	1	0	3
Other biological agents	0	2	7
Animals	**1**	**5**	**6**

Cause	2012	2013	2014
Plants/vegetable-based products (e.g. flour, wood dust)	**11**	**25**	**22**

Source: van der Molen et al. (2015).

Based on the outputs for 2011-2015 from the publicly accessible database, the highest number of registered occupational diseases related to exposure to biological agents occurred in the ‘caregivers’ occupational category (see Annex 6, Table A6-2). These were mainly cases of contact dermatitis (which may not all have been caused by biological agents), intestinal infection and other infectious diseases. However, the numbers of registered occupational diseases due to biological agents as a percentage of the total numbers of registered occupational diseases were highest among trained foresters, fishermen and hunters (51.4 %), farmers, cattle breeders, fishermen, and other hunters and gatherers (32.1 %), food processing workers (28.1 %), trained farmers (18.1 %) and soldiers in the army (17.3 %); one conclusion that can be drawn is that such diseases occur relatively often in agriculture but that training may play a role in prevention. Furthermore, no clear pattern in the diseases in the different occupations could be observed. Although the proportions of registered occupational diseases due to biological agents seemed to be a little higher in the age categories below 21 years and 21-30 years, the absolute numbers of registered occupational diseases were low in these categories (see Annex 6, Table A6-3). Further to this, no clear pattern could be observed with regard to the prevalence of the different types of occupational diseases in the different age categories. With regard to gender, too, no pattern could be observed in the prevalence of the different occupational diseases (see Annex 6, Table A6-4).

OSIRIS

In this RIVM registration system (see Section 5.1.1), a standard question is if a relation to work is considered likely. In 2014, 218 reports of infectious diseases with a possible relation to work were recorded, with pertussis (87), legionellosis (46) and malaria (24) reported the most frequently. Furthermore, an increase in the number of cases of leptospirosis was observed, similar to that observed in the registration of occupational diseases.

Limitations and benefits of the system

The system for reporting occupational diseases in general, including occupational diseases due to exposure to biological agents and the online form for submitting a report, allows for a standardised way of collecting information, and makes it possible to present clear statistics on the basis of the reports and to compare the information entered into the system. Because it is possible to enter more detailed information in addition to the categorisation by means of coding systems, a broader information base can be generated. This additional information can also be used to evaluate and update the system if necessary.

The NCvB presents statistics on reported occupational diseases, including those related to exposure to biological agents, on a yearly basis and makes a comparison with preceding years. Furthermore, the figures are broken down by economic sector and occupation. In addition to these reports, the database is publicly available, and, although these are available at a fairly general level (in relation to main categories of diseases and causes, for instance), statistics concerning diseases, causes, economic sectors, occupations, etc., can be generated for periods from 1997 onwards. This database is a valuable source of information for occupational physicians, occupational hygienists, employers, workers, etc.

Focus on occupational accidents

In general, in the Netherlands, the focus has been more on occupational accidents (with a clear relation between cause and effect directly after the incident in most cases) than on occupational diseases (where the relation between cause and effect is often less clear, and the effect often occurs after a longer period). Unlike in the case of occupational accidents, the government does not investigate serious incidents of occupational disease. The same is true generally at company level regarding investigations into occupational accidents and diseases.

There has been no distinction between occupational and non-occupational causes for a long time

Furthermore, in contrast to other European countries, since 1967, no distinction has been made in the Netherlands between occupational diseases and occupational accidents (*risque professionel*) and conditions that are not work-related (*risque social*). With the abolishment of the *risque professionel*, the risks and financial consequences have been divided between several stakeholders, instead of being primarily the responsibility of the company employing the affected worker. With this change, financial incentives to improve prevention at the company level largely disappeared, and interest in preventing occupational diseases also diminished. Owing to a lack of shared ownership, most of the negative consequences of the work environment fall on the workers. For example, disease that becomes apparent in a worker after retirement does not have direct financial consequences for their former employer. The (financial) motivation for companies/employers to investigate cases of disease or to investigate the relation of a disease to work is limited, as the proof or disproof of this relation does not have direct consequences. As an investigation into the cause of a disease or its relation to work is not covered by insurance systems (e.g. general health insurance), and in many cases this means that the worker would have to pay for it him or herself, this type of investigation is rarely carried out.

Under-recognition of occupational diseases is an issue

The guidance on reporting occupational diseases, as provided by the NCvB, is quite comprehensive, and helps occupational physicians assess the situation in a structured way. Some cases have been described as worked examples, following the whole registration process (including one relating to biological agents, namely a case of an infectious disease). However, although in general the registration system is considered sophisticated, the general level of registration of occupational diseases is known to be quite low in the Netherlands; in other words, occupational diseases are under-reported.

Although this issue has not been studied specifically, it is very likely that occupational diseases due to biological agents are under-reported in the Netherlands. Analysis of data from the National Registry of Occupational Diseases showed that between 2000 and 2010 the number of reported occupational diseases was more or less stable. However, there was an increased number of reports from the construction sector, and, outside construction, the number of reports as well as the number of occupational physicians reporting cases steadily declined (Lenderink, 2012).

The assumption that only a small proportion of all occupational diseases is being reported is supported by the fact that, in comparison with the 6,500 cases of occupational disease officially reported in 2012, institutes such as the NCvB and RIVM estimate that 17,400-22,000 new cases of occupational disease occur every year. Furthermore, in the first survey on self-reporting of occupational diseases among Dutch workers, around 400,000 workers indicated that they had experienced a work-related disease during the previous 12 months (Volksgezondheidenzorg.info, 2016). Nevertheless, the number of registering occupational physicians and thus the number of registered occupational/work-related diseases increased in 2014 compared with previous years, although the annual number of new cases of occupational/work-related diseases per 100,000 workers did not change (van der Molen et al., 2015).

The abovementioned survey and these figures indicate that there seem to be more barriers than before to contact between workers and occupational physicians. These barriers are affected by changes in laws and regulations and by the way in which OSH services are organised. This is partly due to the abolishment of the *risque professional* as described above, as well as the fact that OSH services are privatised (denationalised) and are thus commercial organisations that must make a profit. Moreover, as these organisations are paid by employers, their priorities may be more focused on the wishes/plans of employers rather than the needs of workers.

The assumption of under-reporting is further supported by the fact that physicians in the UK report occupational diseases 14 times more frequently than occupational physicians in the Netherlands. This difference may be partly due to differences in the definitions and diagnoses that are used, but this does not explain everything. One striking difference between the two countries is the fact that in the UK self-reporting of work-related health effects by workers is possible (the number of self-reported occupational diseases is almost 1.5 times higher than that reported by physicians), which in turn may also stimulate registration by professionals (Willems et al., 2014).

Difficulties in identifying biological agents as a cause

Although the registration system for occupational diseases does distinguish occupational diseases due to biological agents as a separate category, with separate information available, the main focus of this category seems to be occupational infectious diseases (see Table 53) and thus it does not cover all types of occupational diseases that can be related to exposure to biological agents. A large number of other (known) relevant occupational diseases are covered in the 'Lungs and airways' category. Although for this category exposure to biological agents may be identified as a cause, the precise distinction between the groups is not clear and may lead to confusion during registration. Furthermore, which category is chosen will largely depend on the starting point/frame of reference of the occupational physician. If an occupational physician is less familiar with biological agents and the diseases related to them, the emphasis may be on the 'Lungs and airways' category with regard to, for instance, searching for information. As the categorisation of the diseases is based on CAS codes, diseases will probably be correctly classified (as, for instance, occupational infectious diseases), but the classification of the cause of the disease may be influenced by the perception of the cause of the disease on the part of the person reporting it.

Considerations for prevention

The focus of health and safety service providers (including occupational physicians) in the Netherlands is on absence (due to illness) and much less on primary and secondary prevention, or periodical medical examinations. Although many occupational diseases occur after retirement, which makes the link to the work environment and registration even more difficult, this does not apply to most of the occupational and work-related diseases that this report focuses on, due to the short latency period of most occupational or work-related diseases caused by biological agents (often infectious diseases, skin or respiratory symptoms).

The RI&E, in which companies are required to record diseases, is an instrument that can be used to recognise risks over a longer period, including both acute and chronic risks, and thus risks that cause occupational diseases. Such a monitoring system is a valuable source of information. However, this depends on how well the companies execute these RI&Es, and what they focus on (or not). Surveillance and inspection of the compulsory RI&E with regard to chemical substances, biological agents, physical stress and psychosocial risks is very limited. Better enforcement by the labour inspectorate could encourage companies to pay attention to biological agents in their RI&Es, which would also result in more attention being paid to these risks in the workplace (i.e. would promote their prevention).

Awareness increasing at the sectoral level

It has been observed that in the agricultural sector communication between occupational health professionals (including occupational physicians) and veterinarians has improved. More and more veterinarians are reporting human health risks to farmers, in case of zoonoses, for instance, and informing farmers about these risks (e.g. the increased risk to vulnerable workers such as pregnant women). Although veterinarians are not obliged to report occupational diseases in the Netherlands, it is assumed that over time this increased awareness among farmers will have a positive effect on the number of cases reported in this sector.

Ways forward

In 2012, the NCvB published a report on a survey undertaken among occupational physicians to better understand the factors that influence the reporting of occupational diseases in a rapidly changing environment (Lenderink et al., 2012). The occupational physicians who reported occupational diseases were found to be intrinsically motivated by their professional mission statement. Based on this study, since the NCvB has limited ability to influence legislation or the enforcement or establishment of health and safety services, it decided to focus on further strengthening the intrinsic motivation of occupational physicians by sharing knowledge, giving feedback on reporting, facilitating easy access to electronic reporting and providing information on the interaction between work-related and other causes. This led to updates to the step-by-step plan for systematic investigation with regard to a number of important aspects of determining if the disease is actually an occupational disease, which resulted in the six-step plan described in Section 5.1.1.

Owing to the large variety of biological agents and the unspecific symptoms that they may cause, it is reasonable to assume that workers will not always relate their symptoms to their work environment. At least for some diseases, instead of contacting their occupational physician, they may be more likely to visit their general practitioner (family doctor) for treatment, for whom the relation to exposure in the work environment will be less of a primary concern. Encouraging (voluntary) registration by general practitioners or other physicians in the curative health system may be a way to increase the registration of occupational diseases caused by biological agents, but it would mean that more attention would need to be paid to the identification and registration of occupational diseases during these doctors' vocational training, since their focus is generally not on the cause of the disease.

Monitoring of exposure

The Dutch system aims to ensure the registration of occupational diseases, and unfortunately no separate system for monitoring occupational exposures exists. The primary focus of, for instance, OSH professionals operating in the field, is on the prevention of exposure rather than monitoring exposure. With regard to measuring occupational exposure to biological agents, the general belief of, for instance, OSH professionals, is that measuring such exposure is rather difficult without standardised methods, and thus they are measured very rarely in the work environment. However, because the relationship with exposure is recorded during the registration of occupational diseases, valuable information regarding exposure is gathered in a more indirect way by occupational physicians. This at least gives an idea of the types of exposures that are related to health effects. Although there are no other official records with regard to, for instance, health surveillance, the occupational physician will not base an assessment of the relationship of a disease with exposure only on the information that he or she receives from the worker. Occupational physicians in the Netherlands also visit workplaces. Furthermore, the NCvB provides them with all sorts of information to enable them to determine the causes of diseases.

5.2 Registration of occupational diseases in the United Kingdom

Relevant legislation and regulations

The Health and Safety at Work Act 1974 is the primary piece of legislation covering OSH in the UK. The Health and Safety Executive (HSE), with local authorities (and other enforcing authorities), is responsible for enforcing it and a number of legal instruments relevant to the working environment.

The Management of Health and Safety at Work Regulations 1999 provide a broad framework for controlling health and safety at work. They place a duty on employers to assess and manage risks to their workers and others arising from work activities. Employers must also make arrangements to ensure the health and safety of the workplace, including planning for emergencies, adequate information and training for workers, and health surveillance where appropriate. Workers must work safely in accordance with their training and the instructions given to them. Workers must also notify the employer or the person responsible for health and safety of any serious or immediate danger to health and safety or any shortcoming in health and safety arrangements.

The Control of Substances Hazardous to Health Regulations 2002 (COSHH) provide a specific framework of actions for assessing, preventing and controlling risks posed by, for instance, bacteria such as *Legionella* and taking suitable precautions. Microorganisms are covered in COSHH by the term 'biological agents', which makes this the main piece of legislation that applies to infections at work. The term 'biological agents' covers microorganisms, cell cultures and human endoparasites that may cause infection, allergy, toxicity or other hazards to human health. Work with hazardous biological agents is subject to specific provisions under COSHH for laboratories, animal rooms and industrial processes, and is covered in Schedule 3 of the main regulations. COSHH also refers to the Approved List of biological agents. This list classifies biological agents into one of four hazard groups (with HG4 being the most hazardous and including, for example, Ebola virus) according to the risk of infection to a healthy worker. This provides the basis for conducting laboratory work with the organisms by indicating what kind of containment and control measures should be in place. The list may also help in assessing risks in other, non-laboratory-based occupations, by indicating the severity of a disease associated with a particular biological agent.

The 1992 Workplace (Health, Safety and Welfare) Regulations are concerned with the working environment. They place a duty on employers to make sure that the workplace is safe and suitable for the tasks being carried out there, and to ensure that it does not present risks to workers or others. These regulations are backed up by the Approved Codes of Practice (and other official guidance), for example *Legionnaires' disease: The control of Legionella bacteria in water systems (L8)* contains practical guidance for employers on how to manage and control risks in their systems.

Description of the systems

In the UK, there are various sources of information on the recording of occupational or work-related diseases.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations

The 2013 Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) require employers, the self-employed and people in control of premises to report work-related fatal injuries, specified non-fatal injuries, certain occupational diseases, dangerous occurrences and certain gas incidents.

It is a legal requirement to inform the enforcing authorities (e.g. HSE, local authorities. the Office for Rail Regulation), so that they can identify where and how risks arise, and if they need to be investigated, target their work and provide advice on how to avoid work-related deaths, injuries, ill health and accidental loss.

These regulations have been amended several times since their introduction, the most recent amendment being RIDDOR 2013, which came into force on 1 October 2013. Aggregated statistics based on the reported incidents are provided in the 'Statistics' web pages maintained by HSE on its website.

RIDDOR defines several types of reportable incidents, namely:

- **Deaths and injuries:** a RIDDOR report is required only when (i) the accident is work-related, and (ii) it results in an injury of a reportable type. This category does not include needlestick injuries.
- **Occupational diseases:** employers and self-employed people must report diagnoses of certain occupational diseases, when these are likely to have been caused or made worse by their work. A reportable disease must be diagnosed by a doctor and this includes identifying any new symptoms, or any significant worsening of existing symptoms. Workers must provide the diagnosis in writing to their employer. Doctors are encouraged to use standard wording when describing reportable diseases in the written statements they make for their patients. Of the eight reportable occupational diseases (under Regulations 8 and 9), the following are relevant to biological agents:
    - **Occupational dermatitis:** reportable when associated with work-related exposure to any chemical or biological irritant or sensitising agent. In particular, this includes any chemical with the warning 'may cause sensitisation by skin contact' or 'irritating to the skin'. Among the substances and tasks relevant for this report, metalworking fluids, wet work, enzymes and wood can cause dermatitis. Construction work, health service work, rubber making, printing, paint spraying, agriculture, horticulture, electroplating, cleaning, catering, hairdressing and floristry are all associated with dermatitis.
    - **Occupational asthma:** asthma is reportable when associated with work-related exposure to any respiratory sensitiser and exacerbated or triggered by exposure at work. In particular,

this will include any chemical with the warning 'may cause sensitisation by inhalation'. Known respiratory sensitisers relevant to this report include grain dusts and wood dusts. Asthma is a common condition in the general population.

- **Disease or acute illness caused by an occupational exposure to a biological agent:** all diseases and any acute illness needing medical treatment must be reported when it is attributable to a work-related exposure to a biological agent. Work-related exposures to biological agents may take place as a result of:
  - (i) an identifiable event, such as the accidental breakage of a laboratory flask, accidental injury with a contaminated syringe needle or an animal bite, or
  - (ii) unidentified events, during which workers are exposed to the agent without their knowledge (e.g. when a worker is exposed to *Legionella* bacteria while conducting routine maintenance on a hot water service system).

A report should be made whenever there is reasonable evidence that a work-related exposure was the probable cause of the disease. Doctors may indicate the significance of any work-related factors when communicating their diagnosis. Minor infections such as colds, bronchitis or stomach upsets are generally not reportable, except when there is reasonable evidence of a work-related cause, such as inadvertent contact with an infectious agent during laboratory work. Acute illnesses requiring medical attention must be reported when they result from a work-related exposure to a biological agent, including its toxins or any infected material. The two key risk occupations for acute illnesses are considered to be healthcare and laboratories, and specific infections mentioned are anthrax, zoonoses, bovine spongiform encephalopathy (BSE), influenza, *Legionella* and SARS (HSE, 2019a). Although RIDDOR places a requirement on employers to report prescribed occupational diseases, such reports are small in number (HSE, 2015a).

- **Dangerous occurrences:** dangerous occurrences are certain specified near-miss events. Not all require reporting. There are 27 categories of dangerous occurrences relevant to most workplaces. One of these categories is 'Biological agents':
  - 'Any accident or incident which results or could have resulted in the release or escape of a biological agent likely to cause severe human infection or illness.' Severe human infection or illness means illness caused by biological agents in Hazard Groups 3 and 4, as defined in COSHH 2002, Schedule 3. These are also listed in the latest edition of *The management and operation of microbiological containment laboratories* (HSE 2018), and include agents classified provisionally by an employer as being in one of these hazard groups. HSE provides more specialised guidance on how to apply this and other aspects of RIDDOR in the healthcare sector.

Rresponsible persons should complete the appropriate online report form (see http://www.hse.gov.uk/riddor/report.htm), which is be submitted directly to the RIDDOR database, and the submitter also receives a copy. A telephone service is also provided for reporting fatal/specified and major incidents only. The forms ask for information on the submitter, the place where the incident occurred, the type of industry and the type of incident. Most information is to be filled in using pre-defined categories, but there is also a field for a more detailed description of the situation, to which an indication of exposure to a specific agent during a specific situation could be added.

The Labour Force Survey

The Labour Force Survey (LFS) is a large, nationally representative survey of households at private addresses in the UK, currently consisting of around 41,000 responding households each quarter. It is designed, developed and managed by the Office for National Statistics and the Department of Finance and Personnel in Northern Ireland on behalf of the Department of Enterprise, Trade and Investment.

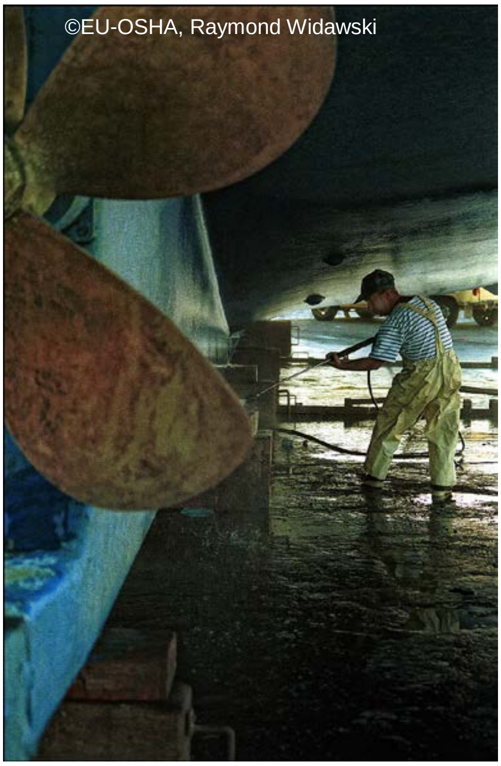
HSE commissions annual questions in the LFS to gain a view of work-related illness and workplace injury based on individuals' perceptions (HSE, 2015a). They are included in two survey modules, the

Workplace Injury survey module and the Self-reported Work-related Illness (SWI) survey module. Each questionnaire module has a core set of questions with a small number of additional questions asked periodically. The Workplace Injury survey module (HSE, 2019b) was first included in the LFS in 1990, with a limited question set included annually since 1993/94. The LFS gives annual estimates of the levels of workplace injury by a range of demographic and employment-related variables and complements the non-fatal injury reports made by employers and others under RIDDOR.

The SWI survey module (HSE, 2019c) was included in the LFS first periodically and then annually from 2003/04 to 2011/12, with a 1-year gap in 2012/13. It provides an indication of the annual prevalence (including long-standing as well as new cases) and incidence (new cases) of work-related illness and its distribution by major disease groups and a range of demographic and employment-related variables. It seeks to capture information about work-related ill health in the broadest sense.

Research undertaken in 1995 (HSE, 1998) and 2010 (HSE, 2013a) indicates a reasonable degree of reliability of self-reports on work-related ill health in the LFS, and, when sensibly interpreted, such surveys provide valid and relevant information not available from other sources.

Since estimates derived from the LFS are based on a sample (rather than the full population), they are subject to a margin of error. The main factor that determines the margin is the number of sample cases on which an estimate is based. In published reports and tables, the sampling errors are often expressed as 95 % confidence intervals, a range with a 95 % chance of containing the true value in the absence of bias. Confidence intervals should be cited rather than prevalence or incidence estimates or rates whenever there are fewer than 30 sample cases. Estimates based on fewer than 20 sample cases are deemed unreliable and are not published.



Voluntary reporting of occupational diseases by general practitioners

THOR-GP is a surveillance scheme in which general practitioners (GPs) are asked to report new cases of work-related ill health. It was initiated in June 2005. Participating GPs report anonymised information on newly diagnosed cases to the Centre for Occupational and Environmental Health (COEH) at Manchester University (Manchester University, 2016).

The pool of voluntary reporters currently consists of around 250 GPs trained at a postgraduate level in occupational medicine by Manchester University through distance learning. The COEH is one of only very few sites in the UK that offers this training. Consequently, volunteer GP reporters practice in areas widely distributed across the UK. The GP reporters are instructed to make the decision about whether or not a new case should be identified as being attributable to work on the balance of probabilities (i.e. whether it is more likely than not). Reports are collected online via web forms. When reporting a case, the GPs are asked to classify it in a broad disease category and to provide information on age, gender, job, industry, type of exposure and absence from work.

An audit of the accuracy of the recording of sickness absence within the surveillance scheme revealed a considerable level of under-reporting. This was primarily because some reporters tended to forget to arrange the updating of the database on occasions when they signed patients off for further sickness absence after the initial period of sickness absence. The published estimates are adjusted to correct for this under-recording.

At the start of THOR-GP data collection, all participating GPs reported incident cases every month (these GPs are termed ‘core reporters’), creating a relatively large incident dataset for analysis and interpretation. As the scheme progressed, as in other THOR schemes, an increasing proportion of GPs were asked to report incident data during only one randomly selected month of the year (these GPs are termed ‘sample reporters’). This helped contain costs and reduce potential ‘fatigue’ on the part of GPs in their reporting.

Voluntary reporting of work-related ill health by specialist doctors

The Health and Occupation Research Network (THOR) is a voluntary surveillance scheme for work-related ill health. As members of this network, specialist doctors systematically report all new cases that they see in their clinics. These reports are collated and analysed by a multidisciplinary team at the COEH (Manchester University, 2016). The THOR network currently consists of two specialist reporting schemes (HSE, 2015b). These are:

1) SWORD (Surveillance of Work-related and Occupational Respiratory Disease, based on reports from hospital consultants specialising in respiratory disease, operating since 1989). The main categories of work-related respiratory diseases reported by consultant chest physicians to SWORD include:
    - allergic alveolitis;
    - asthma;
    - bronchitis/emphysema;
    - infectious diseases;
    - inhalation accidents;
    - benign pleural disease;
    - malignant mesothelioma;
    - lung cancer;
    - pneumoconiosis;
    - other respiratory illness.
2) EPIDERM (an occupational skin disease surveillance scheme, based on reports from consultant dermatologists, operating since 1993). The main categories of skin diseases reported by consultant dermatologists to EPIDERM include:
    - contact dermatitis;
    - contact urticaria;
    - folliculitis/acne;
    - infective skin disease;
    - mechanical skin disease;
    - nail conditions;
    - skin neoplasia;

- other dermatoses.

A third scheme, SIDAW (Surveillance of Infectious Diseases at Work, based on cases reported by consultants in communicable disease control), operated from 1996 until the end of 2015. A fourth, OPRA (based on reports from occupational physicians), operated from 1996 until the end of 2010.

Until the end of 2009, two additional schemes were also in operation, namely SOSMI (reports from consultant psychiatrists) and MOSS (reports from consultant rheumatologists). The databases for several of these schemes extend back more than 10 years and thus constitute powerful resources for investigating particular types of ill health in relation to occupations, industries and causal agents or work activities.

Further analyses can be conducted according to the following data dimensions:

- patient characteristics (age, gender, broad region of residence, occupation);
- workplace and job characteristics (occupation and industry);
- suspected causal agents.

The annual incidence of work-related ill health reported in THOR is estimated on the basis of cases reported by the participating physicians. These reported cases are included in the estimated annual totals with no scaling up. The estimated annual totals are generally based on smaller (often considerably smaller) numbers of actual reported cases and are subject to random variation due to sampling error. Decisions on whether or not particular cases of ill health are work-related are a matter for the professional judgement of the reporters, who are asked to decide on the balance of probabilities.

As is the case with the THOR-GP scheme, most participating doctors are asked to send in reports for one month in each year, and the numbers of reported cases are multiplied by 12 to obtain the estimated annual totals. To avoid any systematic seasonal biases, the sampled doctors are randomly allocated their reporting month, and this allocation changes from year to year. Not all reporting doctors are sampled; some are ‘core reporters’, who report cases every month throughout the year.

In 2014, about 1,551 estimated new cases of respiratory disease were reported by consultant chest physicians to SWORD and about 1,320 estimated new cases of skin disease were reported by dermatologists to EPIDERM.

The THOR schemes for clinical specialists’ reporting cover only a subset of cases of work-related disease. This is because quite a large proportion of cases will either never come to the attention of a hospital consultant or will be dealt with by a general practitioner. Moreover, many workers will not have access to an occupational physician at their place of work. Therefore, the cases recorded within the THOR schemes will largely consist of either the serious or difficult-to-resolve cases that are referred to specialists by general practitioners or the more general cases from industrial sectors that are well covered by occupational physicians. Given this, the numbers of cases recorded in the THOR schemes clearly underestimate the total burden of work-related ill health. Nevertheless, the recorded cases should be identified following reasonably consistent processes each year, thereby making it possible to assess trends over time.

The incidence rates for THOR cases, per 100,000 workers in each occupation or industry, are calculated using denominators from the Annual Population Survey. The analyses by occupation use the Standard Occupational Classification (SOC).

Ill health assessed for disablement benefit

Industrial Injuries Disablement Benefit (IIDB) (GOV.UK, 2016) is for people who are disabled because of an accident at work or who have certain diseases caused by their work. There are no age limits, but the worker must have a contract of employment. It is a no-fault scheme paid for by the Department for Work and Pensions and administered by the Department for Work and Pensions Industrial Injuries Benefits Centres. It applies to England, Wales, Scotland and Northern Ireland. The law provides for payment of benefits to people who are suffering from certain diseases contracted in certain types of employment or while working on an approved employment training scheme or course. These diseases are referred to as prescribed diseases (PDs) and are listed in specific regulations[13].

The Industrial Injuries Advisory Council makes recommendations to the Secretary of State on what diseases the Industrial Injuries Scheme covers (Legislation (45) - Social Security Contributions and Benefits Act 1992[14] section 108(2)). There is no entitlement to benefit in respect of a disease if it is not listed in the regulations, or if the person's job is not listed against the particular disease. However, there may be entitlement to benefit under the industrial accident provisions if a disease has been caused as a result of an accident. If a person is not entitled to benefit for a certain disease, it does not necessarily mean that this person does not have the disease, only that they do not meet the criteria laid down in the law for receiving benefit. This is especially important for diseases common in the population at large.

Diseases or injuries are prescribed where an occupational cause is well established, and when the terms of prescription can be framed to identify cases of genuine occupational origin (i.e. the risk is not common to everybody). Prescribed diseases with common non-occupational as well as occupational causes are usually defined on the basis of epidemiological evidence of occupational circumstances in which the risk is at least doubled. This implies that at least half of the cases would not have occurred but for these particular occupational circumstances. Any individual case in these occupational circumstances can thus be judged to be occupational on the balance of probabilities, and the scheme can be used to give an indication of the annual incidence of the diseases for which the evidence of occupational causation is strongest.

Prescribed diseases are grouped according to their causes. There are four groups of causes, each identified by a letter, and each prescribed disease has a number. The groups are:

A) for a physical cause;
B) for a biological cause;
C) for a chemical cause;
D) for any other cause (miscellaneous).

A full list of the prescribed diseases and types of occupation that are covered by the scheme is set out in an appendix to the Social Security (Industrial Injuries) (Prescribed Diseases) Regulations ([15]). Table 56 provides the diseases listed in category B.

Table 56: Overview of predescribed diseases with a biological cause covered by IIDB in the UK

Disease Number	Name of disease or injury Conditions due to biological agents (caused by an animal, plant or other living organism)	Type of job Any job involving:
B1	Cutaneous anthrax. Pulmonary anthrax.	(a) Contact with anthrax spores, including contact withanimals infected by anthrax; or (b) handling, loading, unloading or transport of animals of a type susceptible to infection with anthrax or of the products or residues of such animals

([13]) (Legislation (43) - SS C&B Act 1992 sec 108(1)) (Legislation (44) - SS (II) (PD) Regs 1985 Sched 1)
([14]) See https://www.legislation.gov.uk/ukpga/1992/4/contents/enacted
([15]) Schedule 4 of the Social Security (Industrial Injuries) (Prescribed Diseases) Regulations 1985, https://www.legislation.gov.uk/uksi/1985/967/schedule/4/made, revised version 31/8/2018

Disease Number	Name of disease or injury Conditions due to biological agents (caused by an animal, plant or other living organism)	Type of job Any job involving:
B2	Glanders	Contact with equine animals or their carcasses. For example, farm and slaughterhouse workers, and grooms handling horses
B3	Infection by *Leptospira*; for example, swamp fever, swineherd's disease and Weil's disease	(a) Work in places which are, or are liable to be, infested by rats, field mice or voles, or other small mammals; or (b) work at dog kennels or the care or handling of dogs; or (c) contact with bovine animals or their meat products or pigs or their meat products
B4	(a) Cutaneous larva migrans; (b) Iron deficiency anaemia caused by gastrointestinal infection by hookworm	Contact with a source of ankylostomiasis
B5	Tuberculosis	Contact with a source of tuberculosis while undertaking– (a) work in a hospital, mortuary in which post mortems are conducted, or laboratory; or (b) work in any other workplace.
B6	Extrinsic allergic alveolitis (including farmer's lung)	Exposure to moulds or fungal spores or heterologous proteins or any other biological substance that causes extrinsic allergic alveolitis by reason of employment in: (a) agriculture, horticulture, forestry, cultivation of edible fungi or malt-working; or (b) loading or unloading or handling in storage mouldy vegetable matter or edible fungi; or Any occupation involving: (c) caring for or handling birds; or (d) handling bagasse or (e) work involving exposure to metal working fluid mists ; or (f) any other workplace

Disease Number	Name of disease or injury Conditions due to biological agents (caused by an animal, plant or other living organism)	Type of job Any job involving:
B7	Infection by organisms of the genus *Brucella*	Contact with (a) animals infected by brucella, or their carcases or parts thereof, or their untreated products; or (b) laboratory specimens or vaccines of, or containing brucella. For example, farm, veterinary, slaughterhouse, animal laboratory workers
B8A	Infection by hepatitis A virus	Contact with raw sewage
B8B	Infection by hepatitis B or C virus	Contact with (a) human blood or human blood products; or (b) any other source of hepatitis B or C virus
B9	Infection by *Streptococcus suis* (a very rare form of meningitis from exposure to infected pigs or pork products)	Contact with pigs infected by *Streptococcus suis*, or with the carcasses, products or residues of pigs so infected. For example, pork butchers, pig breeders, slaughterhouse workers.
B10(a)	Avian chlamydiosis	Contact with birds infected with *Chlamydia psittaci*, or with the remains or untreated products of such birds. For example, duck farm workers, feather processing workers, abattoir workers, poultry meat inspectors, pet shop owners and assistants.
B10(b)	Ovine chlamydiosis	Contact with sheep infected with *Chlamydia psittaci*, or with the remains or untreated products of such sheep. For example, sheep farm workers, veterinary surgeons.
B11	Q fever	Contact with animals, their remains or their untreated products. For example, farm workers involved in the rearing of sheep, abattoir workers, veterinary surgeons.
B12	Orf	Contact with sheep or goats, or with the carcasses of sheep or goats. For example, farm workers, abattoir workers, meat inspectors.
B13	Hydatidosis	Contact with dogs. For example, shepherds, veterinarians and people who care for dogs.

Disease Number	Name of disease or injury Conditions due to biological agents (caused by an animal, plant or other living organism)	Type of job Any job involving:
B14	Lyme disease	Exposure to deer or other mammals of a type liable to harbour ticks harbouring *Borrelia* bacteria.
B15	Anaphylaxis	Contact with products made with natural rubber latex.

Source: https://www.gov.uk/government/publications/industrial-injuries-disablement-benefits-technical-guidance/industrial-injuries-disablement-benefits-technical-guidance#appendix-1-list-of-diseases-covered-by-industrial-injuries-disablement-benefit (website visited December 2018).

For diseases that are prescribed on the basis of a doubling of risk, the IIDB figures potentially overestimate the annual incidence by a factor of up to two: if certain occupational circumstances confer at least a doubling of risk, then at most one half of disease cases arising from these circumstances will be caused by non-occupational factors (if the risk is exactly two, the occupational proportion will be exactly one half). In reality, however, assessed IIDB cases will usually understate the scale of disease incidence because cases may arise from circumstances other than those covered by the terms of the prescription, because individuals may be unaware of the possible occupational origin of their disease or the availability of compensation and because the scheme does not cover the self-employed.

For most diseases, benefit is payable if the extent of disability (from a single PD or from a number of PDs together) is assessed as 14 % or more. However, the published statistics include all newly assessed cases, including those assessed at 1-13 % disability. Care should be taken in interpreting the annual totals for all prescribed diseases and the trends in them. Prescribed diseases do not represent the full spectrum of work-related illness. Figures for individual diseases making up the total are liable to be strongly affected by any changes in prescription criteria and factors affecting the take-up of claims (e.g. the contraction of traditional industries in which the availability of compensation is well known, and the shift in employment to newer industries where it may be less well known).

Much of the total is accounted for by lung diseases, vibration white finger and deafness, and many such cases are a legacy of past working conditions that would be judged inadequate or in some cases illegal by today’s standards.

IIDB statistics are available annually from 2003, but earlier historical data are also available.

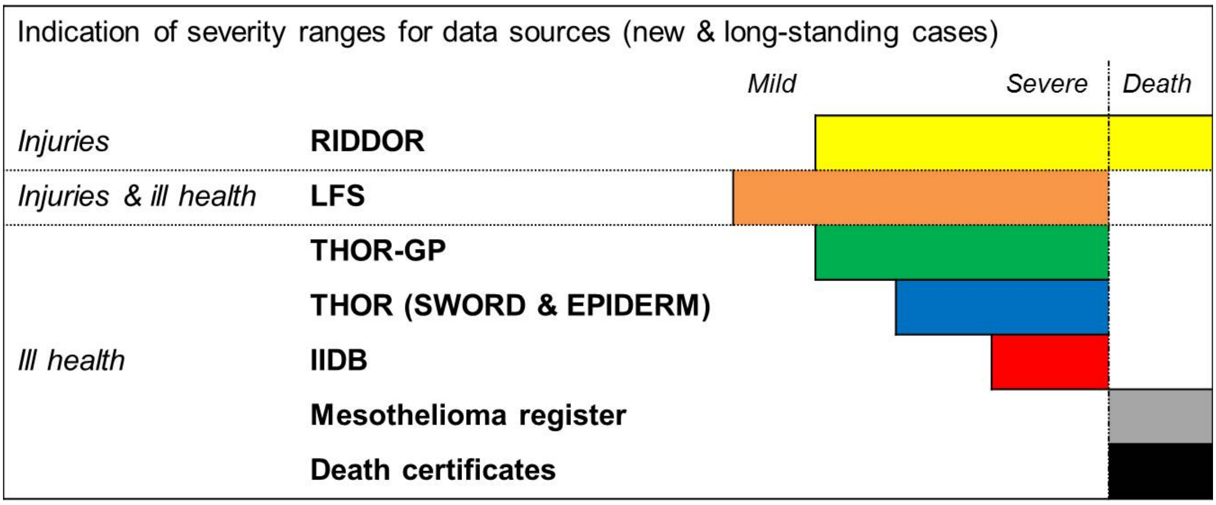
Examples of outputs from the systems

HSE publishes a range of statistics relating to health and safety in Great Britain. Using a variety of data sources, including surveys and surveillance schemes, it provides statistics on (HSE, 2019d):

- work-related ill health and disease;
- workplace injury;
- enforcement of health and safety legislation;
- working days lost and costs to the UK as a result of health and safety incidents;
- working conditions and management of health and safety in the workplace.

Figure 6 shows the main data sources used for injury and ill-health statistics generated by HSE, including an indication of the severity range that each source includes. As the mesothelioma register and the death certificates register are not relevant with regard to diseases caused by biological agents (they mainly focus on asbestos-related diseases, mesothelioma and asbestosis), these are not described in this report.

Figure 6: Main data sources used for injury and ill-health statistics generated by HSE in the UK, including an indication of the severity range



Source: http://www.hse.gov.uk/statistics/sources.htm (visited website October 2016).

HSE has identified preferred sources for several categories of ill health and injuries (HSE, 2019e). The system of ratings it uses provide a general indication of the sources' strength for most purposes. Although there may be a preferred source for a particular item, another source may be more appropriate for a particular data breakdown within that item. The following describes the preferred sources for diseases caused by exposure to biological agents:

- Asthma (SWORD): in theory, GPs are best placed to capture most new cases of asthma. However, the relatively small sample of GPs participating in THOR-GP does not identify sufficiently large numbers of cases to provide good estimates of the overall scale of occupational asthma. SWORD identifies a much larger number of cases of occupational asthma. Although it is restricted to cases referred to consultants and therefore underestimates the overall scale of disease, it provides a good basis for more detailed analyses and is therefore the preferred source.
- COPD (attributable fraction (A/F)): A/F estimates are preferred as they do not rely on the correct occupational attribution of individual cases, which is particularly difficult for COPD, since smoking is its predominant cause. The epidemiological data on which A/F estimates of the overall scale are based provide information on the contribution of different exposures, occupations and industries.
- Skin disorders/dermatitis (EPIDERM): occupational skin disease can vary widely in severity from, for example, skin cancers and serious cases of dermatitis to minor skin irritation, which may not be recognised as an adverse health outcome by the individual. THOR-GP captures the cases of enough concern to have triggered a visit to a GP and be subsequently diagnosed and attributed to work. However, the relatively small sample of participating GPs results in imprecise estimates of the overall scale of occupational skin disease. EPIDERM identifies a much larger number of cases of skin disease. Although it is restricted to cases referred to consultants and therefore underestimates the overall scale of the disease, it provides a good basis for more detailed analyses and is therefore the preferred source.

- Other respiratory disease (SWORD): the specialist reporting scheme includes non-fatal cases and those who have not claimed for IIDB.
- Infections (IIDB): the IIDB scheme provides records of the numbers of individuals who have been assessed for occupational infections that are eligible for IIDB.

HSE runs most of the registration systems and is also responsible for (or at least involved in) the statistical evaluation of the data that are gathered by means of the various systems. In addition to the annual generic overviews published by HSE, Health and Safety Statistics tables (HSE, 2019f) are also specifically generated for each of the systems on an individual basis (HSE, 2019d).

Table 57 provides a general overview of the reported ill health and injuries in the UK over the period 2010-2014, based on Health and Safety Statistics tables. Unfortunately, no distinction is generally made with regard to causes of ill health, and no useful breakdown with regard to industrial sector is provided, which makes the interpretation of these statistics in relation to exposure to biological agents and their related health effects difficult. However, it is assumed that at least some of the reported new cases of respiratory disorders and skin diseases are caused by biological agents.

Table 57: Overview of general health and safety statistics published by HSE over the period 2010-2014 in the UK

Key figure	2010 (HSE, 2011)	2011 (HSE, 2012)	2012 (HSE, 2013b)	2013 (HSE, 2014b)	2014 (HSE, 2015g)
People at work suffering from an illness believed to be caused or made worse by their work	1.2 million	1.1 million	1.1 million	1.2 million	1.2 million
People at work suffering from an illness believed to be caused or made worse by their work that is a new condition started during the year	0.5 million	0.5 million	0.5 million	0.5 million	0.5 million
Former workers suffering from an illness caused or made worse by their past work	0.7 million	0.7 million	0.7 million	0.8 million	0.8 million
Number of workers killed at work (RIDDOR)	171	173	148	133	142
Number of other injuries that occurred at work (RIDDOR)	115,379	111,163	78,222	77,593	76,000
Number of injuries that occurred at work (LFS)			175,000	629,000	611,000
New cases of skin disorders (THOR-GP) ([a])				± 5 %	± 9 %
New cases of respiratory disorders (THOR-GP) ([a])					± 4 %

Key figure	2010 (HSE, 2011)	2011 (HSE, 2012)	2012 (HSE, 2013b)	2013 (HSE, 2014b)	2014 (HSE, 2015g)
New cases of skin disease (EPIDERM)			1,550	1,268	1,320
Occupations most at risk of skin disease (EPIDERM)	Hairdressers/barbers and florists				
New cases of asthma (SWORD)			177	177	132
Occupations most at risk of asthma (SWORD)	Vehicle spray painters and bakers				

([a]) Percentage of all new cases identified in a certain year, estimated on the basis of a graphical representation of the output.

The following paragraphs set out a selection of the information available from the various individual systems. When making this selection, an effort was made to identify what information could be considered relevant to exposure to biological agents in the workplace and the related health effects.

The release or escape of biological agents is one of the dangerous occurrences that need to be registered under RIDDOR. The numbers of occurrences seem to be relatively stable over the years. In 2014, 411 of these occurrences (out of a total of 6,960 reportable dangerous occurrences of all sorts) were reported, compared with 339 (out of 7,041) in 2013, 338 (out of 6,908) in 2012, 365 (out of 6,779) in 2011 and 416 (out of 6,587) in 2010.

Table 58 provides an overview of the numbers of occupational/work-related diseases caused by biological agents reported to HSE under RIDDOR for the period 1 April 2014 to 31 March 2016 . It should be noted that RIDDOR was amended in 2013, when the number of disease categories was reduced. All reported cases are used for operational purposes by HSE and local authority inspectors (for targeting their inspection resources) and not for statistical analysis. The figures in the table should not be used to gauge the scale of illness in the workplace. It is known that all RIDDOR incidents are substantially under-reported; however, we do not know how under-reported RIDDOR disease notifications really are. When reporting a disease, reporters are required to select the disease category from a list of eight diseases, as described in Section 5.2.2. They are then asked to specify, using free text, the name of the disease. HSE holds information on specific diseases, although only in free-text format. Regarding the specific agent, the reporter is also asked to provide a textual narrative of the work activity that gave rise to the disease, and so the agent may be specified in this description. However, the information received in the narrative is of variable levels of detail and may not always identify the agent in any detail, and certainly not in any consistent form.

Table 58: Numbers of occupational/work-related diseases caused by biological agents reported to HSE under RIDDOR for the period 1 April 2014 to 31 March 2016 in the UK, based on date of diagnosis, where known

Year	Diseases caused by biological agents	All reported diseases
2014/15	105	1,594
2015/16	100	1,790

Source: provided by HSE by means of a personal communication.

Injuries with sharp objects/needles are also recorded in RIDDOR. In theory, when a release (or, for example, a needlestick injury) has occurred with no confirmed disease diagnosis, then the incident should be reported as a dangerous occurrence. Only when a confirmed disease diagnosis has been made should it be reported as a disease. If the injury has resulted in a disease attributed to biological exposure, then the incident should in theory be recorded as a disease notification. However, if there is no attributable disease, it is entirely possible that such cases could be reported as injuries in RIDDOR if they resulted in more than 7 days' absence from work. However, as the coding framework does not explicitly identify such cases for either disease or injury notification, HSE is unable to obtain a robust estimate of such reports.

Table 59 provides an overview of the identified causative biological agents with regard to the diagnosis of both occupational asthma (SWORD) and occupational dermatitis (EPIDERM). For occupational dermatitis in particular, the number of cases caused by biological agents is relatively low (and the biological agents in question are not further specified). However, a large proportion of the 'organic agents' that are specified in relation to occupational asthma are considered biological agents under the definition used in this report. Although, for the data from both EPIDERM and SWORD, a further breakdown by occupation/industry is given, this information is not linked to causative agents and thus not included in Table 57, since the number of non-biological causative agents is large.

Table 59: Overview of identified causative biological agents with regard to cases of occupational asthma (SWORD) and occupational dermatitis (EPIDERM) in the UK

Disease/agent	Average annual estimates over 3-year periods and for the period 1998-2017						
	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	2015-2017	1998-2017
Occupational asthma: estimated number of diagnoses in which particular causative substances were identified, reported by chest physicians to SWORD between 1998 and 2017 (category: organic agents)							
Fungi and moulds	4	9	5	2	2	0	3
Other biological substances	4	1	4	1	1	1	2

Disease/agent	**Average annual estimates over 3-year periods and for the period 1998-2017**						
	2000-2002	**2003-2005**	**2006-2008**	**2009-2011**	**2012-2014**	**2015-2017**	**1998-2017**
Enzymes, amylase	9	8	8	5	6	7	8
Fish and crustaceans	5	1	1	1	1	1	4
Flour	47	33	23	23	18	18	27
Grains	13	10	5	2	5	9	8
Laboratory animals	15	13	11	5	4	4	9
Other creatures (mites, dogs, horses)	10	4	2	0	6	6	6
Latex	13	7	2	1	1	0	5
Solder/colophony	38	8	8	7	6	4	12
Vegetables, spices and tea dusts	6	0	4	0	1	0	2
Wood dusts	18	14	4	8	12	5	12
Total number of known causative substances	**375**	**288**	**213**	**138**	**138**	**175**	**325**
Total number of cases	**435**	**370**	**336**	**182**	**166**	**151**	**301**
Occupational dermatitis: estimated number of diagnoses in which particular causative substances were identified, reported by dermatologists to EPIDERM between 1998 to 2014 (agents that are considered to be at least possibly biological agents)							
Irritants (unspecified)	99	22	47	40	39	22	48
Foods and flour	108	105	109	57	47	68	88
Other biological substances	68	68	82	63	68	67	73

Disease/agent	Average annual estimates over 3-year periods and for the period 1998-2017						
	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	2015-2017	1998-2017
Total number of known causative substances	**2,753**	**2,787**	**2,588**	**2,186**	**1,825**	**1,850**	**2,423**
Total number of cases	**1,905**	**1,694**	**1,509**	**1,317**	**1,076**	**1,032**	**1,498**

Source: http://www.hse.gov.uk/statistics/tables/index.htm#thor (visited website December 2018).

Table 60 provides an overview of the registered prescribed industrial diseases recorded as part of assessments of ill health for IIDB. Since the largest proportion of diseases reported under this system is made up of lung diseases, HSE presents this output as lung diseases and non-lung diseases. Of particular relevance are diseases categorised as category B (conditions due to biological agents) although some in category D (miscellaneous) may also be caused by biological agents. A steady number of cases of allergic alveolitis (5-10) and tuberculosis (5) is reported each year, but the rest of the diseases on the list have not been reported in the latest few years. Considerable numbers of cases of occupational asthma, rhinitis and dermatitis are also reported, but only a small proportion of these cases is assumed to be caused by biological agents, as can be seen in Table 61. Unfortunately, the data available from the HSE website do not allow the results to be broken down further by occupation/industry.

Table 60: Overview of prescribed industrial diseases linked to biological agents reported under IIDB each year between 2010 and 2017 and during the period 2008-2017 in the UK

Disease	2010	2011	2012	2013	2014	2015	2016	2017	Total, 2008-2017 (10 years)
Prescribed industrial diseases of the lungs									
B6: allergic alveolitis (including farmer's lung)([a])	5	5	10	5	10	10	5	5	75
D1: pneumoconiosis ([b]),([c])	1,420	1,045	1,280	1,220	1,255	1,420	1,290	1,115	12,320
D7: occupational asthma ([b]),([d])	125	95	90	85	70	70	85	45	970
Total, all lung diseases	**4,445**	**3,995**	**4,305**	**4,265**	**4,350**	**4,440**	**4,240**	**3,910**	**41,825**

Disease	2010	2011	2012	2013	2014	2015	2016	2017	Total, 2008-2017 (10 years)
Prescribed industrial diseases not of the lungs									
B3: leptospirosis (contact with certain animals including rats)	—	—	—	—	—	—	—	—	5
B5: tuberculosis (contact with source of tuberculosis infection)	5	5	5	5	5	—	5	5	35
B7: brucellosis (contact with animals/lab specimens/ vaccines containing *Brucella*)	—	—	—	—	—	—	—	—	—
B8A: viral hepatitis A (contact with raw sewage)	—	—	—	—	—	—	—	—	—
B8B: viral hepatitis B or C (contact with human blood or other sources of hepatitis B or C)	—	—	—	—	—	—	—	—	5
B10A: avian chlamydiosis (contact with birds infected with *Chlamydia psittaci*)	—	—	—	—	—	—	—	—	—
B11: Q fever (contact with animals, their remains or their untreated products)	—	—	—	—	—	—	—	—	10

Disease	2010	2011	2012	2013	2014	2015	2016	2017	Total, 2008-2017 (10 years)
B14: Lyme disease (contact with deer/other mammals with ticks harbouring *Borrelia*)	—	—	—	—	—	—	—	—	10
B15: anaphylaxis (natural rubber latex products used in healthcare)	—	5	—	—	—	—	—	—	20
D4: Allergic rhinitis (various agents mainly used in manufacturing processes) ([d])	35	30	30	20	15	15	15	5	245
D5: dermatitis (various agents excluding chrome) ([d])	60	65	55	40	30	45	20	25	500
Total, all non-lung diseases	**25,680**	**4,610**	**2,360**	**1,875**	**1,750**	**1,970**	**1,910**	**1,300**	**53,335**

Source: http://www.hse.gov.uk/statistics/tables/index.htm#iidb.

([a]) From 30 March 2017, the prescription for B6 was extended to include any biological substance that causes allergic alveolitis, and disease C34 (allergic alveolitis due to isocyanates and other chemicals) was introduced.

([b]) See also B6 and B7.

([c]) See also B8 and B9.

([d]) Category D: miscellaneous (a small proportion of these cases is assumed to be caused by biological agents).

Table 61: Overview of cases of occupational asthma reported under IIDB each year between 2010 and 2017 and during the period 2008-2017 in the UK, by causative agent

Agent	2010	2011	2012	2013	2014	2015	2016	2017	Total 2008-2017 (10 years)
Isocyanates	25	20	10	15	10	25	10	5	190
Open category	20	15	15	15	20	5	10	5	170
Flour/grain	25	15	15	15	5	5	15	10	150
Wood dusts	10	10	15	10	10	5	10	5	100
Fumes from stainless steel welding	10	5	10	15	10	—	10	—	85
Latex	5	10	10	5	5	10	5	—	60
Soldering flux	5	5	5	5	—	5	5	5	55
Hardening agents	10	—	5	—	5	5	—	—	35
Animals/insects	5	5	—	—	—	—	5	—	25
Crustaceans	—	—	—	—	—	5	—	—	20
Glutaraldehyde	5	—	—	—	—	—	—	—	15
Platinum salts	5	—	—	—	—	—	—	—	10
Antibiotics	—	—	—	—	—	—	—	—	5
Proteolytic enzymes	—	—	—	—	—	—	—	—	5
Reactive dyes	—	—	—	—	—	—	—	—	5
Tea dust	—	—	—	—	—	—	5	—	5
Animals/insects (larval forms)	—	—	—	—	—	—	—	—	—
Castor bean dust	—	—	—	—	—	—	—	—	—
Persulphate salts and henna	—	—	—	—	—	—	—	—	—

Agent	2010	2011	2012	2013	2014	2015	2016	2017	Total 2008-2017 (10 years)
Total, occupational asthma	**125**	**95**	**90**	**85**	**70**	**70**	**85**	**45**	**965**

Source: http://www.hse.gov.uk/statistics/tables/index.htm#iidb (visited website October 2016).

In addition to the overviews presented above, for some of the more frequently occurring occupational diseases the information gathered from the various systems is reported and analysed in more detail (HSE, 2019g). With regard to biological agents, the following diseases are considered relevant, and will be discussed in brief below (the information relevant for biological agents is in bold):

- asthma;
- COPD;
- other respiratory diseases (farmer's lung and other allergic alveolitis, allergic rhinitis, byssinosis);
  - skin diseases.

HSE data sources suggest that, during the past decade, there has been an overall reduction in occupational asthma (HSE, 2015c). However, new cases continue to occur, particularly in jobs where there is exposure to isocyanates in spray paint or to **flour dust**. Data sources suggest that the total number of new cases each year in the wider category of work-related asthma (asthma caused or made worse by work) could be more than 10 times higher (LFS, THOR-GP).

- For the period 2012-2014 and the previous two 3-year periods, 'vehicle paint technicians' and '**bakers and flour confectioners**' were the occupations with the highest rates of new cases per year (SWORD).
- The most common causes of occupational asthma continue to be isocyanates, and **flour/grain**, followed by wood dusts (SWORD).

COPD is a serious long-term lung disease in which the flow of air into the lungs is gradually reduced by inflammation of the air passages and damage to the lung tissue. Chronic bronchitis and emphysema are common types of COPD (HSE, 2015d).

- COPD is common in later life: it is likely that over a million individuals currently have the disease in the UK, and there are over 25,000 deaths each year.
- The most important cause of COPD is smoking, but past exposures to fumes, chemicals and **dusts** at work will also have contributed to causing many currently occurring cases.
- Reports by respiratory and occupational physicians (SWORD) and assessments for IIDB greatly understate the annual number of new cases of work-related COPD.
- Other research suggests that about 15 % of cases of COPD can be attributed to workplace exposures, which would be equivalent to about 4,000 COPD deaths currently each year in the UK.
- Workplace exposures likely to contribute to COPD include various **dusts** (including coal, **grain**, and silica) as well as certain fumes and chemicals (including welding fume, isocyanates and polycyclic aromatic hydrocarbons). Research is under way to provide details of the main causes in the UK.

Allergic alveolitis, rhinitis and byssinosis, diseases known to be caused by exposure to biological agents, are discussed in one HSE report (HSE, 2015e). With regard to farmer's lung and other allergic alveolitis the following summary is given:

- The estimated number of new cases reported by respiratory physicians (SWORD) each year has fluctuated, with no obvious trend.
- The numbers of annual deaths and IIDB cases have typically been much lower than might be suggested by the number of estimated cases: there were 78 deaths and 75 IIDB cases over 2004-2014.

With regard to allergic rhinitis, annual IIDB cases have tended to reduce in recent years, with 5 new cases in 2017 compared with an average of 25 per year over the previous 10 years. With regard to byssinosis, numbers of annual deaths and IIDB cases continue to be very low: there were on average fewer than 5 deaths and fewer than 5 IIDB cases per year between 2008 and 2017.

Work-related skin disease, of which biological agents are one of the possible causes, continues to be common, particularly in certain occupations, and can be severe in some cases (HSE, 2015f). The latest information shows:

- Most occupational skin disease cases are cases of contact dermatitis, and similar numbers of these are caused by exposures to allergens and by exposure to irritants (EPIDERM).
- Reports of more severe cases of occupational dermatitis from specialist doctors suggest that the number of new cases per year is now lower than it was a decade ago, but cases resulting from certain specific causes may still be increasing (EPIDERM).
- Working with wet hands and contact with soaps and cleaning materials continue to be the most common causes of occupational contact dermatitis (EPIDERM).

Occupations with the highest rates of work-related skin disease are florists, hairdressers, cooks, beauticians, and certain manufacturing and healthcare-related occupations (EPIDERM).

Benefits and limitations of the systems

As part of its description of the data sources that it uses to generate its statistics on injuries and ill health, HSE also summarises the main strengths and weaknesses of the data sources it uses (HSE, 2015a). These strengths and weaknesses are presented in Table 62. Although these strengths and weaknesses relate to the systems in general, and do not specifically focus on reported diseases due to biological agents, they are considered relevant, as reporting of diseases due to biological agents is one function of these systems.

Table 62: Main strengths and weaknesses of data sources for injuries and ill-health statistics in the UK, according to HSE

System	Strengths	Weaknesses
IIDB	A large number (more than 5,000) of clinically validated individual disease cases are recorded each year in the scheme The scheme permits an assessment of the incidence of rare diseases and time trends (with caution); it is HSE's only data source for certain conditions It gives a lower-bound estimate of the total incidence of diseases that are most clearly	Coverage is limited to diseases that can be clearly defined and attributed to an occupational cause, either based on clinical features or where there is epidemiological evidence to allow attribution in certain circumstances on the balance of probabilities

System	Strengths	Weaknesses
	occupational in origin, rather than the wider category of work-related diseases It has been running since the late 1940s and for many diseases there are several decades of information; HSE holds electronic data dating back to the mid-1980s. The method of data collection has been unchanged since April 2002	For those diseases that are included, annual incidence will tend to be underestimated due to: ▪ cases arising from circumstances other than those covered by the terms of the prescription ▪ individuals being unaware of the possible occupational origin of their disease ▪ a lack of knowledge regarding the availability of compensation ▪ the scheme not including self-employed workers, which is a particular issue in occupations with a high proportion of self-employed workers Large increases in claims can coincide with media campaigns, as well as with newly prescribed diseases, where an initial backlog of cases may be assessed, rather than a steady stream of incident cases. Any analysis of trends must take this into account Many of the diseases reflect occupational conditions in the past rather than current working conditions
LFS	Covers the broadest definition of work-related illness and workplace injuries, based on a large, well-established, nationally representative survey Provides a comprehensive picture of workplace injuries and work-related ill health in relation to a range of demographic and job-related factors, and a consistent time series Individuals are uniquely well placed to report details of an accident resulting in an injury and to assess the role that work factors play in their illness The LFS complements information from other data sources; there is no one definitive source that covers all aspects of either work-related illness or workplace injury	Estimates of work-related illness and workplace injury are based on survey data, and there is an element of uncertainty about these sample estimates. This generally increases as the sample size decreases Cases of workplace injury and work-related illness are based on self-reports and have not been medically verified Around one third of responses to the LFS are by proxy, usually a spouse Only limited information is available on causal factors, particularly for ill health
RIDDOR	It is an administrative resource, so already available and not subject to the complexities or costs of survey methodology	Under-reporting (apart from in relation to fatalities) The effect on trend analysis due to changes in reporting legislation

System	Strengths	Weaknesses
	The ease of understanding the basic concepts, which have changed relatively little in nearly 30 years It is comparable with international definitions The richness of the data at individual record-level. In particular, (a) details about injuries sustained and (b) free-text descriptions that may be useful for operational staff and ad hoc research	The actual time off work (in days) is not available
THOR	All consultant physicians within the relevant specialties in the UK are invited to take part in the reporting, and the participation rate and response rate have been consistently high Reported cases are clinically assessed by consultant physicians The physicians collect not only information on the diagnosis and the associated job and industry but also information on suspected causal agents to allow the further investigation of work-related causes of ill health and the identification of novel work-related health risks The THOR schemes make it possible to assess the reported incidence and incidence rates of diseases and to monitor trends over time They are long-standing clinical-based reporting schemes that date back more than 20 years. The quality of the data collected is continually assessed and improved They are complementary to other sources of data on work-related ill health and probably provide the best available data on the causal agents for occupational asthma and occupational contact dermatitis in the UK All information collected is anonymous. No identifiable information about a patient is collected	The majority of the reporters report for one randomly allocated month in each year, with a small group of about 20 reporters reporting every month The systems can capture only more serious cases of ill health that have been referred to a specialist physician and will underestimate the total burden of work-related ill health The estimated incidence rates and trends are influenced by patients' healthcare-seeking behaviours, clinical referral patterns and the reporting behaviours of the reporters, and therefore are sensitive to methodology changes The estimates of incidence rates and trends are based on many assumptions and subject to uncertainties that prevent firm conclusions being drawn
THOR-GP	Reported cases are clinically assessed and reported by GPs who have been trained at postgraduate level in occupational medicine Cases are reported according to predefined criteria	Only a small number of GPs (1 % of all GPs in the UK) report, and most report only for one randomly assigned month per year. The incidence rate and trend analyses are often based on only a few actual reported cases. The incidence rate estimates may be subject to wide random variations

System	Strengths	Weaknesses
	The system collects information on all types of work-related ill health seen in GP clinics throughout the UK	The system can capture only work-related ill-health cases seen in GP consultations
	It collects not only information on the diagnosis/symptom and the associated occupation and industry but also information on suspected work-related causes, certified sick leave days and clinical referrals that is not available from other data sources	The estimated incidence rates and trends are influenced by patients' healthcare-seeking behaviours and the reporting behaviours of the reporters and are sensitive to methodology changes
	It makes it possible to estimate incidence rates and trends for broad ill-health categories in the UK	The estimates of incidence rates and trends are based on many assumptions and subject to uncertainties that prevent firm conclusions being drawn
	It uses methods developed from other, more long-standing clinical-based reporting schemes, and the quality of the data collected is continually assessed and improved	
	It is complementary to other sources of data on work-related ill health at the national level	
	All information collected is anonymous. No identifiable information about a patient is collected	

Source: HSE, 2015a.

5.3 Registration of occupational diseases in Germany

Description of the system

In order to set up medical treatment, potential compensation and improved workplace safety, workers are advised by the statutory sectoral social security organisations (Berufsgenossenschaften) to seek medical advice as early as possible if they feel ill as a result of occupational activity. In these cases, consultation of a physician specialising in occupational medicine is advised, rather than consultation of a general practitioner. Furthermore, workers themselves may report suspected occupational diseases.

When diseases arise independently of occupational activity, the costs associated with treatment and compensation are covered by statutory health insurance or private health insurance.

Occupational diseases are monitored in Germany through the notification of cases and suspected cases by physicians and dentists, who are legally obliged to submit notifications of cases and suspected cases of occupational disease to the responsible employer's liability insurance association or to the state authority responsible for OSH when they observe disease symptoms in a patient that confirm or give reason to suspect the occurrence of an occupational disease.

Definition

Occupational diseases are defined as diseases that, according to the available knowledge in medical science, occur among individuals who, due to their occupational activity, experience a specific illness at a noticeably higher level than the overall population (in the legal statute Soziales Gesetzbuch VII (SGB VII), § 9). The list of occupational diseases is available in the Ordinance on Occupational Diseases (Berufskrankheitenverordnung) (Gesetze-im-internet.de, 2016). As of October 2017, the list comprised

80 recognised occupational diseases. The basic classification is by aetiology: Group 1, caused by chemical effects; Group 2, caused by physical effects including radiation; Group 3, caused by biological agents, as well as by topology; Group 4, diseases of the respiratory tract, pleura and peritoneum; Group 5, skin diseases; and Group 6, occupational diseases with other causes. Some of these occupational diseases can be caused or aggravated by biological agents, namely four infectious diseases, five respiratory disorders caused by organic dust and one skin disease:

A) Occupational infectious diseases

- 3101: infections in healthcare and welfare;
- 3102: zoonoses;
- 3103: worm infections among miners (*Ankylostoma duodenale* or *Strongyloides stercoralis*);
- 3104: tropical infections, typhus.

B) Occupational diseases caused by organic dust

- 4201: exogen-allergic alveolitis;
- 4202: diseases of the lower respiratory tract and lungs caused by raw cotton, flax or hemp fibre (byssinosis);
- 4203: adenocarcinomas of the nasal cavities caused by oak or beech wood dust;
- 4301: respiratory diseases caused by sensitising agents, including rhinopathy, which require the cessation of all activities that may provoke manifestation or recurrence of the disease;
- 4302: respiratory diseases caused by chemically irritating or toxic agents, which require the cessation of all activities that may provoke manifestation or recurrence of the disease.

C) Skin diseases

- 5101: severe or recurrent skin disorders, which require the cessation of all activities that may provoke manifestation or recurrence of the disease.

The German classification system for occupational diseases is similar to some degree to the international ICD-10 classification, which also has categories based on topology and aetiology, and moreover pathology, for example in the case of airway diseases.

Reporting by physicians

The physician's duty of notification is legally implemented by SGB VII, § 202. The doctor has a duty to notify regardless of the patient's consent or dissent, with a few exceptions. Importantly, the notification of an occupational disease by a physician does not violate the physician's obligations with regard to confidentiality.

The earlier a case or suspected case is recognised and notified, the more effective any subsequent medical treatment will be. Preventive measures gain efficacy if communicated and put in place at the earliest stage possible. Furthermore, worker compensation may then be claimed earlier. Suspected cases of occupational disease have to be notified as soon as symptoms occur that give reasonable grounds for being work-related, that is, caused by conditions in the work environment. It is therefore crucial that physicians are aware of the symptoms related to all the currently 77 recognised occupational diseases. These diseases are on the list of recognised occupational diseases for which compensation is provided. If the physician fails to report an occupational disease, he or she may be subject to a liability claim by the patient.

Acting as an adviser to the patient requires critical judgement and professional competence on the part of the physician. The Statutory Accident Insurance Association (DGUV) provides bulletins on individual occupational diseases, which contain information on incidence, potential sources of risk, trends and the course of the disease (BAuA, 2016a). Bulletins are available for all occupational diseases that involve or may involve biological agents, namely for occupational infections (3101 to 3104), for respiratory disorders caused by organic dust (4201, 4202, 4203), for obstructive respiratory diseases caused by organic dust (4301, 4302) and for skin diseases (5101). This may help physicians decide if they should report a case of occupational disease to the accident insurance authorities. The purpose of these extensive bulletins is to distribute information on the potential occupational causes of a disease, such as recurrent exposure scenarios, and to reduce the number of unreported cases. Accident insurance schemes are interested in facilitating the reporting procedure in order to improve occupational health care and prevention

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When diseases arise from occupational activity, the costs associated with treatment and compensation are covered by the DGUV. A form is available from the DGUV website (DGUV, 2016a) for notification of an occupational disease. Personal data are collected together with information on the potential occupational disease (and its assigned number) that may correspond to the symptoms, the symptoms themselves, the first occurrence of the symptoms, other causes that may be related to the symptoms (e.g. coughing caused by smoking), assumed causes of the disease in the workplace, effect on the ability to work of the worker, and effect on the employer. The disease field uses preset choices/categories, while the other fields are free-text fields. The physician declares that he or she has informed the patient that the case will be sent to the employer's liability insurance association or, in the case of workers for federal or state services, to the competent state institution (*Landesbehörde*). A second copy of the notification has to be kept by the physician. The notification can be sent by letter or fax. Some employer's liability insurance associations also allow notifications to be sent by email if data security will not be violated or make notification available through an online procedure. Most employer's liability insurance associations require immediate notification by phone or (e)mail in very serious cases of severe injury or fatality, which are generally related to occupational accidents rather than to occupational diseases. However, if, for example, there were suddenly high case numbers of malign cancer, in such cases immediate notification should take place first and then the form would be sent as described above.

Any physician or dentist has the right, and indeed an obligation, to evaluate the diagnosis and, if appropriate, make a notification to the DGUV if they suspect an occupational disease on the basis of medical and circumstantial indications. The notified suspected case is evaluated by responsible experts at the employer's liability insurance association on the basis of the medical diagnosis and the occupational and private circumstances of the individual and is either accepted or rejected as an occupational disease. These experts evaluate the case and must consult, if appropriate, the diagnosing physician, the worker and the employer. It is not easy to differentiate between health effects caused by occupational activity and those caused by non-work-related activity when biological agents are involved, particularly in agriculture and forestry. Smoking may also render decisions difficult. Evidently, a thorough evaluation and an evidence-based decision are strongly in the interests of the creation of a safe and healthy working environment and the fair the distribution of the associated costs among statutory health insurance associations, the DGUV and their respective insured customers.

Reporting obligations of employers

Employers are also obliged to report suspected occupational diseases. The employers' duty to notify of suspected occupational diseases is independent from the duty of physicians to notify occupational diseases (BGRCI.DE, 2016). In these cases, the worker's personal data and information on the worker's symptoms and disease form the basis of the notification, and the potential causes of the disease (e.g. activities, exposures and other causes in the workplace) are reported to the accident insurance association. Information is also provided on the results of health surveillance (preventive health examinations carried out by occupational physicians), the name of the examining physician and if there have been workplace safety controls with regard to the activities and exposures that may have caused the disease. If the employer submits the notification, one copy is sent to the employer's liability insurance association, one to the work council, and one copy is kept by the employer. Furthermore, health insurance associations may also submit notifications of cases and suspected cases of occupational disease. Like physicians, workers, employers and health insurance associations also have to report any notification to the employer's liability insurance association. Physicians and employers have forms to fill in. One study showed that, in cases dealt with by the accident insurance association for federal and state workers, 61 % of the notifications were by physicians, 9 % by statutory health insurance associations, 11 % by the insured workers themselves, 9 % by employers and 10 % by others (e.g. regional authorities for labour) (Standke, 2005).

Upon notification, the responsible employer's liability insurance association contacts the affected worker for clarification of relevant case data. The course of the disease is jointly evaluated by the worker and the employer's liability insurance association, taking into account relevant workplace conditions. At the end of the evaluation, the employer's liability insurance association makes a decision on if the notified disease indeed originates from the occupational activity of the worker. Further medical assessments may be requested.

Health surveillance

In addition, there are health examinations for preventive worker health surveillance. Periodic health examinations are obligatory for workers exposed to hazardous substances. The following types of health examination are conducted, depending on the type of exposure and the individual situation of the worker:

- pre-employment health examinations;
- health examinations for workers in hazardous jobs, including jobs involving contact with pathogens (e.g. in healthcare);
- health examinations after long periods of sick leave;
- continuous health examinations to assess work ability;
- health examinations after retirement from hazardous jobs (e.g. asbestos work).

These preventive health examinations, in the context of occupational activity, may be either optional or mandatory, depending on the professional activity (type of work) and the underlying legal provisions. General preventive health examinations are optional, because the right of an individual to decide to agree on an examination is prioritised. In some work areas, workers have to cooperate; in others, they have a choice. This is laid down in the Ordinance on Preventive Occupational Medicine (Verordnung zur arbeitsmedizinischen Vorsorge). Examples of specific work areas in which preventive health examinations are mandatory include work that involves activities with pressurised air, work that involves contact with radioactive agents, and mining, as well as work in which young workers are involved (e.g. education). With regard to biological agents, the mandatory health examinations that are in place include the protection of individuals not involved in the actual occupational activity. This is particularly relevant in healthcare and has been laid down in the Law on Protection against Infections (Infektionsschutzgesetz). The examinations need to be performed by a physician with expertise in the relevant field of occupational medicine. The employer must ensure that the examinations take place and that an appropriate physician is engaged. If the examinations indicate that workers have developed work-related diseases, this is notified to the DGUV or the relevant accident insurance association linked to it. The examinations may indicate or reveal work-related health effects when the medical data of exposed workers are compared with those of unexposed workers. However, it should be noted that the legal term ‘occupational disease’ is used in Germany only when a physician, upon examination of a patient, makes a notification because he or she perceives indications that the patient has developed a work-related disease.

Epidemiological and other studies

The BAuA and the DGUV are engaged in research and policy-making. They perform and promote field research in critical occupational sectors such as agriculture and waste handling, in which health disorders caused by occupational exposure may occur more frequently than in other sectors. For example, workers exposed to organic dust who volunteer to participate may be monitored throughout the duration of a study with varying underlying rationales and objectives.

Examples of outputs from the system

Statistics on occupational accidents and diseases are provided on an annual basis by the DGUV in reports entitled *DGUV statistics for practice* (*DGUV-Statistiken für die Praxis*) (see, for example, DGUV, 2016b). At least part of this statistical overview is also available in English (see, for example, eDGUV, 2016c). These annual publications on occupational accidents and diseases provide detailed statistics on the country’s workforce and the prevalence of accidents and diseases due to occupational activity (including travelling to the workplace). The statistics provide a list of all currently recognised occupational diseases, and compile information on notifications of suspected occupational disease cases and on confirmed cases, compensation and fatalities. A breakdown is available for the individual states of the German federation, and their individual occupational health statistics. In 2016, these data were publicly available for every year from 2007 onwards, on the DGUV’s website.

In these annual DGUV statistical publications, there is also data on specific sectors provided by the responsible employer’s liability insurance associations. These data include the number of insured companies and the size of the workforce, and also the numbers of cases of accidents, the cost of compensation, the numbers of notified suspected cases and recognised occupational diseases, retirement pensions due to occupational diseases and information on incentives for awareness raising. The distribution of specific occupational diseases across specific employment sectors cannot be retrieved from these reports.

Furthermore, the annual *Safety and health at work* reports (BAuA, SUGA, 2013 and other years) provide a statistical overview of OSH. These reports contain tables that provide data on disease groups (e.g. of the respiratory tract, of the skin, of the musculoskeletal system) by industry sector.

In addition, there are individual publications on, for example, the epidemiology of occupational infections (Fischer et al., 2013) and occupational infections in the healthcare sector (Dulon et al., 2015).

In 2017, there were 75,187 notifications of suspected cases of occupational disease, and 38,080 were recognised as occupational diseases (see Table 63). Not all of the diseases that were recognised as related to work were notified in the same year. The recognition rate can therefore not be assessed on an annual basis, as not all cases will be decided upon within the same calendar year. Furthermore, there is a distinction between recognition that a disease is work-related and actual recognition of it as an occupational disease, and even fewer occupational diseases than recognised are compensated for.

There were 2,580 fatalities due to occupational diseases in 2017. With regard to infectious diseases, in 2017, there were 2,958 notified suspected diseases, 1,332 recognised cases of occupational disease and 21 fatalities. With regard to respiratory disorders caused by organic dust and obstructive airway diseases, there were 2,848 notified suspected diseases (of which 260 were caused by organic dust), 799 recognised cases of occupational disease (of which 89 were caused by organic dust), and 52 fatalities (of which 30 were caused by organic dust). There were 27,695 notifications of suspected occupational skin diseases, 22,355 confirmed cases of occupational skin disease and 10 fatalities due to occupational skin disease.

Table 63 presents the same statistics for the period 2012-2017. Notifications have increased recently, which may point to increased awareness among workers and physicians. In comparison, confirmed cases do not show a proportional increase. Nevertheless, confirmed cases have shown a slight increase in recent years. This can be attributed to increased actual case numbers, which relates to a continuous increase in hours worked over recent years, while OSH efficacy has remained steady. The overall number of hours worked increased from 60.0 million kilohours in 2012 to 60.3 million kilohours in 2013, 60.9 million kilohours in 2014, 61.9 million kilohours in 2015 (DGUV, 2016d), 62.9 million kilohours in 2016 (DGUV, 2017a) and 64.4 million kilohours in 2017 (DGUV, 2018). In addition, in March 2014, a revised code of practice, the TRBA (Technical Rule for Biological Agents) 250 on needlestick injuries was released (ABAS/BAuA 2014). The healthcare sector is one of the most important and most affected sectors with regard to occupational infections, with 927 notified suspected occupationally acquired infections in 2014 (Dulon et al., 2015). Whether the recent reduction in occupational infections stems from the implementation of the revised TRBA 250 (ABAS/BAuA 2014) remains to be seen.

Table 63: Overview of notified suspected and confirmed cases of occupational disease due to biological agents in Germany, 2012-2017

Category	2012	2013	2014	2015	2016	2017
All diseases						
Notifications of suspected cases of occupational disease (total)	70,566	71,579	71,685	76,991	75,491	75,187
Notified cases confirmed as occupational diseases (total)	35,293	36,202	36,754	37,149	40,056	38,080
Infectious diseases						
Notified cases of infectious diseases	2,367	2,614	2,799	2,542	2,958	2,958
Notified cases of infectious diseases confirmed as occupational diseases	1,044	1,023	1,177	969	1,257	1,332
Fatalities due to infectious diseases	13	15	15	14	17	21
Respiratory disorders						
Notified cases of respiratory disorders and obstructive airway diseases	3,668 (208)	3,579 (209)	3,516 (250)	3,479 (234)	3,034 (232)	2,848 (260)
Notified cases of respiratory disorders and obstructive airway diseases confirmed as occupational diseases	1,002 (65)	949 (67)	909 (80)	973 (80)	856 (89)	799 (89)

Category	2012	2013	2014	2015	2016	2017
Fatalities due to respiratory disorders and obstructive airway diseases	54 (21)	62 (27)	56 (14)	53 (17)	41 (35)	52 (30)
Skin diseases						
Notified cases of occupational skin disease	24,619	24,393	24,355	29,573	28,881	27,695
Notified cases of occupational skin disease confirmed as occupational diseases	20,056	20,686	20,791	22,030	23,423	22,355
Fatalities due to occupational skin disease	1	1	1	2	3	10

Note: The numbers in brackets indicate the number of notifications within a group that were caused by organic dust.

Sources: DGUV, 2013, 2014, 2015, 2016d, 2017a.

Benefits and limitations of the system

Limitations

It should be noted that health disorders arising from occupational activity may not always be registered through this monitoring system.

In any case, all notified health disorders, irrespective of if the cause is identified as occupational or not, are treated. The associated costs are covered by either health insurance associations (for disorders with non-work-related causes) or employer’s liability insurance associations (for occupational disorders). The evaluation of notifications may result in the decision that cases can be attributed to non-work-related activity even if they are actually caused by effects arising from occupational activity. For biological agents, this may be the case for infections from tick bites or contact with animals, if it is possible that these incidents could have occurred during either working time or leisure time.

By definition, occupational diseases are health disorders that occur at a noticeably higher incidence in a population of people in a specific profession than in the general population. For these statistical reasons, some diseases arising from occupational activity may not be or have not yet been identified as occupational diseases. The identification of certain health disorders as occupational diseases is nevertheless flexible and designed in such a way as to incorporate novel diseases into the category of occupational diseases.

It is not always easy to distinguish those diseases that are related to exposure to biological agents, especially for those diseases that also have other causes or may be related to mixed exposure, such as exposure to organic dust. Therefore, it is crucial to gain more information on specific exposures of workers in certain professions to certain biological agents. There is some information from workplace measurements but unfortunately these are not directly related to and fed into the recognition system for occupational diseases, although they are managed by the same umbrella organisation.

Benefits

Cases and case numbers of occupational diseases provide a comprehensive picture of health effects in a wide range of occupational activities. This is achieved through notifications and the subsequent evaluation and decision on occupation or non-occupational illness. If rates of notifications and confirmed cases increase, a closer look at OSH implementation at the relevant sites or branches may be taken. This is carried out by competent authorities and by field contact persons and OSH experts in employer's liability insurance associations. In this way, the system ensures monitoring of the treatment, rehabilitation and compensation of affected workers, and also provides data for OSH assessments.

5.4 Registration of occupational exposures in Germany

Occupational exposure to biological agents in Germany is monitored by research and development projects as well as routine data collection conducted by the BAuA, the Institute for Occupational Safety and Health of the German Social Accident Insurance Institutions (Institut für Arbeitsschutz, IFA), the DGUV, accident insurance associations, employer's liability insurance associations and individual universities. These institutes have joint projects and initiatives, for example aerosol research on biological agents that workers are exposed to unintentionally in industry and agriculture. These activities provide insights into workplace exposures, and the results may support policy advice and scientific publications. Research funding of individual projects is decided on at federal level or provided by third parties, for example the DGUV, or both.

Exposure measurement projects are often initiated by employer's liability insurance associations in sectors with known high exposure and reported adverse health effects. Sectors in which exposure to biological agents are critical are agriculture, waste handling and specific areas of metalworking that use water-miscible metalworking fluids. In the past, many attempts to measure exposure have provided valuable data, but these have been conducted with varying protocols, leading to results that are not directly comparable with each other.

In recent years, molecular techniques, as well as standardised microbiological assays for reproducible measurements of occupational exposure to biological agents, have increasingly been developed and established. In contrast to the mandatory exposure measurements of hazardous chemical agents, measurements of occupational exposure to biological agents are not mandatory. Under the current legislation, measurements of biological agents and exposure monitoring are not mandatory at federal or regional state level. Accident insurance associations have nevertheless established individual data collection strategies that can be used by scientists and consultants. Measurements, for example sampling of bioaerosols, are conducted on site and microbiological data are generated and collected by the laboratories of the IFA, which is associated with the DGUV. In this regard, reference is made to the DGUV's MEGA database (see section 5.4.3).

At present, no national monitoring system for exposure to biological agents is in place, and there is no legally binding requirement for the existence of such a system. Furthermore, Germany has no upper limit values for biological agents, unlike in the case of hazardous chemical agents, for which upper limits exist and have to be implemented by applying technical and organisational measures, and as a last resort, the use of PPE. However, a technical control value for spores of mesophilic moulds in the air at waste handling facilities has been set (5×10^4 spores per m^3 of respiratory air, according to TRBA 214) (ABAS/BAuA, 2018). To date, no other technical control values exist.

Research conducted by BAuA

With regard to the analysis of occupational exposure to biological agents, the major activity of the BAuA is in the agricultural sector, particularly in livestock raising facilities, where workers are at increased risk of respiratory disorders. Respiratory disorders in livestock workers are associated with elevated concentrations of airborne microorganisms, also referred to as bioaerosols. These bioaerosols are mainly bacteria and fungi, and subcellular aerosolised particles deriving from them and from higher organisms.

Previous and ongoing research projects undertaken by dedicated working groups, in particular Unit 4.7 on biological agents at BAuA, focus on these issues (BAuA, 2016b). Ongoing projects focus on health risks in poultry farming, the use of rRNA gene libraries to characterise biological agents in the air in workplaces, exposure to biological agents in biogas production, antibiotic-resistant bacteria in emissions from industrial livestock farming, exposure of hatchery workers to airborne bacteria taking into account existing antibiotic resistance, and the detection of airborne biological agents under difficult analytical conditions. In the past, projects have focused on health risks in composting plants, and the development of a gene-based detection system for bacteria as causative organisms for respiratory problems due to bioaerosols in workplaces. The validation of a fluorescence-microscopy method for analysing bioaerosol samples from different workplaces has also been investigated. Project results are published in scientific papers or as reports in German or English (BAuA, 2016c).

To further explore the relationship between high bioaerosol concentrations in livestock production facilities and respiratory disorders in exposed workers, the BAuA group on biological agents conducts field sampling and subsequent bioaerosol investigations using microbiological and molecular techniques. Further research fields in relation to occupational exposure to biological agents are waste recycling and paper production.

One focus of the research performed by BAuA, the IFA and other institutes is the quantification of exposure. Since many airborne microorganisms are not readily amenable to cultivation, culture-dependent investigations are complemented with culture-independent microscopic quantification techniques based on DNA staining ([16]).

Another focus is identification: genetic information is obtained from DNA that has been isolated from bioaerosol field samples and prepared for DNA sequencing. Information on bioaerosol composition (i.e. on microbial species occurring in the air of sampled workplaces) is gathered from DNA sequences and interpreted using the available information on occurring microbial species. This method also allows for the identification of novel species and may thus lead to further investigation into their putative contribution to occupational health disorders.

In one research project in a facility for duck breeding, two different personal air sampling devices were used to identify potential differential sampling bias. To obtain a detailed picture of the heterologous composition of bioaerosol in stables of intensified livestock rearing, aerosol samples were analysed with microbiological and molecular tools (Martin et al., 2015,). Furthermore, another project found that eggshells from a turkey hatchery provided a relevant source of bacteria with impact on workplace airborne exposure (Brauner et al., 2016).

Classification of biological agents

A crucial aspect of exposure assessment is the combination of qualitative and quantitative risk. An important tool for qualitative risk assessment is the classification of biological agents into risk groups, which is organised in Germany by the Committee for Biological Agents (Ausschuss für Biologische Arbeitsstoffe, ABAS). In this committee, experts in occupational safety from the accident insurance associations work together with federal authorities. The procedure and criteria for classification into risk groups are outlined in TRBA 450 (ABAS/BAuA, 2016a). It is based on and expands on the regulations set out in Directive 2000/54/EC. Classified biological agents are listed in individual TRBAs for bacteria (TRBA 466) (ABAS/BAuA 2015), fungi (TRBA 460) (ABAS/BAuA 2016b), viruses (TRBA 462) (ABAS/BAuA 2012) and parasites (TRBA 464) (ABAS/BAuA 2013). In addition to the biological agents listed in Annex III to Directive 2000/54/EC (classified in risk groups 2-4), these TRBAs include biological agents in Risk Group 1 (according to Directive 2000/54), which means that they do not have the potential for infection according to current knowledge. Particular attention is paid to both the infection potential, which determines the classification, and the sensitising and toxic potential of the biological agents. If biological agents have hazardous properties independently of their infection potential, this is noted through the use of additional labels.

Some of this information is provided in the GESTIS Biological Agents Database (see Section 5.4.4)

([16]) Staining is an auxiliary technique used in microscopy to enhance contrast in the microscopic image. Stains and dyes are used to highlight structures in biological tissues for greater visibility. In biochemistry, it involves adding a class-specific (DNA, proteins, lipids, carbohydrates) dye to a substrate to qualify or quantify the presence of a specific compound.

The MEGA exposure database

The results of exposure measurements are published in the MEGA database (Messdaten zur Exposition gegenüber Gefahrstoffen am Arbeitsplatz, Data on Exposure to Hazardous Agents in the Workplace) provided by the DGUV and the IFA (DGUV, 2016e). MEGA is a compilation of data gathered through atmospheric measurements and material analyses. Data on hazardous chemicals have been compiled in the database since 1972. For a few fields, early (archived) data has been added from other sources at a later date. Measurement values are available from 1962 onwards. Since 1998, the documentation has included data on biological agents in the workplace. The data are gathered through the measurement system for exposure assessment run by the German Social Accident Insurance Institutions. The data in the MEGA database provide information on:

- the industrial workspace;
- working and manufacturing methods;
- substances used;
- protective measures;
- the exposure situation;
- the conditions under which sampling and chemical analysis take place.

At the end of 2015, 2.95 million data records were available, collected in 67,000 companies in 802 sectors with 4,891 workspaces, covering 33,510 combinations of sectors and workspaces. The substances analysed comprise 871 hazardous chemicals and 661 biological agents.

The MEGA exposure database is maintained and evaluated for statutory accident insurance and prevention institutions by the IFA of the DGUV. The MEGA data pool is available to institutions associated with the DGUV and covers background information to improve prevention, epidemiological issues, retrospective exposure assessments in connection with suspected substance-related occupational diseases, and identification of exposures reflecting the current exposure situations in specific workplaces. There is no direct access for bodies other than statutory accident insurance and prevention institutions.

Biological agents measured in workplaces in various industries include moulds, bacteria and endotoxins. Since 2000, data have been stored on the MEGA database, which contains data on whole colony counts for single species of different bacteria and fungi (including yeasts). The DGUV’s biological agents unit has analysed the MEGA data for concentrations of moulds and endotoxins in workplaces. An extract from this analysis has been published in TRBA 400 on risk assessment (ABAS/BAuA 2017), which has been updated to take this information into account.

Selected measurement results from the MEGA database

Publications containing MEGA data are available through the DGUV, and some of them cover biological agents (see, for example, DGUV, 2016f). The IFA has published a report on the microbiological background values of outdoor air, which provides an overview of moulds and fungi, bacteria and endotoxin concentrations in the outdoor air at various measurement sites in Germany. A total of 1,172 measurement results were analysed over an 8-year period (Kolk et al., 2009).

The DGUV has also published reports on the bioburden of water-miscible cutting coolants, which states that microorganisms thriving in these types of cutting coolants are widespread and include frequently occurring environmental bacteria belonging to Risk Groups 1 and 2 (DGUV, 2011, 2016g). However, no limits or guidance values are available to help in assessing the microbial colonisation of water-based cutting fluids. Cutting fluids represent a health hazard to workers for several reasons. Chemicals may be irritating or toxic to the skin and respiratory tract through aerosol generation during turning. As it may not be possible to use gloves when handling machinery with turning parts because of the risk of entanglement and injury, the skin of the hands may be particularly exposed. Water-miscible cutting coolants also provide an environment that encourages the development of microorganisms, particularly bacteria and fungi, which can release sensitising cellular breakdown products and metabolites such as endotoxins and mycotoxins. In addition, as the technical functions of the fluids can be compromised by microbial growth, biocides are generally applied. The generation of inhalable aerosols mainly occurs at the tool-workpiece interface. However, machinery can be fitted with various types of shielding to reduce the aerosol exposure of workers.

In addition, a publication on endotoxin exposure in natural fibre textile processing and manufacturing is available (Kraus et al., 2007). Depending on their origins, as well as on the degree of contamination and on the processing methods, moulds, bacteria, endotoxins and other substances are released during the processing of natural fibres. A large variation in endotoxin values was observed, which did not correlate with the observed dust concentrations. Microbe-contaminated raw cotton fibres caused the highest bacteria and endotoxin emissions in spinning mills, with levels decreasing from around 2,000 endotoxin units ([17]) (EU)/m³ to around 10 EU/m³ during the course of the spinning process. In cotton knitting mills, the measured values were around 120 EU/m³, and in weaving mills around 70 EU/m³; even lower values were observed for mixtures with man-made or other fibres. Primary technical measures reduced inhalation exposure, and PPE was considered necessary when carrying out maintenance of ventilation equipment. The authors state that preventive measures, along with occupational medical prevention, are more practical means of avoiding work-related health impairment than health-based limit values

Finally, a publication on endotoxin exposure in the workplace is also available (Kolk and Koppisch, 2007). By 10 November 2006, 1,681 air samples with an exposure reference for endotoxins were available in the MEGA database. These measurements originated largely from textile plants, various

([17]) Because endotoxin molecular weight may vary a great deal (10,000-1,000,000 Da), endotoxin levels are measured in 'endotoxin units' (EU). One EU is approximately equivalent to 100 pg of *E. coli lipopolysaccharide* — the amount present in around 105 bacteria. Humans can develop symptoms when exposed to as little as 5 EU/kg of body weight. These symptoms include but are not limited to, fever, low blood pressure, increased heart rate and low urine output; even small doses of endotoxin in the bloodstream are often fatal.

facilities in the agricultural sector, companies that were members of the wholesale trade and warehousing trade association, and waste incinerators. After the textile sector, with 394 measurements, the sea transport sector provided the second largest number, with 261 measurements. A project was carried out in this sector after occupational physicians observed that 50 % of all cases of ill health aboard German seagoing vessels were diseases of the upper respiratory tract. Since very low concentrations of endotoxins were observed (mean values between 0.2 EU/m³ and 16.2 EU/m³ and a highest observed level of 292 EU/m³), endotoxin exposure does not seem to be the primary cause of the observed respiratory diseases in this sector.

GESTIS Biological Agents Database

The GESTIS Biological Agents Database is part of the DGUV's hazardous substance information system (GESTIS) (DGUV, 2017b, Smola et al., 2017). It is a joint project by the DGUV, the German Social Accident Insurance Institution for the Raw Materials and Chemical Industry (BG RCI), the Federal Ministry for Labour and Social Affairs and the IFA. The biological agent datasheets originating from the system are issued by acknowledged experts on behalf of the BG RCI.

Biological agent datasheets containing basic information

GESTIS contains so-called basic information on almost 15,000 biological agents. In addition to their classification into risk groups, it also outlines basic OSH measures for 'specific' activities with biological agents in laboratories, with laboratory animals and in biotechnology. These basic datasheets also include links to relevant information on the biological agent in question, where available. Biological agent datasheets containing basic information can be found by searching the database in various ways and there is also an alphabetical list.

For biological agents considered high priority, these datasheets are developed further by experts to create biological agent datasheets containing extended information. These datasheets provide details of medical significance, the relevant sectors and activities, protective measures for specific pathogens, decontamination, first aid measures, preventive health care, morphology and physiology, natural distribution, occurrence, pathogenicity, diseases, epidemiology, resistance and legal principles.

Activity datasheets

Datasheets are issued not only on biological agents but also on activities. The GESTIS database contains on the one hand information on safe activities with biological agents, that is, the technical, organisational and personal protection measures required when carrying out specific activities in laboratories, in biotechnology and with laboratory animals. It also supplies information on important properties of the various biological agents, for example where they occur and their pathogenic properties.

Information on activities in other sectors in which biological agents may occur ('non-specific' activities, such as litter collection or the wastewater industry) can be found in non-specific activity datasheets. During many activities, there is unintentional contact with biological agents, although it is often not known which biological agents are actually present. The Biological Agents Ordinance terms such activities 'non-specific activities'. These include activities in in the waste industry, wastewater treatment, agriculture and forestry, the healthcare sector, and cleaning and refurbishment of buildings. If a risk assessment has to be performed for such activities, it is not usually sufficient to examine the properties of the biological agent. Suitable activity datasheets are gradually being issued through GESTIS for such activities. The activity datasheets provide information on biological agents that may arise during these activities, their routes of transmission and possible risks, and they list the technical, organisational and personal protective measures to be taken. In addition to references to the relevant rules and regulations, there are also links to operational instructions for practitioners in various sectors and activities that need to be adapted within individual companies following workplace risk assessment.

Biological agent and activity datasheets can either be selected from an alphabetical list or searched for with the aid of various filters.

GESTIS has the following data structure:

- General information
    - Name and synonyms
    - Document number
    - Category of the biological agent (bacterium, parasite, fungus, virus)
    - Genus
    - Pathogen classification
    - Strain type
    - Risk group
    - Note
    - Conciliar/reference laboratory
    - Picture
    - Medical significance
    - Transmission routes
- Occupational safety and health
    - Sector
    - Activity
    - Workplace signs
    - Protective measures (technical, organisational, personal, occupational hygiene, vaccination)
    - Inactivation/decontamination measures
    - Immediate measures/first aid/post-exposure prophylaxis
    - Occupational healthcare
- Morphology and physiology
    - Morphology
    - Physiology
    - Information on molecular biology
- Occurrence/natural habitat
    - Free-living/host-bound
    - Hosts
    - Transmission vectors
    - Geographic distribution
- Pathogenicity/pathogenic properties
    - Pathogenicity
    - Minimal infective dose
    - Carcinogenicity/mutagenicity/reproductive toxicity
    - Allergenicity/sensitising effect
    - Toxigenicity/toxin formation
- Disease
    - Name
    - Zoonosis
    - Infectious stages
    - Incubation period
    - Potency
    - Symptoms and course of disease
    - Lethality
    - Therapy
    - Prophylaxis
- Epidemiology
    - Transmission routes/portal of entry
    - Pathogen reservoir

  - o Incidence
- Resistance/tenacity
  - o Sporulation
  - o Conidia formation
  - o Resistances
- Legal principles/regulations
  - o Laws and ordinances
  - o Technical rules and other regulations.

5.5 Registration of occupational diseases in France

Description of the National Network for Monitoring and Prevention of Occupational Diseases (rnv3p)

The National Network for Monitoring and Prevention of Occupational Diseases (Le Réseau national de vigilance et de prévention des pathologies professionnelles, rnv3p) was created in 2001 on a voluntary basis in collaboration with some occupational disease clinics (ODCs). In 2007, the French Agency for Food, Environmental and Occupational Health and Safety ([18]) (L'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, ANSES) took over the coordination of the network. Since 2008, according to the agreement between ANSES and each teaching hospital on ODCs, it is obligatory to record all consultations in ODCs. Since 2016, rnv3p has brought together all the 31 ODCs in mainland France and 9 occupational health services (OHSs) as part of the network (Figure 7).

The network provides records of all consultations carried out in the ODCs and all occupational health problems diagnosed by the OHSs participating in rnv3p (i.e. demographic data, and data on diseases, exposures, industry sectors, professions, causality links between diseases and exposures) in a standardised way. Occupational physicians, other clinical experts and their staff record the data.

The main objectives of the rnv3p network are to:

- identify and describe occupational health risk situations in France;
- investigate new aetiologies and emerging risks;
- improve and harmonise diagnostic practices in relation to work-related diseases.

As operator of the network, ANSES is responsible for coordinating all its activities in partnership with:

- The National Health Insurance Fund for Salaried Workers, CNAM-TS ([19]): responsible for coordinating all activities related to workplace accidents and occupational diseases. It funds some consultations in ODCs and coordinates the regional prevention activities of stakeholders.
- The National Health Insurance Fund for Agricultural Workers and Farmers, CC-MSA ([20]): its main mission is the prevention of ill health among agricultural workers.
- The French national public health agency, SPF ([21]): its main objectives as regards occupational health are epidemiological observation and monitoring of the population's health status, particularly through the coordination of the network of occupational physicians responsible for signalling health

([18]) ANSES's duties include risk assessment in the fields of food, the environment and the workplace, for the purpose of assisting the authorities with their policies on health and safety. ANSES is a public organisation reporting to the Ministries of Health, Agriculture, the Environment, Labour and Consumer Affairs (https://www.anses.fr/fr/node/79617).

([19]) http://www.securite-sociale.fr/Professionnels?id_mot=65

([20]) http://www.msa.fr/lfr

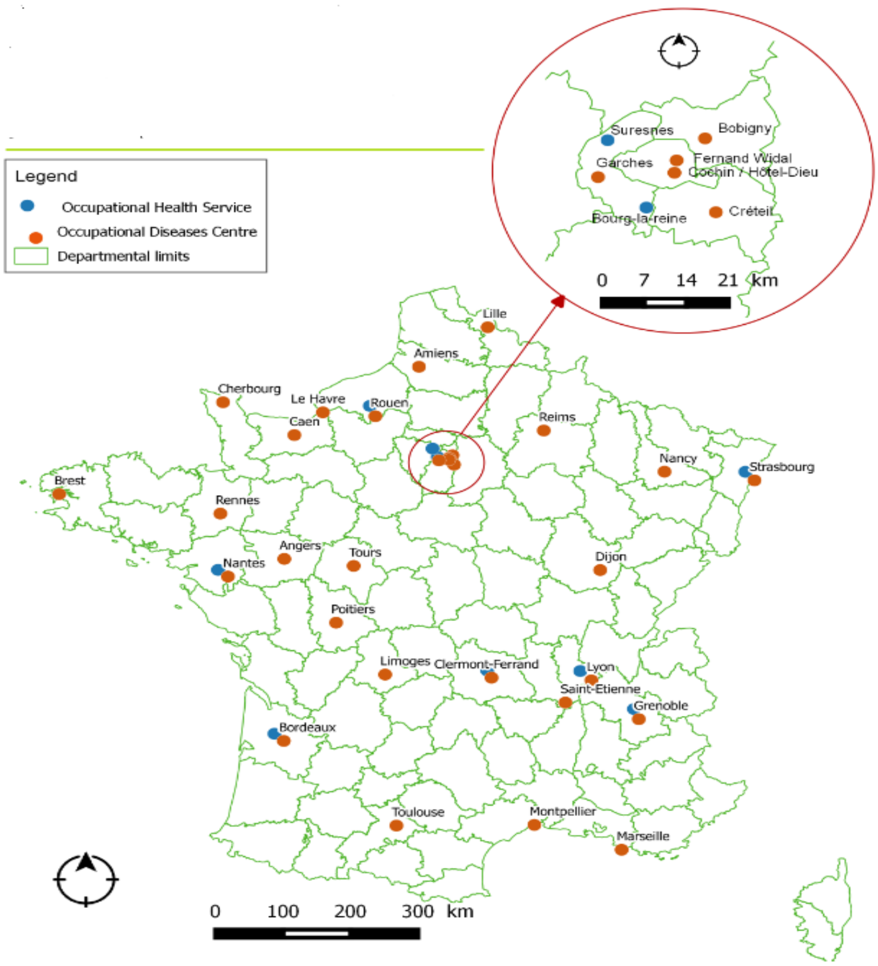
([21]) http://www.invs.sante.fr/en

events judged to be of professional origin (the work-related disease programme) and through the implementation of specific programmes for monitoring professional risks.

- The national OSH institute, INRS ([22]), the French institute competent in the area of occupational risk prevention: its objectives include anticipating needs (through studies and research programmes), raising awareness (through information products and prevention campaigns) and assistance (through technical guidance, information resources and training).
- The French Society for Occupational Medicine, SFMT ([23]): it is responsible for the dissemination of rnv3p information to occupational physicians through its website and meetings. It participates in running rnv3p and checking the data.

These activities include participation in the network's funding, collaboration on various joint projects (partnership) and defining the direction of the network together.

Figure 7: The French National Network for Monitoring and Prevention of Occupational Diseases (rnv3p) in 2016



Source: rnv3p/ANSES

([22]) http://en.inrs.fr/
([23]) http://www.chu-rouen.fr/sfmt/pages/accueil.php

The rnv3p network is thus simultaneously a network of experts in the field of occupational diseases (academics, practitioners and institutional experts sharing information through working groups, comittees and other forms of information exchange) and a health database containing information on diseases and occupational exposure.

ANSES publishes an annual activity report based on the data collected by the network, which is available on its website (ANSES, 2016).

For inclusion in the national rnv3p database, data are recorded according to the following (international) standards:

- **Diseases:** World Health Organization (WHO) International Classification of Diseases (ICD), 10th revision (ICD-10).
- **Occupations:** International Standard Classification of Occupations (ISCO-08). Between 2001 and 2013, the 1988 version was used. Since 2014, the new information system has used the 2008 version.
- **Industry sectors:** French Classification of Activities (NAF-08). Between 2001 and 2013, the 1993 version was used. Since 2014, the new information system has used the 2008 version.
- **Occupational exposures:** French Thesaurus of Occupational Exposures (TOE), a dedicated classification (a modified version of the European Classification of Causal Agents of Occupational Diseases).

The French TOE was developed by a working group of experts involved in the rnv3p system in collaboration with many institutions working in occupational health in France (associations of occupational health services, SPF, INRS, SFMT, CNAM-TS, CCMSA and CISME/PRESANSE([24]). The aim of the TOE is to provide occupational health stakeholders with a common reference tool for coding occupational exposures. The TOE ensures that the users share the same references in order to:

- ensure the continuity of worker monitoring;
- facilitate cooperation among partners;
- enable the data provided to be exploited;
- contribute further to protecting workers' health.

The new Beta-2 version of the TOE (available since 2014) contains more than 8,000 labels, and is divided into two parts:

- substances and agents, with six categories (chemical agents, biological agents, stone and mineral substances, physical agents, biomechanical factors, and organisational and managerial factors);
- context of use and industrial process.

About 3,000 out of the more than 8,000 labels relate to biological agents, which are divided into the following categories: microorganisms (bacteria, viruses, fungi, parasites), animals (invertebrates, vertebrates) and plant materials. Users of the TOE are provided with guidelines. The TOE does not provide information on exposure levels but does provide an assessment of work-relatedness (in which the attribution of a disease to exposure in the workplace is assessed by clinical experts in terms of the overall relation between exposure and disease). The TOE is shared at a national level by a majority of the partners in the system, which allows for comparable recorded information on exposures to biological agents, and it can also be expanded with new exposures. These additions are always discussed by a TOE working group.

Medical experts also assess the causal relationship between exposure and disease (as unlikely, possible, probable or certain). Carrying out this assessment of the causal relationship forms part of the training of the clinical experts operating within the network.

([24])Centre Interservices de Santé et de Médecine du travail en Entreprise, now PRESANSE (**Pr**évention, **san**té, **s**ervices, **e**ntreprises), representing the occupational health centres at enterprise level.

Information on rnv3p, including the database, is directly available to all the network's partners (all 31 ODCs and 9 OHSs of rnv3p and all institutional partners (CNAM-TS, CCMSA, SFP, INRS and SFMT)) via a secure website (https://www.rnv3p.fr). Anyone outside the network can also access the data by making a request to ANSES.

Examples of reports from the system on exposure to biological agents

Information on biological agents for the period 2001-2015 was extracted from the national rnv3p database, consisting of:

- data recorded either by ODCs or by OHSs;
- health effects labelled 'work-related diseases';
- exposures for which a causal association between the main disease and the biological exposure was at least 'possible'.

From 2001 to 2015, exposure to biological agents accounted for only a relatively small percentage of all reported work-related diseases. Of the 127,801 occupational health problems that were recorded as work-related diseases in the national database, only 2,742 (2 %) were related to at least one biological exposure. Patients with work-related diseases due to exposure to biological agents were mostly male (60.2 %; *n* = 1,650). The average age in this group was 43.1 years for men and 40.6 years for women.

As one work-related disease can be related to several exposures, the 2,742 work-related diseases due to exposure to biological agents were related to 3,210 exposures to biological agents (see Annex 7). Table 64 provides an overview of exposure to biological agents reported over the period 2001-2015. During this period, the numbers of reported exposures to biological agents seem stable, with the exception of the categories of animal and plant material, representing more than 70 % of total exposures to biological agents. More details on these biological agent groups (e.g. on the types of microorganism) can be found in Annex 7.

Table 64: Overview of exposure to biological agents reported over the period 2001-2015 in the national rnv3p database in France

Biological agents	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Microbiological	49	55	60	59	59	46	41	76	54	54	37	55	66	34	55	800
Bacteria	16	13	6	13	16	10	9	27	15	20	13	15	16	11	14	214
Fungi	27	26	33	27	29	21	24	35	33	22	16	21	42	19	35	410
Parasites	0	3	3	3	3	1	0	2	0	2	0	2	0	0	0	19
Viruses	5	7	6	14	10	9	8	7	3	5	4	15	6	4	6	109
Microbiological, other	1	6	12	2	1	5	0	5	3	5	4	2	2	0	0	48
Animal origin	71	66	66	81	61	41	81	65	67	50	46	57	84	80	71	987
Invertebrates	45	54	35	55	33	25	53	40	37	33	29	35	47	50	58	629
Vertebrates	26	12	31	26	28	16	28	25	30	17	17	22	37	30	13	358
Plant material	78	73	68	63	59	64	65	80	81	75	66	71	160	217	140	1,360

Biological agents	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Algae	1	0	1	0	0	0	0	0	1	0	0	0	1	4	0	8
Lichen and foam	0	0	1	0	0	1	0	0	0	0	0	1	0	1	2	6
Trees and plants	76	71	66	62	58	63	64	78	79	75	66	70	158	208	134	1,328
Other vegetable material	1	2	0	1	1	0	1	2	1	0	0	0	1	4	4	18
Specific biological rnv3p codes ([a])	3	5	1	7	3	5	4	4	5	2	5	4	8	6	1	63
Total	201	199	195	210	182	156	191	225	207	181	154	187	318	337	267	3,210

([a]) Biological agents not yet included in the TOE.

Source: national rnv3p database; output generated by ANSES in April 2016.

Table 65 provides an overview of the industry sectors in which the 2,742 work-related diseases due to exposure to one or more biological agents recorded over the period 2001-2015 were reported. More than 60 % of the work-related diseases occurred in seven industry sectors: food industries (12.6 %), health and social care (12.3 %), farming, hunting and ancillary services (7.2 %), retail trade and repair of household goods (8.5 %), construction (7 %), hotels and restaurants (6.1 %) and public administration (5.5 %).

Table 65: Overview of industry sectors (according to NAF-93[25]) for which work-related diseases due to exposure to one or more biological agents were reported in rnv3p over the period 2001-2015 in France

Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Food industries	15	25	20	24	18	19	16	27	21	17	9	11	42	46	36	**346**
Health and social services	18	17	13	24	20	15	23	35	12	29	23	29	29	29	22	**338**
Farming, hunting,	17	13	14	13	9	17	13	27	17	11	15	20	31	17	20	**254**

([25]) The Nomenclature des Activités Francaises (NAF) is a statistical nomenclature used in France that allows the codification of the main activity carried out in a company or association, i.e. NAF code. It is equivalent to the Euroepean NACE code , the Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE (for the French term "nomenclature statistique des activités économiques dans la Communauté européenne"), the industry standard classification system used in the European Union.

Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
ancillary services																
Retail trade and repair of domestic goods	11	14	16	22	19	12	20	15	16	17	11	7	10	25	17	**232**
Construction	7	8	14	12	3	6	10	7	6	7	8	5	30	51	19	**193**
Hotels and restaurants	7	11	6	8	4	14	16	16	25	12	12	13	9	7	8	**168**
Public administration	6	9	7	7	5	5	7	14	15	11	7	7	21	16	14	**151**
Services provided mainly to enterprises	9	9	8	5	10	6	5	11	0	5	2	7	10	16	14	**117**
Research and development	8	6	9	7	9	4	6	8	5	4	5	10	10	5	2	**98**
Education	4	8	7	4	4	5	8	4	8	5	8	3	10	9	11	**98**
Manufacture of wood and wood products	5	7	3	9	3	8	5	2	5	5	5	4	1	0	0	**62**
Wholesale trade and intermediary trade	4	4	2	6	7	3	4	1	5	3	1	6	0	0	0	**46**
Chemical industry	3	6	2	3	2	2	1	0	5	2	0	1	2	2	2	**33**
Personal services	3	1	1	1	1	0	4	4	3	1	0	5	7	1	4	**36**
Others	61	43	48	38	29	21	22	30	35	32	25	33	52	50	52	**570**

Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Total	**178**	**181**	**169**	**183**	**143**	**137**	**160**	**201**	**178**	**161**	**131**	**161**	**264**	**274**	**221**	**2,742**

Source: national rnv3p database; output generated by ANSES in April 2016.

Examples of reports on work-related diseases due to exposure to biological agents

Over the period 2001-2015, 2,742 work-related diseases were related to at least one exposure to biological agents, of which for 1,237 work-related diseases a strong causality with exposure to biological agents was indicated. Table 66 presents an overview of work-related infectious diseases and diseases caused by parasites for which biological agents were indicated as the cause of the disease, reported over the period 2001-2015. Of the 194 work-related diseases reported, tuberculosis forms the biggest group (n = 60), followed by mycoses (n = 37) and viral hepatitis (n = 22).

Another relevant category of reported occupational diseases is non-infectious diseases, such as hypersensitivity pneumonitis due to exposure to organic dust (allergic alveolitis, farmer's lung, mushroom worker's lung, etc.). An overview of hypersensitivity pneumonitis due to exposure to organic dust reported over the period 2001-2015 is given in Table 67. Farmer's lung represents a third of all hypersensitivity pneumonitis cases reported.

Table 66: Overview of reported work-related infectious and parasitic diseases over the period 2001-2015 for which biological agents were indicated as the cause of the disease in the national rnv3p database in France (by ICD-10 category, A00-B99).

ICD-10 code	ICD-10 category (A00-B99)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
A00-A09	Intestinal infectious diseases	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
A15-A19	Tuberculosis	4	7	0	3	9	2	3	5	4	6	3	3	3	4	4	60
A20-A28	Certain zoonotic bacterial diseases	2	1	1	1	0	1	1	1	1	0	0	0	0	0	3	12
A30-A49	Other bacterial diseases	0	1	0	1	0	2	0	2	1	2	0	2	2	0	0	13
A50-A64	Infections with a predominantly sexual mode of transmission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ICD-10 code	ICD-10 category (A00-B99)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
A65-A69	Other spirochaetal diseases	0	0	0	0	0	1	0	1	0	0	0	3	0	0	1	6
A70-A74	Other diseases caused by *Chlamydia*	1	1	0	1	0	0	0	0	0	0	1	0	1	0	0	5
A75-A79	Rickettsioses	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
A80-A89	Viral infections of the central nervous system	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A90-A99	Arthropod-borne viral fevers and viral haemorrhagic fevers	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
B00-B09	Viral infections characterised by skin and mucous membrane lesions	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	4
B15-B19	Viral hepatitis	1	3	3	3	0	1	2	0	0	0	0	4	1	0	4	22
B20-B24	HIV infection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B25-B34	Other viral diseases	0	0	0	0	0	0	0	0	0	0	0	7	1	1	0	9
B35-B49	Mycoses	3	2	4	5	3	0	2	3	3	2	0	1	3	3	3	37
B50-B64	Protozoal diseases	0	1	2	0	1	0	0	0	0	0	0	0	0	0	1	5
B65-B83	Helminthiases	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

ICD-10 code	ICD-10 category (A00-B99)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
B85-B89	Pediculosis, acariasis and other infestations	0	0	0	0	1	0	5	0	0	6	0	2	1	0	0	15
B90-B94	Sequelae of infectious and parasitic diseases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B95-B98	Bacterial, viral and other infectious agents	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
B99	Other infectious diseases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A00 - B99	Total	12	16	11	14	14	9	13	14	10	16	6	22	13	8	16	194

Source: national rnv3p database; output generated by ANSES in April 2016.

Table 67: Overview of hypersensitivity pneumonitis due to exposure to organic dust over the period 2001-2015 for which biological agents are indicated as the cause of the disease in the national rnv3p database in France (ICD-10: J67)

ICD-10 code	Disease	2001-2015
J67	Hypersensitivity pneumonitis due to organic dust	25
J67.0	Farmer's lung	20
J67.2	Bird fancier's lung/disease	3
J67.5	Mushroom worker's lung	1
J67.8	Hypersensitivity pneumonitis due to other types of organic dust (cheese washer's lung, coffee worker's lung, fishmeal worker's lung, furrier's lung, sequoiosis ([a])	3
J67.9	Hypersensitivity pneumonitis due to unspecified organic dust (allergic alveolitis (extrinsic) NOS, hypersensitivity pneumonitis NOS)	7

ICD-10 code	Disease	2001-2015
	Total	**59**

Note: Because of the small totals, the results for 2001-2015 have been pooled.

([a]) Extrinsic allergic alveolitis caused by inhalation of redwood sawdust containing spores of *Graphium*, *Pullularia*, *Aureobasidium* and other fungi.

Source: national rnv3p database; output generated by ANSES in April 2016.

As an example of a more detailed output from the rnv3p system, in Table 68, the output on hypersensitivity pneumonitis is further subdivided by biological agent, sector and level of causality. Nearly half of the biological agents belong to the 'fungi, mould' category, with 'vertebrate' being the next largest category. The main industry sectors concerned are farming, hunting and ancillary services and food industries.

Table 68: An example of a more detailed output from the rnv3p system on hypersensitivity pneumonitis in France (ICD-10: J67; J67.0; J67.2; J67.8; J67.9) by biological agent, sector and level of causality

Biological agents/industry sectors	Causality		
	Weak	Medium	Strong
Microbiological	**0**	**3**	**3**
Fabrication of machines and equipment	0	1	0
Farming, hunting and ancillary services	0	1	3
Food industries	0	1	0
Bacteria			
Actinobacillus actinomycetemcomitans	**0**	**0**	**2**
Agricultural and animal production, hunting and ancillary services	0	0	1
Farming, hunting and ancillary services	0	0	1
Micropolyspora faeni	**0**	**0**	**3**
Agricultural and animal production, hunting and ancillary services	0	0	1
Farming, hunting and ancillary services	0	0	2
Mycobacterium	**0**	**0**	**1**
Automobile industry	0	0	1
Mycobacterium vaccae	**0**	**0**	**1**

Biological agents/industry sectors	Causality		
	Weak	Medium	Strong
Automobile industry	0	0	1
Streptomyces	**0**	**0**	**1**
Food industries	0	0	1
Thermoactinomyces	**0**	**1**	**1**
Public administration	0	1	1
Thermoactinomyces vulgaris	**0**	**0**	**2**
Agricultural and animal production, hunting and ancillary services	0	0	2
Other bacteria	**0**	**0**	**1**
Farming, hunting and ancillary services	0	0	1
Fungi, moulds			
Fungi, moulds	**5**	**13**	**23**
Activities for human health	1	0	0
Agricultural and animal production, hunting and ancillary services	2	2	3
Construction	0	0	1
Farming, hunting and ancillary services	1	4	9
Food industries	1	2	6
Leisure, cultural and sports activities	0	2	0
Public administration	0	0	2
Unknown	0	0	1
N/A	0	3	1
Specific fungi/classes			
Actinomyces	**0**	**3**	**2**
Agricultural and animal production, hunting and ancillary services	0	1	1
Farming, hunting, ancillary services	0	1	1
Food industries	0	1	0

Biological agents/industry sectors	Causality		
	Weak	Medium	Strong
Alternaria alternata	**0**	**1**	**0**
Food industries	0	1	0
Aspergillus	**0**	**2**	**6**
Farming, hunting and ancillary services	0	0	5
Food industries	0	2	0
Sanitation, roadway work and waste handling	0	0	1
Aspergillus fumigatus	**1**	**0**	**1**
Farming, hunting and ancillary services	0	0	1
Public administration	1	0	0
Basidiomycetes	**0**	**0**	**1**
Farming, hunting and ancillary services	0	0	1
Other basidiomycetes	**0**	**1**	**0**
Forestry and logging	0	1	0
Cladosporium	**0**	**1**	**0**
Services mainly provided to enterprises	0	1	0
Penicillium	**1**	**2**	**1**
Farming, hunting and ancillary services	0	0	1
Food industries	1	1	0
Services provided mainly to enterprises	0	1	0
Saccharomyces cerevisiae	**0**	**1**	**0**
Farming, hunting and ancillary services	0	1	0
Other fungi and moulds	**0**	**1**	**1**
Agricultural and animal production, hunting and ancillary services	0	0	1
Farming, hunting and ancillary services	0	1	0
Plants			

Biological agents/industry sectors	Causality		
	Weak	Medium	Strong
Herbaceous plants	**0**	**1**	**0**
Food industries	0	1	0
Grasses or cereals	**0**	**1**	**3**
Farming, hunting and ancillary services	0	0	3
Wholesale trade, except automobiles and motorcycles	0	1	0
Wheat	1	0	0
Food industries	1	0	0
Other vegetal leaf or flower or stem	**0**	**1**	**0**
Culture and animal production, hunt and ancillary services	0	1	0
Birds			
Birds	**0**	**2**	**7**
Activities relating to human health	0	0	1
Agricultural and animal production, hunting and ancillary services	0	0	1
Construction	0	0	1
Food industries	0	0	2
Health and social care	0	1	0
Retail trade and repair of domestic articles	0	1	2
Budgies	**0**	**1**	**0**
Woodwork and manufacture of wood articles	0	1	0
Chicken	**0**	**0**	**5**
Farming, hunting and ancillary services	0	0	2
Agricultural and animal production, hunting and ancillary services	0	0	2
Food industries	0	0	1
Ducks	**0**	**1**	**0**
Agricultural and animal production, hunting and ancillary services	0	1	0

Biological agents/industry sectors	**Causality**		
	Weak	**Medium**	**Strong**
Pigeons	**0**	**0**	**1**
Manufacture of other mineral products, no metals	0	0	1
Other animals			
Beef, calves or cows	**0**	**0**	**1**
Farming, hunting and ancillary services	0	0	1
Rodents	**0**	**0**	**1**
Health and social care	0	0	1
Insects			
Arachnida	**0**	**1**	**0**
Farming, hunting and ancillary services	0	1	0
Mites or scabies	**0**	**0**	**1**
Food industries	0	0	1
Sitophilus	**1**	**1**	**0**
N/A	0	1	0
Fishing	1	0	0
Total([a])	**9**	**38**	**69**

([a]) All categories (marked in bold in the table)

Source: national rnv3p database; output generated by ANSES in April 2016.

Examples of reports from the Emergence Working Group on the detection and expert appraisal of suspected new occupational diseases (emerging diseases)

One of the main objectives of rnv3p is to identify emerging occupational risks. This is done through the Emergence Working Group, whose objectives are to establish a platform for sharing information to assess the early detection of potential emerging diseases, and to set up a process for reporting any occurrence of an emerging disease.

The signals discussed by the working group experts (occupational physicians, university professors, representatives of the national partners) are:

- clinical case reports from ODCs;

- statistical signals of emergence (based on data mining ([26]) in the national rnv3p database performed by ANSES);
- proactive/specific searches performed by ANSES (in the literature, case studies reported by the US National Institute for Occupational Safety and Health NIOSH, information from the European Modernet Network) following alerts from other sources or organisations.

When an emerging occupational disease is suspected, exposure to one or more biological agents may also be involved.

So far, 60 reports have been or are being assessed by the experts in this working group, of which only three reports were related to exposure to biological agents, namely:

- inhaled corticosteroid and lung infection with atypical mycobacteria (*Mycobacterium fortuitum*);
- asthma and exposure to *Chrysonilia sitophila* in a coffee machine service agent;
- pneumococcal vaccine in metallurgical workers.

In addition to acquiring expertise, the aim of this working group is to make information available for prevention. Therefore, information on these case reports is disseminated to the rnv3p network members and prevention stakeholders (through internal processes, external publication, etc.).

Because of patients' enrolment in ODCs, the rnv3p network focuses on unknown cases rather than on cases compensated or recognised by health insurance funds, which makes it possible to identify emerging diseases even when only a few cases are reported.

Limitations and benefits of the system

The rnv3p network records in a standardised way all the consultations carried out in all the ODCs in mainland France, and all occupational health problems, including those due to exposure to biological agents, diagnosed by nine OHSs participating in the rnv3p network.

Guidance provided by ANSES with regard to reporting of occupational health problems makes it possible to assess the situation in a structured way. This guidance is provided in the form of:

- telephone support;
- a guidance document with sample cases (but no case on biological agents);
- a 'school of quality and methodology', held once a year for all occupational physicians, clinical experts and other staff who record data.

The standardised way of collecting information makes it possible to present clear statistics in a very detailed manner on:

- exposures;
- industry sectors;
- occupations;
- diseases (including causality between disease and exposure).

Since the rnv3p system is a healthcare-based system that depends on a network of occupational physicians referring patients to ODCs, rather than a patient cohort in which gathering information on exposure is a primary aim in most cases, exposure monitoring information is, however, not part of the database.

The data collected via this network primarily reflect the cases of work-related disease that surface in a system that is aimed at individuals seeking treatment. There are no inclusion and exclusion criteria with regard to recording cases in the database, and the enrolment of cases depends on the network of doctors referring patients to the ODCs (regardless of the medico-legal considerations with regard to compensation). Therefore, the data collected via this network cannot be comprehensive and

([26]) Data mining is the computational process of discovering patterns in large datasets, involving methods at the intersection of artificial intelligence, machine learning, statistics and database systems.

representative of the whole population of workers in France, which makes it hard to estimate epidemiological indicators such as the incidence and prevalence of cases.

The data are used to improve knowledge about and to prevent occupational diseases, for instance, through the Emergence Working Group, to detect and appraise suspected new occupational diseases. The network is a high-quality system that contributes to the dissemination of knowledge on the occurrence of occupational diseases in France, and to the debate on this topic. Another strong point of the rnv3p network are its historical connections and complementarity with prevention stakeholders, especially safety engineers (with experience in, for instance, agriculture, electrical engineering, construction and chemistry) from the Occupational Health Pension Insurance Funds (CARSAT), which have a long history of cooperation with ODCs. This makes it possible to study the trends and consequences of specific actions, for example. In 2017, a new partnership with the Central Fund for Independent Workers began, and it is expected to provide information on the occurrence of occupational disease among independent (self-employed) workers. Until now, such data has been lacking.

Registration of recognised occupational diseases in France

In France, compensation for accidents at work and (recognised) occupational diseases is paid by the local health insurance fund (in the case of metropolitan France) or the General Social Security Fund (in the case of the overseas departments). French law classifies the occupational diseases itemised on a special list of 98 diseases in the same category as accidents at work because they are work related (INRS, 2016a). Of these 98, 24 occupational diseases are related to exposure to biological agents (see Table 69). The CNAM-TS and the CC-MSA are responsible for the registration of the recognised occupational diseases in France.

If the disease is registered in one of the occupational disease tables, and if the relevant criteria to establish a link to work are met, the origin of the disease is presumed to be occupational, and the disease is automatically recognised. Since 1993, it has been possible to report other occupational diseases (i.e. not in the list and/or not meeting the criteria), after which regional committees determine whether the reported case is work-related/compensatable (Carder et al., 2015).

Table 69: List of recognised occupational diseases (ROD) in France that are related to biological agents, by CNAM-TS number

No in list of ROD for CNAM-TS	No in list of ROD for CC-MSA	Recognised occupational disease
Infectious risks		
7	1	Occupational tetanus
18	4	Anthrax
19	5/5*bis*	Spirochaetoses (leptospirosis, Lyme disease)
24	6	Brucelloses
28	2	Ancylostomiasis
40	16	Tuberculosis and other microbacterial infections
45	33	Hepatitis A, B, C, D and E

No in list of ROD for CNAM-TS	No in list of ROD for CC-MSA	Recognised occupational disease
46	15	Skin mycosis
53	49	Rickettsioses and Q fever
54	38	Poliomyelitis
55	—	Infections related to protozoa
56	30	Rabies
68	7	Tularaemia
76	—	Infections related to infectious agents encountered in hospital or during care at home
77	15	Perionyxes and onyxes (fungal nail lesions)
80	-	Viral keratoconjunctivitis
86	50	Pasteurelloses
87	52	Ornithosis/psittacosis
88	51	Swine erysipelas
92	55	Streptococcus infections
96	56	Hantavirus infections
Immuno-allergenic risks		
66	45A	Rhinitis and asthma
66*bis*	45B/C/D	Hypersensitivity pneumonitis
Toxic risk		
90	54	Respiratory diseases caused by/linked to the inhalation of textile fibres

Source: INRS, 2014.

Any accident at work or the occurrence of an occupational disease at work must be reported to the employer within 24 hours. The employer must report the accident or disease to the worker's local health insurance fund within 48 hours and give the worker a special form (*feuille d'accident*), which the worker then gives to their doctor. A temporary period of (total or partial) disablement starts immediately after the injury or diagnosis of the disease and ends with the worker's recovery or the healing of the injury. The payment of workplace accident and occupational disease benefits is not contingent on registration with the social security system or the duration of the period during which the worker has made contributions to it.

The individual (or their representative) seeking compensation must make a claim to the relevant insurance fund (for 87 % of French workers in the private sector, this is the CNAM-TS), which will subsequently determine recognition and compensation. The claim is accompanied by a medical certificate describing the disease, from the doctor chosen by the claimant (Carder et al., 2015).

More information on the system operated by the CNAM-TS can be found on their website (http://www.risquesprofessionnels.ameli.fr), where statistics from the database can also be generated. However, the level of detail of the output that can be generated, as well as the level of detail in the available reports, is limited. A report from 2014 (L'Assurance Maladie, 2014) presents an overview that mainly focuses on the number of occupational diseases registered in the list of recognised occupational diseases and those recognised by CRRMP (the regional health insurance fund for recognised occupational disease). The statistics mainly concern major occupational diseases (with > 100 cases in 2014). No distinction based on industry sector is made. Statistics of cases of recognised occupational diseases for the CNAM-TS can be generated by the National Technical Committee (CNT) for nine major industry sectors and the French Classification of Activities (NAF), from 2010 onwards (CNAM-TS, 2016).

Regarding agriculture, which is not covered by the CNAM-TS, more information on the system operated by the CC-MSA, which focuses on the agricultural sector, can be found on their website, but information on the number of reported cases and other statistics is not available (CC-MSA, 2016). The CC-MSA is primarily responsible for occupational risk prevention among agricultural workers, and can also provide data on compensated occupational diseases for agricultural workers, particularly for workers with direct contact with animals (large animals, small animals, fish farming) and workers in professional hunting and tracking wildlife, zoos, pet shops, etc. The indicators provided by the CC-MSA are based on regulatory definitions and compensation criteria. Their prevention documents are available online (CC-MSA, 2018a, 2018b). Furthermore, the CC-MSA coordinates a network on surveillance of zoonoses, which consists of:

- An observatory: since 2008, this observatory, Zoonoses Surveillance in Agriculture, has allowed doctors working for CC-MSA to report cases of zoonosis (via standardised reports). These reports provide information that can be used to confirm the diagnosis and the relation between work and the transmission chain. Each report is validated and is added to a database (which is not publicly available). The statistics from this database are not representative for all French agricultural workers, as they depend on voluntary input from doctors, but a goal of the observatory is to create a qualitative and analytical database on exposure to biological agents. A questionnaire is being developed to improve the observatory.
- One reference couple (an occupational physician and a prevention adviser) for zoonoses in each CC-MSA OHS service (n = 35).
- A national committee on zoonoses that meets once a year.
- Technical support for the CC-MSA OHS network (individual and collective) and agricultural companies.
- The provision of training on zoonoses.
- Some epidemiological studies, publications and prevention documents.
- A serum bank available for research projects (since 2012).

The number of new recognised occupational (and thus compensated) diseases that were compensated by the CNAM-TS was 51,631 in 2014 (+ 0.3 % compared with 2013). Only 438 cases of recognised occupational diseases related to biological agents were registered in 2014 (Table 70). In contrast, musculoskeletal diseases represented 87 % of the recognised occupational diseases in 2014 and occupational diseases related to asbestos accounted for more than 7 %.

Table 70: Number of recognised occupational diseases related to biological agents for which a first compensation payment from CNAM-TS was made between 2011 and 2014

CNAM – TS list number	Recognised occupational disease	2010	2011	2012	2013	2014
Infectious risks						
7	Occupational tetanus	0	0	0	0	0
18	Anthrax	0	0	0	0	0
19	Spirochaetoses (leptospirosis, Lyme disease)	5	3	2	11	6
24	Brucelloses	0	1	0	0	0
28	Ancylostomiasis	0	0	0	0	0
40	Tuberculosis and other microbacterial infections	50	59	63	42	48
45	Hepatitis A, B, C, D and E	15	8	11	12	9
46	Skin mycosis	5	2	3	3	4
53	Rickettsioses and Q fever	6	2	1	2	1
54	Poliomyelitis	0	0	0	0	0
55	Infections related to protozoa	1	0	0	0	3
56	Rabies	0	0	0	0	0
68	Tularaemia	0	0	0	0	0
76	Infections related to infectious agents encountered in hospital and during care at home	77	89	136	107	139
77	Perionyxes and onyxes (fungal nail disorders)	3	7	4	2	5
80	Viral keratoconjunctivitis	4	0	3	3	1
86	Pasteurelloses	0	1	0	0	0
87	Ornithosis/psittacosis	0	2	2	0	2
88	Swine erysipelas	1	5	3	1	0
92	Streptococcus infections	0	1	0	0	1
96	Hantavirus infection	0	3	4	2	2
Immunoallergenic risks						

CNAM – TS list number	Recognised occupational disease	2010	2011	2012	2013	2014
66	Rhinitis and asthma	217	222	225	241	211
66*bis*	Hypersensitivity pneumonitis	8	10	8	7	5
Toxic risk						
90	Respiratory diseases caused by the inhalation of textile fibres	3	1	1	0	2
All ROD						
Total (98 ROD)		**50,6887**	**55,057**	**54,015**	**51,452**	**51,631**

Source: L'Assurance Maladie, 2014.

5.6 Registration of occupational exposures in France

An example of the registration of occupational exposures in France is the work undertaken by the French Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (L'Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles (INRS)) The focus of the INRS is strictly speaking not on epidemiology and/or monitoring exposure; its efforts with regard to exposure monitoring are performed with the aim of providing technical assistance for health surveillance. The institute has two databases for collecting occupational hygiene measurements, mainly on chemical agents, namely COLCHIC (using data from prevention and research activities) and SCOLA (using data from compliance-checking activities). Although both databases are based on measurements from the same population of workers, they have different goals, with corresponding differences in, for instance, the sampling strategies applied (Mater et al., 2016). With regard to biological agents, data registered in COLCHIC relate to endotoxins and mycotoxins, for which guidance values are defined (which are not OEL values (OELVs)).

COLCHIC

COLCHIC, the database of occupational exposure to chemical products, was established in 1986, and is managed by the INRS. This database contains the results of workplace air measurements by eight French regional health insurance funds, inter-regional chemical laboratories and the laboratories of the INRS in the context of occupational risk prevention. The objectives of setting up COLCHIC were to centralise measurement data from various laboratories, to harmonise workplace sampling and air analysis methods, and to support chemical risk assessment in France. The supplementary data in COLCHIC can be classified into four major categories: administrative information, sampling conditions, exposure conditions and analytical conditions. Most of the data are coded using standardised classifications specific to COLCHIC (e.g. with regard to tasks and ventilation) or national classifications (industries and occupations are coded in accordance with the French national systems: NAF and the Operational Directory of Occupations and Jobs (ROME)). In 2002, a second version of COLCHIC was developed, to which workers' occupations and the product or process category were added. The data collected in COLCHIC stems from measurement campaigns performed in establishments under the national social security scheme. The choice of targets for these campaigns, and thus leading to the measurements in COLCHIC, is determined by general prevention programmes defined for a period of 4 years by the national health insurance system, as well as by national sampling surveys. The eight interregional chemical laboratories are assigned to defined geographical areas and cover companies insured by the national social security scheme (55 % of companies in France; public services, agriculture, and small retailers and artisans are excluded). Three main situations can trigger a visit to a company:

- First, a visit by a safety controller or engineer from the regional health insurance fund can be requested. Such a request may come from an establishment, from a worker representative or from an occupational physician.
- Second, visits can be made for research purposes (e.g. when carrying out industry-wide surveys) by the French prevention network. In this context, companies are usually contacted by the researchers.
- Third, a visit can occur in the context of specific prevention actions performed by individual regional laboratories. The laboratory will identify and contact companies. Establishments cannot refuse to be visited, but the visits are scheduled in advance.

From 1987 to 2012, 841,682 air measurement results covering 670 agents were recorded in COLCHIC by the 8 interregional chemical laboratories; the results were drawn from 49,145 interventions in 37,569 companies.

SCOLA

The occupational exposure database SCOLA results from the French requirement that measurements made during the assessment of compliance with regulatory OELs should be archived in a national register. The measurements stored in SCOLA are performed by certified laboratories, which are independent of the establishment being monitored. The data are used to define priorities for national prevention programmes. SCOLA was built using the same software system as COLCHIC. The coding of supplementary data is very similar to that used in COLCHIC. The data collected in SCOLA come from certified laboratories that take measurements at the request of companies in order to fulfil their regulatory obligations. In France, company directors are legally responsible for risk assessment. An initial evaluation is performed by company experts or consultants, which results in a document identifying situations with the potential for overexposure. For each of the potential risk situations for which an OEL exists, a measurement strategy has to be developed in compliance with the regulations. The current law requires a minimum of three and up to nine samples representative of the workers' exposure in order to verify compliance with an OEL.

From 2007 to 2012, 152,486 air measurement results covering 70 agents were recorded in SCOLA by 86 certified laboratories; the results were drawn from 37,277 interventions in 7,449 companies.

Prevention

The INRS collates the information collected either by itself or by partners such as prevention stakeholders (e.g. CARSAT) and organises awareness-raising campaigns. One of the topics on which the INRS provides information is the EFICATT guide ('Exposition fortuite à un agent infectieux et conduite à tenir en milieu de travail', which translates as 'Accidental exposure to an infectious agent and measures to be taken in the workplace'). This guide, designed especially for physicians, aims to support them when they are faced with workers who have accidentally been exposed to biological pathogens (viruses, bacteria, etc.), and provides them with useful advice to help assess risks, set actions to be taken immediately, define future actions to be undertaken and implement medical monitoring. A database designed for occupational physicians provides information on more than 30 infectious agents and diseases (INRS, 2016b). The database can be searched by disease or infectious agent; those covered are listed in Table 71.

Table 71: Infectious agents and diseases on which information is provided in the EFICATT guide

Disease	Infectious agent
AIDS	HIV
Anthrax	*Bacillus anthracis*
Bronchiolitis	Respiratory syncytial virus
Brucellosis	*Brucella*
Chikungunya	Chikungunya virus
Conjunctivitis	Adenovirus
Coronavirus (MERS-CoV) infection	Coronavirus (MERS-CoV)
Cytomegalovirus infection	Cytomegalovirus
Dengue fever	Dengue virus
Diphtheria	*Corynebacterium diphtheriae*
Erysipeloid	*Erysipelothrix rhusiopathiae*
Haemorrhagic fever with renal syndrome	Puumala virus
Hepatitis A, B, C and E infection	Hepatitis A, B, C and E viruses
Herpes B virus infection	Herpes B virus
Infection with digestive multiresistant bacteria	Digestive multiresistant bacteria (BMR)
Influenza	Influenza virus
Legionnaire’s disease	*Legionella* spp.
Leptospirosis	*Leptospirosa interrogans*
Lyme disease	*Borrelia*
Malaria	*Plasmodium* spp.
Measles	Morbillivirus
Meningococcal meningitis	*Neisseria meningitidis*
Mumps	Mumps virus
Ornithosis/psittacosis	*Chlamydia psittaci*
Parvovirus B19 infection	Parvovirus B19

Disease	Infectious agent
Pasteurellosis	*Pasteurella* spp.
Pediculosis of the scalp	*Pediculus humanus* var. *capitis*
Pertussis	*Bordetella pertussis*
Q fever	*Coxiella burnetii*
Rotavirus diarrhoea	Rotavirus
Rabies	Rabies virus
Rubella	Rubella virus
Scabies	*Sarcoptes scabei* var. *hominis*
Shingles	Varicella zoster virus
Streptococcus infection	*Streptococcus*
Streptococcus pyogenes infection	*Streptococcus pyogenes*
Transmissible spongiform encephalopathies	Unconventional transmissible agent (NCTA) or prion
Tuberculosis	*Mycobacterium tuberculosis*
Typhoid fever	*Salmonella typhi*
Varicella	Varicella virus
Zika	Zika virus

Source: INRS, 2016b.

Other programmes and surveys for monitoring professional risks in France are coordinated by the French Institute for Public health and Surveillance (Santé Publique France) or the General Directorale for labour in the ministry (SUMER) (DARES, 2016).

5.7 Registration of occupational diseases in Denmark

Description of the system

The Danish Working Environment Authority (DWEA) registers and reports registered and approved occupational diseases and accidents. As prescribed in the Working Conditions Regulation (Arbejsmiljøloven, paragraph 75), all physicians (thus including both general practitioners and occupational physicians) and dentists are obliged to notify suspected or confirmed occupational diseases to the DWEA and Labour Market Insurance (Erhvervssygdomsudvalget). Labour Market Insurance is responsible for the Danish compensation system for occupational diseases. This notification duty does not explicitly cover the aggravation of an existing disease, but this is also often notified. It does cover occupational diseases that have arisen during a previous job or in previous employment. The employer is obliged to notify the DWEA and Labour Market Insurance of occupational accidents, but not occupational diseases.

Labour Market Insurance [27] publishes a list of diseases and associated occupational exposures (Erhvervssygdomsfortegnelsen); the diseases on this list are recognised as occupational diseases and should be notified as such. The content of the list is based on evidence from the literature, but there are no strict rules regarding the quality of the evidence required for a disease to be included on the list. Furthermore, more elaborate guidelines and review documents on specific areas are available. Since around 2004, the DWEA and Labour Market Insurance have organised a public tender for consultation once or twice a year. The winners of the tender review and evaluate the available evidence on specific issues; it is mostly occupational physicians and other OSH professionals who apply.

The following diseases relating to biological agents are included in the list of occupational diseases:

- allergic rhinitis and conjunctivitis;
- allergic alveolitis (including, for example, farmer's lung, mushroom worker's lung, bird fancier's lung/disease);
- byssinosis;
- asthma (allergic and non-allergic);
- chronic bronchitis;
- COPD;
- allergic and toxic dermatitis;
- infectious diseases transmitted by animals, humans or the environment, mostly tropical diseases (e.g. tetanus, ornithosis, Q fever, Weil's disease, tuberculosis, hepatitis, malaria, trypanosomiasis, dengue fever and yellow fever);
- cancer after hepatitis infection.

An electronic online notification/registration system is used, on which all occupational diseases/work-related diseases can be registered (including ones that are not on the list). Although there are no other specific guidelines with regard to the registration process, information on the disease (using ICD-10 codes), the worker's occupation and the exposure has to be included, using predefined categories. A notification of an occupational disease should contain the following information:

- diagnosis (ICD-10 code);
- worker's name and national unique ID number, including birthday and gender;
- the nature and extent of the work or working conditions;
- the nature of the work when the occupational disease arose;
- the worker's profession at the time of exposure;
- the industry, classified according to the Danish DB07 system of codes, a slightly modified version of the NACE rev. 2 job classification system, in which the main groups are used;
- the worker's job classified according to the Danish DISCO 08 system of codes, a slightly modified version of ISCO-88, at a two-digit level.

Although there is no formal step-by-step plan that physicians must follow to systematically investigate a disease and determine if it is actually an occupational disease, each region in Denmark has at least one governmental occupational hospital department that employs occupational physicians. Physicians operating in the field can refer to these departments if they are in doubt (in exactly the same way as they refer to other specialist departments, such as cardiology). There are national guidelines for most occupational diseases, including diseases linked to biological material([28]), provided by the Danish Society for Occupational and Environmental Medicine([29])

([27]) www.aes.dk
([28]) www.armoni.dk
([29]) www.dasam.dk

If an (occupational) physician suspects that they have encountered a new combination of health effect(s), exposure and work situation for which the relationship may not (yet) be well established, this case can be submitted to a committee attached to Labour Market Insurance, consisting of, for example, occupational physicians, employers, workers, Labour Market Insurance representatives and DWEA members. This committee then decides whether this new combination of health effects and exposure at work can be recognised as an occupational disease and eventually be included in the list of recognised occupational diseases. Apart from this, there is no alert system for new or emerging occupational risks.

The main purpose of the registration system is the surveillance of risk jobs and industries, including to ensure that there is awareness of new risk areas in order to prevent occupational diseases and accidents. Each year, information about new registrations is made available on the DWEA website in the form of tables, broken down by broad diagnostic categories and industry sectors([30]); in addition, a yearly report is published.

In addition to the DWEA and the Labour Market Insurance, the Statens Serum Institut (SSI) also collects some information about occupational infectious diseases and the agents that cause them. The SSI[31] is an institute operating as part of the Danish Ministry of Health, the purpose of which is to prevent and control infectious diseases, congenital disorders and biological threats. All physicians are obliged to notify contagious and serious infectious diseases (a specific list is available([32])). Information on the circumstances of the infection and possible sources of it — including occupational sources — must be reported as part of this notification.

Examples of reports from the system

For the period 2004-2009, tables of registered occupational diseases can be generated from an online database([33]). For the period after 2009, it is necessary to rely on information made publicly available by means of annual reports provided by the DWEA. The information available in the public database is very general. For instance, health effects are broken down into only eight categories (musculoskeletal disorders, hearing loss, psychiatric diseases, dermal diseases, respiratory diseases, neurological disorders, cancer, and other and unknown), and no information about specific causes (exposures) is given. The data can be broken down by'industry category, job category, gender and age (in 5-year categories). This information, which is also available in the annual reports and statistical overviews provided by the DWEA, offers some detail on diseases caused by biological agents but does not, for instance, generally identify the specific biological agent involved.

The examples that are presented here are based on the annual reports and statistical overviews generated by the DWEA, for the period 2010-2014 or 2011-2014 (Arbejdstilsynet, 2011, 2013a, 2013b, 2014, 2015). During that time, the numbers of notifications of occupational diseases related to biological agents were relatively stable. In 2012, 2 % (471 out of 27,336) of the notified exposures were biological agents (40 % microorganisms, 25 % organic dust, 15 % animal products and 11 % food products), compared with 1 % (428 out of 32,065) in 2014 (type of biological agents not further specified). However, these percentages are probably underestimations, as some biological agents are likely to be included in the chemical and industrial exposures group, which was mentioned as the relevant group of agents for 4,300 notifications (13.4 %).

Table 72 provides an overview by sector of the numbers of reported diseases over the period 2011-2014 for which biological agents were stated as the cause of the disease. In general, the percentage of the registered diseases caused by biological agents per sector has been relatively constant over the years and is also relatively low (on average 1.2-2 %). However, in some sectors, such as agriculture, forestry and fishing (8-11 %), the food and beverage industry (4-6 %), restaurants and bars (3-10 %),

([30]) www.at.dk
([31]) www.ssi.dk
([32]) https://en.ssi.dk/surveillance-and-preparedness/surveillance-in-denmark/mandatory-notification-systems
([33]) https://amid.dk/arbejdsmiljoe-i-tal/analyser-og-publikationer/anmeldte-erhvervssygdomme-i-tal/

and hotels and camping (2-6 %), the percentage is relatively high, indicating that biological agents are a risk factor that needs particular attention.

Table 72: Overview of numbers of reported diseases over the period 2011-2014 caused by biological exposures, by sector/occupation, in Denmark

Sector/occupation	Number of reported occupational diseases caused by biological agents, as number/total number of reported diseases and %						
	2011 ([a])	2012		2013 ([b])		2014	
01. Construction	0 %	1/222	0.5%	4/270	1.5%	1/1,309	0.1%
02. Building and demolition of buildings	2 %	20/1,256	1.6%	25/1,270	2.0%	11/1,401	0.8%
03. Finalisation of construction	1 %	15/881	1.7%	4/985	0.4%	0/1,013	0.0%
04. Shops	3 %	35/1,214	2.9%	20/1,334	1.5%	23/1,430	1.6%
05. Wholesale	2 %	11/934	1.2%	50/1,157	4.3%	12/1,211	1.0%
06. Electronics	1 %	1/321	0.3%	1/358	0.3%	1/313	0.3%
07. Energy and raw material	1 %	0/176	0.0%	2/163	1.2%	0/162	0.0%
08. Installation and repair of machinery and equipment	0 %	1/100	1.0%	2/110	1.8%	2/96	2.1%
09. Chemistry and medicine	1%	4/193	2.1%	3/278	1.1%	3/221	1.4%
10. Metal and machines	0%	2/1,349	0.1%	3/1,459	0.2%	5/1,610	0.3%
11. Plastics, glass and concrete	0%	2/465	0.4%	1/478	0.2%	1/481	0.2%
12. Textile and paper	2%	2/164	1.2%	1/172	0.6%	4/158	2.5%
13. Transport	1%	1/503	0.2%	3/516	0.6%	0/505	0.0%
14. Wood industry	4%	3/270	1.1%	4/279	1.4%	7/309	2.3%

Sector/occupation	Number of reported occupational diseases caused by biological agents, as number/total number of reported diseases and %						
	2011 ([a])	2012		2013 ([b])		2014	
15. Film, press and books	3%	6/165	3.6%	0/179	0.0%	1/187	0.5%
16. IT and telecommunication	2%	4/179	2.2%	0/202	0.0%	0/176	0.0%
17. Office work	2%	83/4,309	1.9%	50/5,029	1.0%	47/4,938	1.0%
18. Agriculture, forestry and fishing	10%	40/371	10.8%	45/529	8.5%	48/509	9.4%
19. Slaughterhouses	0%	5/810	0.6%	10/676	1.5%	16/635	2.5%
20. Food and beverage industry	4%	23/447	5.1%	30/490	6.1%	32/550	5.8%
21. Police, emergency services (e.g. fire brigade) and prisons	1%	10/651	1.5%	10/847	1.2%	11/1,001	1.1%
22. Religious institutions and funeral services	1%	3/123	2.4%	2/146	1.4%	4/173	2.3%
23. Water, sewage and garbage	2%	1/131	0.8%	4/156	2.6%	0/152	0.0%
24. Hairdressers and other personal care	1%	0/317	0.0%	6/361	1.7%	3/352	0.9%
25. Hotels and camping	5%	8/133	6.0%	3/165	1.8%	4/212	1.9%
26. Culture and sports	3%	2/213	0.9%	4/225	1.8%	4/298	1.3%
27. Cleaning	1%	4/754	0.5%	1/734	0.1%	2/842	0.2%
28. Restaurants and bars	10%	24/497	4.8%	30/559	5.4%	19/609	3.1%
29. Transport of goods	0%	3/784	0.4%	1/791	0.1%	5/931	0.5%

Sector/occupation	Number of reported occupational diseases caused by biological agents, as number/total number of reported diseases and %						
	2011 ([a])	2012		2013 ([b])		2014	
30. Transport of people	1%	1/371	0.3%	0/449	0.0%	8/411	1.9%
31. Daycare centres	3%	26/971	2.7%	30/1,148	2.6%	10/1,372	0.7%
32. 24-hour care centres and home care	1%	15/1,507	1.0%	12/1,900	0.6%	7/2,287	0.3%
33. Hospitals	1%	14/1,185	1.2%	10/1,287	0.8%	23/1,396	1.6%
34. Physicians, dentists and veterinarians	2%	15/362	4.1%	8/410	2.0%	9/511	1.8%
35. Education	2%	18/1,030	1.7%	30/1,339	2.2%	23/1,803	1.3%
36. Universities and research	2%	4/279	1.4%	15/292	5.1%	7/289	2.4%
37. Unknown and others	—	—	—	—	—	1/475	0.2%
TOTAL	**2%**	**407/23,637**	**1.7%**	**424/26,743**	**1.6%**	**354/30,328**	**1.2%**

Source: Arbejdstilsynet, 2013a; 2013b, 2014, 2015.

([a]) In the 2011 report, only percentages were given.

([b]) Although it was included in the 2013 report, no figures were given for the category 'Biologiske'; therefore, these have been estimated on the basis of the information in the report.

Table 73 presents an overview of the proportion of skin and respiratory diseases which were related to exposure to biological agants over the last years, illustrating that a very small proportion is attributed to biological agents.

Table 73: Overview of numbers of reported skin and respiratory diseases related to biological agents over the period 2015-2017 caused by biological exposures, in Denmark

Diseases	2015	2016	2017
Skin diseases	129	133	133
Respiratory diseases	152	206	178
All diseases	**34,237**	**31,797**	**30,020**

Source: https://amid.dk/arbejdsmiljoe-i-tal/analyser-og-publikationer/anmeldte-erhvervssygdomme-i-tal/

Table 74 presents an overview of all reported lung/airway diseases and skin diseases over the period 2010-2014, which shows a steady situation during that period. No numbers specifically for infectious diseases are available, but, based on the numbers of patients referred to Danish occupational hospital departments with possible occupational infectious diseases, these probably amount to only a few cases. It must also be mentioned that only small proportion of these disease were indicated as being caused by biological agents.

Table 74: Overview of reported lung/airway diseases and skin diseases over the period 2010-2014 in Denmark (total number and as a percentage of all occupational diseases reported)

Condition	2010	2011	2012	2013	2014
Lung/airway diseases	624 (4 %)	638 (4 %)	684 (5 %)	660 (3 %)	674 (3 %)
Skin diseases	1,892 (12 %)	2,368 (16 %)	2,668 (15 %)	2,765 (13 %)	2,956 (14 %)

Source: personal communication from Vivi Schlünssen.

During the period 2011-2015, 269 cases of occupational asthma were recognised, and around 30 % of those were indicated as being caused by biological agents. The largest numbers of cases were in workers in bakeries (*n* = 29), workers in farm-related industries (*n* = 29) and workers in the food industry (*n* = 13).

Limitations and benefits of the system

The system for reporting occupational diseases in general, including occupational diseases due to exposure to biological agents, and including the online form for submitting the report, enables the information to be collected in a standardised way, which also makes it possible to present some statistical material on the basis of these reports, although it is not possible to identify specific biological agents.

From the annual reports published by the DWEA, it is possible to obtain information on reported occupational diseases due to biological agents by industry and by job category on a yearly basis. This also enables comparison with preceding years. However, occupational diseases are presented only in eight broad disease categories, and thus no distinctions with regard to specific type of disease can be made. Moreover, the causes of occupational diseases are reported only in broad categories (e.g. 'biological agents'), and thus no distinctions with regard to specific type of biological agent can be made. Using the publicly available database, statistics can be generated on diseases (eight broad categories, no infectious disease category), occupations and industries for the period 2004-2009. These statistics are presented at the level of fairly categories (e.g. of diseases or causes), and therefore not all details are provided, but this database is a valuable source of information for occupational physicians, occupational hygienists, employers, workers, etc.

Although in the annual reports, occupational diseases due to biological agents are specifically covered, as this is a separate category, most biological agents are probably included in other exposure categories. A large proportion of relevant exposures are probably included in the chemical and industrial exposures category. The precise distinction between these groups is not clear and may lead to some confusion during registration. Furthermore, which category is chosen will thus largely depend on the starting point/frame of reference of the physician, and it can be assumed that, if a physician is less familiar with biological agents, the exposure will be recorded under another exposure category.

Owing to the large variety of biological agents, and in many cases the rather specific symptoms that they cause, it can be assumed that workers will not always relate their symptoms to their work environment. It is presumed that, while occupational physicians are well aware of the relation between disease and occupational exposure, many of the notifications are submitted by general practitioners, for whom the relation to exposure in the work environment is less of a primary concern.

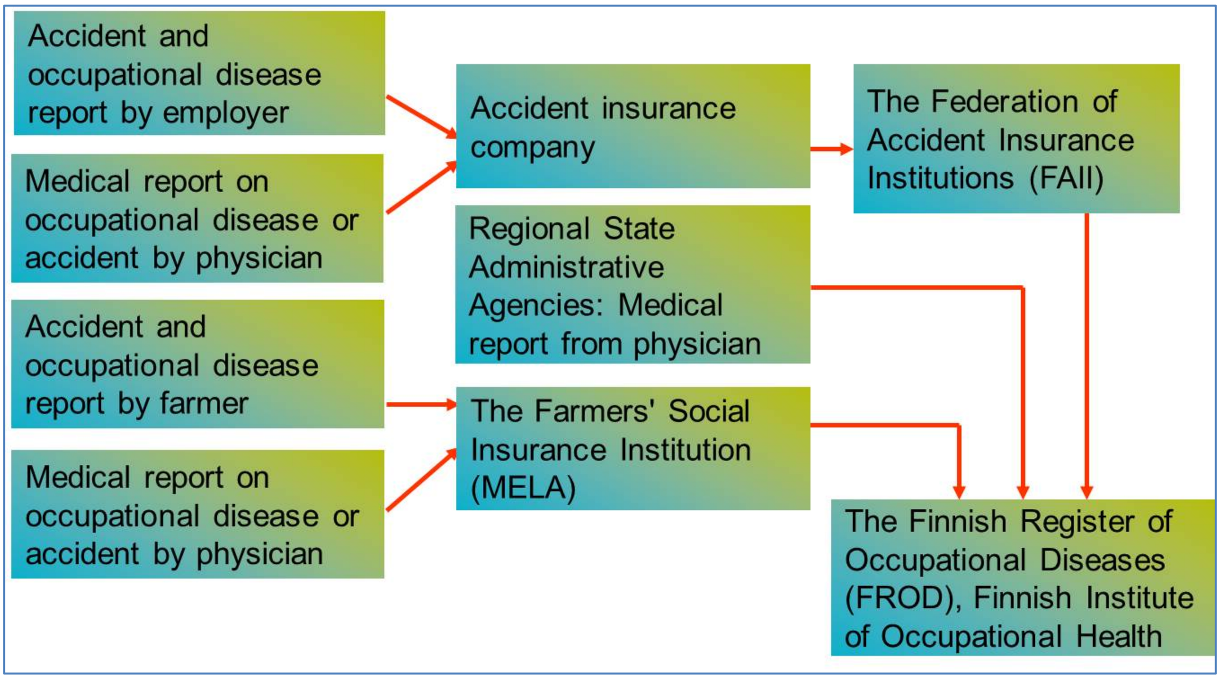
Although in general the registration system is considered comprehensive, there is a substantial degree of under-reporting in Denmark. This has been shown to be the case for 'signal' diseases (e.g. mesothelioma) and has also been demonstrated by estimations of the number of, for example, occupational asthma or lung cancer cases from other sources.

5.8 Registration of occupational diseases in Finland

Description of the system

The Finnish Institute of Occupational Health (FIOH) maintains the Finnish Register of Occupational Diseases (FROD). This register contains all new cases notified by insurance companies and the Farmer's Social Insurance Institution (MELA). Both suspected and recognised occupational diseases are covered by the register. Figure 8 indicates where the register's data come from.

Figure 8: Overview of stakeholders with regard to registration of occupational diseases in Finland



Source: FIOH.

Registration follows the requirements set out in the Act on Occupational Diseases (1343/1988; 1317/2002), which defines an occupational disease as a disease caused by any physical factor, chemical substance or biological agent encountered in the course of work. In principle, any disease or adverse health outcome that meets the above criteria is cause for compensation, provided that the disease is contracted as a consequence of exposure at work under an employment contract with a private employer, in the public service or in public office.

Diseases that are not recognised as occupational diseases but classified as work-related are not covered by occupational disease compensation. If such a work-related disease results in an inability to work, compensation comes from general disability schemes. Registration of occupational diseases with

FIOH is organised through the insurance companies. There are no specific guidelines for registration of diseases, only for claiming for compensation. The determination that a disease is occupational disease is based on the occupational physician's expertise and recognition by the insurance company. No specific classification schemes are in use.

Some diseases caused by biological agents are covered by the system, for example asthma caused by microbes at work. Biological agents are a frequently debated topic in Finland and special attention is paid to these diseases. However, the degree of public interest in the risks posed by biological agents is not reflected in the system or the reporting. The obligation to register rests with the employer under the Act on Occupational Diseases.

So far, no special alert system has been established with regard to new/emerging risks. There is no dedicated website for the register.

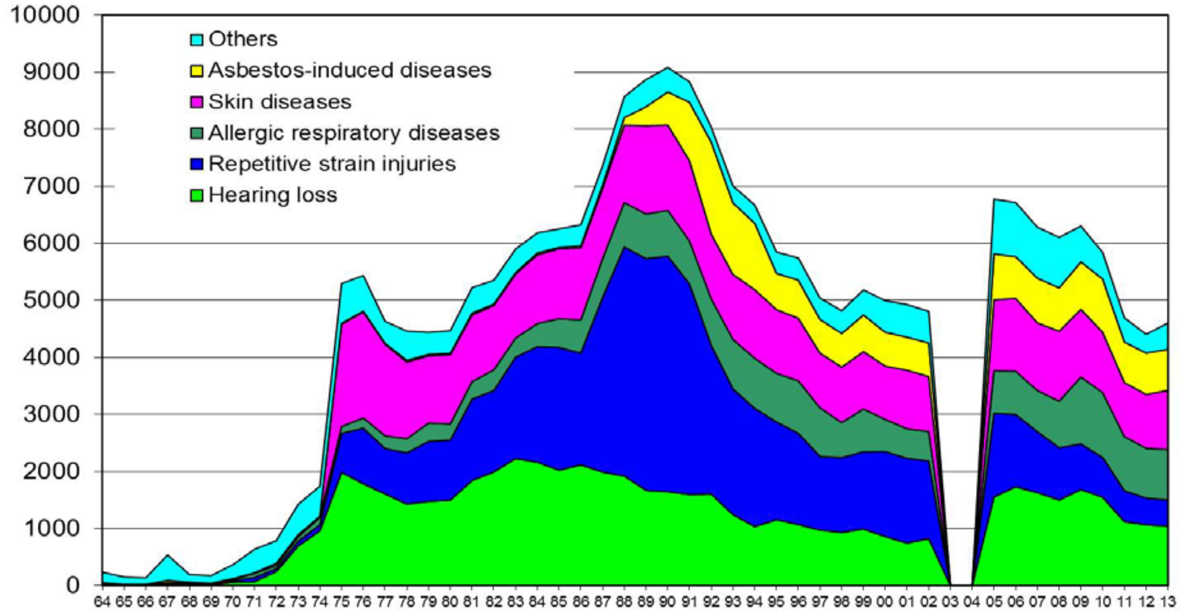
Examples of reports from the system

The data are not publicly available and can be accessed only on request and if there are sufficient resources. The responsibility for reporting on the system rests with FIOH, and the extent to which this is done also depends on the availability of resources to analyse the data. Following the 2015 restructuring of the organisation, it is unclear how this reporting will be organised. The latest report referenced in this research describes the data until 2013 and was published in 2015 (Oksa et al., 2015). That report and previous ones are available on request.

The register can provide statistics on disease diagnosis, occupation and branch of industry, and year of reporting. Owing to changes in the notification and recognition processes, the data from 2005-2013 are not comparable with the previous FROD figures and occupational disease trends over a longer period can therefore not be compared with previous figures.

The numbers of cases reported in recent years have remained stable or declined. Figure 9 gives an overview of the reported health effects and trends over time. The total number of reported suspected cases is around 4,500 per year, and the number of recognised cases is around 1,800 per year. As can be inferred from Figure 9, the proportions of cases of allergic respiratory diseases and skin diseases are increasing owing to reductions in other conditions.

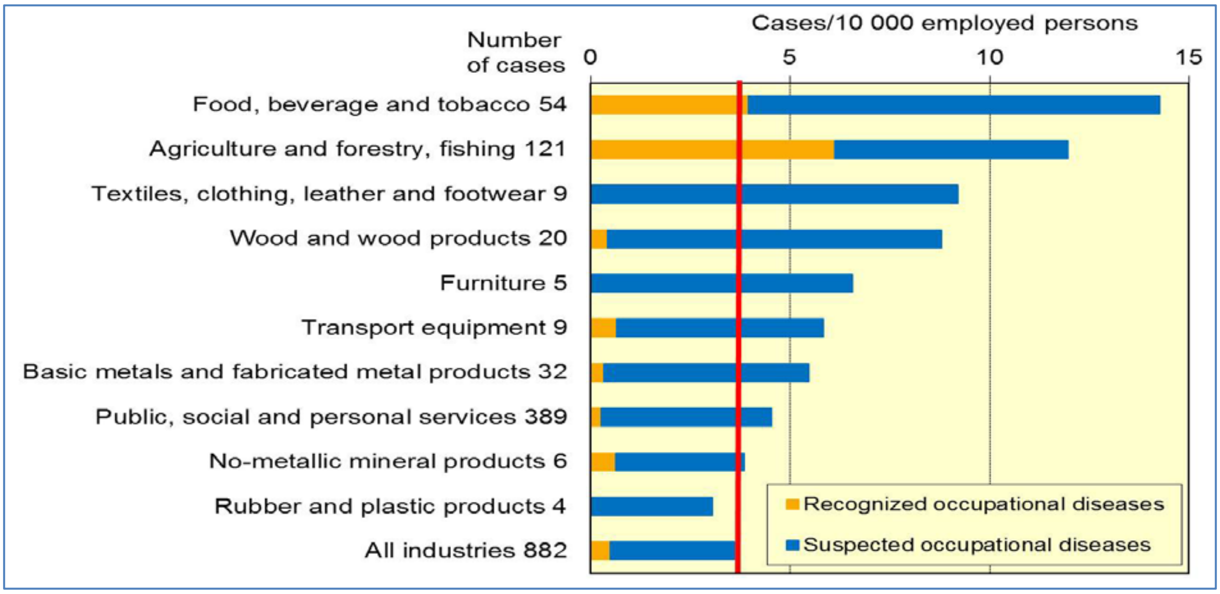
Figure 9: Overview of numbers of registered recognised and suspected occupational diseases and other health effects in Finland over the period 1964-2013 (cases from 2003-2004 not available)



Source: Oksa et al., 2015

With respect to occupational diseases caused by exposure to biological agents, allergic diseases are reported most frequently, in particular allergic asthma and allergic rhinitis. To a lesser degree, allergic alveolitis and laryngitis are also reported. Skin diseases are most frequently reported in the furniture and metal industries and do not seem to be closely related to biological hazards. As can be seen from Figure 10, the number of suspected diseases is much larger than that of those that have been recognised. The sector with the most cases is agriculture.

Figure 10: Overview of registered recognised and suspected allergic respiratory occupational diseases in Finland in 2013, by sector



Source: Oksa et al., 2015.

Limitations and benefits of the system

One benefit of the system is that the data are clearly organised and readily available.

A limitation of the system is that it draws heavily on the reporting of workers who apply for compensation from their insurance companies. It is therefore probable that work-related diseases will be omitted, as will cases with lower disability weights.

Another limitation is the availability of the information that is collected, for instance for preventive measures. As the database is not publicly available and the capacity, with regard to human and financial resources, of FIOH to analyse the data and report the findings is very limited, the registration system is not used to its fullest potential, including with regard to the identification of new/emerging risks. The lack of a dedicated website for the register is also a limitation.

5.9 Registration of occupational exposures in Finland

FIOH keeps records of exposure measurements made as part of the occupational hygiene services it provides to companies. These services are commercial services provided on a competitive basis for which the companies have to pay, performed to fulfil the legal requirements, based on EU law, for employers to take action to prevent workplace risks. FIOH is one of the main providers of these services in Finland and has a large market share. It keeps a database with the results of samples taken for the purpose of (bio)monitoring workers' exposure.

With regard to exposure to biological agents, FIOH's Work Environment Laboratories focus on measuring endotoxins, moulds, bacteria and parasites in workplaces, as well as IgE and IgG antibodies ([34]) among workers exposed in these workplaces. As indicators of worker exposure, IgE measurements and others, for example relating to specific microorganisms, are made and the data stored for individuals. IgG measurements are only made and the data stored at group or workplace level because of the amount of variation at individual level.

Exposure measurements have been performed in several thousands of workplaces, and data has been gathered in a database since the beginning of the century. However, these data are not readily accessible (only raw data are available). Most measurements can probably be traced back to a workplace or occupation, but as the data are only stored and not prepared for analysis, no overview of the measurements for biological agents can be provided. Furthermore, the data are not publicly available and can be analysed only on request and if there are sufficient resources. In addition, FIOH has not published any reports on these exposure data.

Based on the database of exposure measurements, FIOH has developed FINJEM, the Finnish Job-Exposure Matrix, which consists of more polished data. Even when only a job title is known, the exposure of a worker can be estimated based on exposures measured in large groups of workers with similar job titles that have been logged in the database over a long period. The exposures that are relevant to biological hazards in the FINJEM database are those to organic dust (e.g. animals, flour, plants, softwood and hardwood dust) and to microbiological agents (e.g. mould spores and Gram-negative bacteria of non-human origin) (Kauppinen et al., 2014). Estimates for the past 50 years are available. The FINJEM database is available for research purposes only and analyses can be made only on special request and if there are sufficient resources.

([34]) Immunoglobulins (also know as antibodies) are proteins made by our immune system to fight antigens such as bacteria, viruses and toxins. Immunoglobulin E (IgE) allergies are immediate responses to a foreign substance that has entered the body, which may have come from food or inhalation. IgE allergies can cause very serious symptoms such as difficulty breathing, swelling and hives. In even more severe cases, IgE reactions can lead to anaphylactic shock. Immunoglobulin G (IgG) allergies are usually food sensitivities; they tend to be less severe and last longer than the better known IgE allergies.

5.10 Comparison of selected monitoring systems

Monitoring systems for occupational diseases

Table 73 provides an overview of the key parameters that define the monitoring systems for occupational diseases that were evaluated in this project. As becomes clear from the descriptions of the various monitoring (or surveillance) systems for occupational diseases evaluated in this review, the way in which these systems operate in European countries, the type of information that is registered in these systems, the way in which biological agents and diseases caused by biological agents are incorporated in these systems, and the way in which the outputs from these systems are made available vary greatly.

In the questionnaire survey, 48 out of the 62 respondents, who represented 26 countries, indicated that they were familiar with one or more monitoring systems for occupational diseases in their country. According to the respondents, these systems were mostly used to register occupational diseases, and specifically infectious diseases. As stated by the respondents to the questionnaire, some of the systems are used as information systems to provide categorised data on occupational disease and some focus on a specific disease (e.g. legionnaires' disease, brucellosis or MRSA) for which mandatory reporting is required by law, with this reporting sometimes linked to public health requirements.

Although national system-specific lists are also used, the lists of diseases used in the systems evaluated in this project are generally comparable to the ICD-10 codes, and all contain at least a few diseases related to biological agents. However, the exact numbers of these vary and can be very limited, and the types of diseases recorded vary too. Therefore, it is difficult to obtain an overview of the numbers of reported diseases due to biological agents on the basis of the outputs from the systems evaluated.

Identification of new and emerging risks

In some of the systems evaluated in this project, the identification of new and/or emerging occupational diseases (or risks) forms part of the registration system, and in most cases this involves a process of evaluation by a group of experts. In the Netherlands (and Belgium), the SIGNAAL system is a separate notification system for new and/or emerging risks that has been implemented recently. Another exception is the French rnv3p system, which incorporates a sentinel function.

As part of the questionnaire survey (Section 4.5.3, Table 45, and Annex 4, Table A4-4), 26 out of 62 respondents (representing 16 out of 29 countries) indicated that they were familiar with one or more sentinel/alert systems. The descriptions of the purposes of these systems provided by the respondents varied widely, with the categories 'registration of occupational diseases', 'reporting system', and 'sentinel system' mentioned more than once. The purposes of the systems are further discussed in Section 6.4.2.

A lack of guidance for those who report work-related diseases

As shown in Table 75, registration with most of the systems evaluated in this project is mandatory, but the authorities do not always provide much guidance or training for those who have to register cases, and thus (detailed) information on how to diagnose diseases due to biological agents, for instance, is not always available. However, some of the systems evaluated do provide guidance with regard to biological agents (specifically those in Germany, the Netherlands and Denmark). The rnv3p system ensures training of OSH professionals operating as part of the network.It can be concluded that providing more guidance and training may result in less under-reporting, and thus a better overview of the prevalence of work-related diseases due to exposure to biological agents in the workplace.

Detailed information not publicly available

Furthermore, in general, the data collected by the individual systems is not publicly available, which makes it difficult for, for instance, companies or sectoral organisations to take a closer look at the information that is relevant for their sector.

There are exceptions: for instance, the data collected in the Dutch system is publicly available, and output tables can be generated for one or a combination of two parameters (including diagnosis, cause, sector, job, age and gender) for 1 year or a period of up to 5 years. Furthermore, THOR in the UK also operates an ad hoc data enquiry service enabling interested parties to request information on cases of work-related ill health reported to the system. Money et al. (2015) reported that THOR received a total of 631 requests between 2002 and 2014. These requests were predominantly submitted by participating THOR physicians (34 %) and HSE (31 %). The majority (67 %) of requests were for information about work-related respiratory or skin diseases, and relatively few requests were made in relation to other diagnoses, such as musculoskeletal disorders or mental ill health. Requests frequently related to a specific industry and/or occupation (42 %), and/or a specific causal agent (58 %).

Although in at least some of the countries the output from the systems is also provided in English, in general the most detailed information was available only in the language of the country itself, which hampered comparisons between countries.

Table 75: Comparison of characteristics of selected monitoring systems for occupational diseases

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
Operated by	Dutch Centre for Occupa-tional Diseases (NCvB)	Health and Safety Executive (HSE)	HSE/Office for National Statistics (ONS)	Manchester University Centre for Occupa-tional and Environ-mental Health (COEH)	Manchester University Centre for Occupa-tional and Environ-mental Health (COEH)	Department for Work and Pensions Industrial Injuries Benefits Centres	Statutory Accident Insurance Association (DGUV)	L'Agence nationale de sécurité sanitaire de l'alimenta-tion, de l'environne-ment et du travail (ANSES)	National Health Insurance Fund for Salaried Workers (CNAM-TS) and National Health Insurance Fund for Agricultural Workers and Farmers (CC-MSA)	Danish Working Environment Authority (DWEA) and Labour Market Insurance	Finnish Institute of Occupa-tional Health (FIOH)
Website	In Dutch: http://www.beroepsziekten.nl In English: http://www.o	http://www.hse.gov.uk/riddor/index.htm	http://www.hse.gov.uk/statistics/sources.htm	http://research.bmh.manchester.ac.uk/epidemiology/COEH/research/thor	http://research.bmh.manchester.ac.uk/epidemiology/COEH/research/thor	https://www.gov.uk/industrial-injuries-disablement-benefit	http://www.dguv.de/medien/formtexte/aerzte/F_6000/F6000.pdf	https://www.rnv3p.fr	www.risquesprofessionnels.ameli.fr/statistiques-et-analyse/sini	https://www.amid.dk/viden-og-forebyggelse/arbejdsskader/erhverv	Not applicable

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	rnv3p	Registry of recognised occupational diseases	Registry of occupational diseases	FROD
	ccupationald iseases.nl/								stralite-atmp.html http://www.msa.fr/lfr/web/msa	ssygdomme / /	
Type of diseases covered	Work-related diseases or occupational diseases, including suspected cases	Prescribed occupational diseases	Work-related illness	Work-related illness	Work-related illness	Prescribed occupational diseases	Occupational diseases, including recognised occupational diseases	Work-related diseases or occupational diseases	Recognised occupational diseases, but other diseases can also be reported	Work-related diseases or (recognised) occupational diseases	Work-related diseases or occupational diseases
New/emerging risks included	By another system, SIGNAAL: https://www.signaal.info/	Not specified	Not specified	Not specified	Not specified	No	Yes	Yes	No	Yes	No
Part of compensation system for workers	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
Registration done by	Occupa-tional physicians (or health and safety service providers), other physicians, and through three specific surveillance projects	Employers, the self-employed and people in control of work premises	Individuals (household survey)	General practitioners	Specialist doctors	Workers	Physicians and dentists, employers and workers	Occupa-tional disease clinics and occupational health services	Workers	All physicians (including general practitioners and occupational hygienists) and dentists	Employers and insurance companies
Mandatory/ voluntary	Mandatory for occupational physicians, voluntary for other physicians	Mandatory	Voluntary	Voluntary	Voluntary	Mandatory	Mandatory for physicians, dentists and employers	Voluntary	Mandatory	Mandatory	Mandatory

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
All occupational diseases covered	Yes	No	Yes	Yes	No	No	Yes	Yes	Not specified	Yes	Yes
All industries covered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not specified	Yes	Yes
Registration by means of predefined categories/ free-text fields	Both	Both	Not specified	Not specified	Not specified	Not specified	Both	Both	Not specified	Both	Not specified
Coding system for diagnosis/ clinical description	CAS codes ([a])	Not specified	Not specified	Not specified	Not specified	System-specific coding system	System-specific coding system ([b])	ICD-10 codes	Not specified	ICD-10 codes	Not specified
Coding system for occupation/ job	ISCO-08	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	ISCO-08	Not specified	DISCO-88 (a slightly modified	Not specified

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	rnv3p	Registry of recognised occupational diseases	Registry of occupational diseases	FROD
										version of ISCO-88)	
Coding system for sector/ industry	Standard Business Indicator (SBI) codes	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	French Classification of Activities (NAF-08)	Not specified	DB07 (slightly modified version of NACE rev. 2)	Not specified
Biological agents included in list of causes/ exposures	Yes	Not specified	Not specified	Not specified	Yes	Yes	Yes	Yes	Not specified	Yes	Not specified
Guidelines provided for registration process	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	Not specified	Yes	No
Biological agents covered by guidance	Yes	Not specified	Not applicable	Not specified	Not specified	Not specified	Yes	No	Not specified	Yes	Not applicable

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
Training provided for registration process	Not specified	Not specified	Not applicable	Yes	Yes	Not specified	Not specified	Yes	Not specified	Not specified	Not specified
Information from system is used for	Improving knowledge of and providing insights into occurrence and prevention of occupational diseases	Informing enforcing authorities of risk identification and priorities for investiga-tion, advice and prevention	Gaining a view of work-related illness and workplace injury based on individuals' perceptions	Surveillance	Surveill-ance, and investigating increased risk of particular types of ill health in relation to occupations, industries and causal agents or work activities	Compensa-tion	Compensa-tion; research, policy-making and prevention	Identification and description of OSH risk situations, investigating new aetiologies and emerging risks, and improving and harmonising diagnostic practices in relation to work-related diseases.	Compensa-tion	Compensa-tion; surveillance of risk jobs and industries to prevent occupational diseases and accidents	Compensa-tion, not otherwise specified

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
Way in which outputs from system are made available	Annual report, including annual statistical report (tables)	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Annual reports and annual statistics	Annual reports (the latest for the period 2013-2014)	Not specified	Annual reports and annual crude statistics	Annual reports until 2013
Language in which outputs are made available	Dutch, some in English	English	English	English	English	English	German, some in English	French, some in English	French	Danish	Finnish
Website(s) on which outputs are made available	In Dutch: http://www.beroepsziekten.nl/statistiek-introductie; http://www.beroepsziekten.nl/kerncijfers	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	In German: http://www.dguv.de/de/zahlen-fakten/bk-geschehen/index.jsp In English: http://www.dguv.de/en/facts-	https://www.anses.fr/fr/content/rnv3p-le-r%C3%A9seau-national-de-vigilance-et-de-pr%C3%A9vention-des-pathologies-	CNAM-TS: http://www.risquesprofessionnels.ameli.fr/statistiques-et-analyse/sinistralite-atmp/dossier/nos-statistiques-sur-les-	www.at.dk	Not specified

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
	In English: https://www.occupationaldiseases.nl/ncvb/statistics						figures/ods/index.jsp	professionnelles	maladies-professionnelles-par-ctn.html CC-MSA: not specified		
Biological agents specifically included in data that are made available	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Database publicly available	Yes: https://ncvb.amc.nl/NCVB-MenR	No	No	No	No	No	No	No	CNAM-TS: yes CC-MSA: no	Yes, for period 2004-2009: https://amid.dk/viden-og-forebyggelse/arbejdsskader/erhvervssygdomme/viden-om/statistik-	No

Parameter	Country/name										
	Nether-lands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupa-tional diseases	rnv3p	Registry of recognised occupa-tional diseases	Registry of occupa-tional diseases	FROD
										om-erhvervssyg domme/	

([a]) A conversion table for the translation of CAS codes into ICD-10 codes and vice versa is available.

([b]) The German classification system for occupational diseases is similar to some degree to ICD-10.

Outputs from the systems analysed

Table 76 provides an overview of the main outputs from the various systems. It should be noted that there was no direct access to the data collected in most of the monitoring systems evaluated, and thus the analysis relies on the data that were publicly available. As can be seen from Table 76, Sections 5.1.2, 5.2.3, 5.3.2, 5.5.1, 5.5.2, 5.7.2 and 5.8.2, and Annexes 6 and 7 (which present examples of outputs from the systems evaluated), the level of detail of the outputs that were available for this review varies greatly, both with regard to how the registered occupational diseases are presented (in broad categories or as specific diseases) and with regard to how the related causative exposures to biological agents are presented (again, in broad categories or as specific agents). This makes comparing the outputs from the systems evaluated difficult.

However, in general the percentage of registered diseases due to exposure to biological agents compared with the total number of registered diseases seems to be relatively low. For instance, in France exposure to biological agents accounted for 2 % of all reported work-related diseases over the period 2001-2015. It is, however, hard to estimate exact numbers, since for some countries it is not clear how diseases caused by biological agents, which tend to be mostly infectious diseases, with the exception of some respiratory diseases such as farmer's lung, are actually recorded, since they are reported as a group (biological agents) that tends to make up a low proportions of the all occupational diseases. In some systems, though, more detailed information is available. For instance, in the Netherlands, for around 30 % of the reported cases of conditions of the lungs and airways, biological agents are indicated as the cause of the condition; plants/vegetable-based products and bacteria were most frequently reported.

With regard to trends observed, apart from an upwards trend in the Netherlands in diseases due to biological agents and a downwards trend in the UK, diseases due to exposure to biological agents seem to be stable, although the finding is questionable owing to the differences in recording and under-reporting.

The sectors or industries in which cases of occupational disease due to biological agents are registered (relatively) frequently are agriculture and healthcare. Unfortunately, the available outputs from most of the systems did not make possible a detailed review of the data with regard to industry, occupation, gender or age, although some findings point to food production, waste management, construction, and to the risks posed by tropical diseases imported by travellers and workers working abroad.

Public availability seems to be a limiting factor, but farmer's lung, diseases in food production, hepatitis, travel-related diseases and baker's asthma are relevant issues, as are smaller outbreaks of, for instance, zoonoses, which were also referred to in the questionnaire answers regarding case studies of diseases (Section 4.4, Table 38).

With regard to detailed information about the causes of the registered diseases, the French rnv3p monitoring system is the only one that actually provides information about (assumed) causes of registered diseases on an agent-specific level, as a result of the French TOE, which is applied during the registration process. For at least some other monitoring systems, additional information on causes of diseases should be available (at a more detailed level than the broad categories of 'biological agents', 'animals', 'bacteria', 'fungi', 'parasites', 'plant material', etc.), but this information is often collected by means of free-text fields in the registration form and is presumably not always processed directly. The level of detail on exposures in the TOE does resemble more or less the level of detail in the list of biological agents presented in Annex III to Directive 2000/54/EC. However, since around 3,000 (out of 8,000) labels in the TOE relate to biological agents, divided into microorganisms (bacteria, viruses, fungi, parasites), animals (invertebrates, vertebrates) and plant material, compared with 151 bacteria and similar organisms, 26 fungi, 69 parasites and 129 viruses listed in Annex III, the TOE allows for even more detailed information on this type of exposure.

Table 76: General overview of outputs from selected monitoring systems for occupational diseases with regard to diseases due to exposure to biological agents

Country	Summary of available outputs from the evaluated monitoring system
NL	Occupational diseases due to exposure to biological agents account for only a relatively small percentage of all reported occupational diseases, but their number is steadily increasing over time (as is the case for occupational diseases in general, probably at least partly due to a higher frequency of reporting). Occupational diseases due to bacteria and parasites are most frequently reported and considered the major cause of the disease in the case of zoonoses, infectious diseases and hypersensitivity pneumonitis, while for other diseases biological agents are indicated as the cause of the disease for half or less of the reported cases (e.g. occupational asthma, asthma aggravated by work and contact dermatitis). Within the category occupational diseases due to biological agents, the main focus is on occupational infectious diseases. In 2014, 115 occupational infectious diseases were reported (a 37 % increase on 2013, and in 2015 a further increase was observed), with the highest number of reports in curative healthcare, aviation/air transport and the construction industry. Skin conditions were reported most frequently (of which almost half were caused by a fungal infection), followed by airway symptoms and Lyme disease. In addition, conditions of the lungs and airways show a more or less steady increase over the years. For around 30 % of these reported cases, biological agents were indicated as the cause of the condition, with plants/vegetable-based products and bacteria most frequently reported as causes. The highest number of registered occupational diseases related to exposure to biological agents occurred among caregivers (mainly cases of contact dermatitis, intestinal infection and other infectious diseases), but the proportions of registered occupational diseases due to biological agents to all registered occupational diseases were highest among petty officers (army), trained farmers, trained foresters, fishermen and hunters, farmers, cattle breeders, fishermen, hunters and gatherers, and food processing workers, indicating that this type of occupational disease seems to occur relatively often in agriculture.

Country	Summary of available outputs from the evaluated monitoring system
UK	Dangerous occurrences in relation to biological agents registered under RIDDOR account for 5-6 % of the total during 2014-2016.. Equally, cases of occupational/work-related disease caused by biological agents reported under RIDDOR during the period 2014-2016 account for around 6 % of the total. The number of cases of occupational dermatitis caused by biological agents (as reported to EPIDERM) is relatively low (and the biological agents in question are not further specified). However, a large proportion of the 'organic agents' that are specified in relation to occupational asthma (in SWORD) are considered biological agents under the definition used in this report. In the IIDB system, steady numbers of cases of allergic alveolitis (5-10) and tuberculosis (5) are reported each year in relation to exposure to biological agents, but the rest of the diseases on the list have not been reported in recent years. A considerable number of cases of occupational asthma, rhinitis and dermatitis are also reported, but only a small proportion of these cases is assumed to be caused by biological agents. At least some of the cases of occupational asthma (mainly in bakery workers, caused by exposure to flour dust), COPD (caused by exposure to grain dust), allergic alveolitis, rhinitis and byssinosis, and work-related skin disease (caused by exposure to allergens) result from exposure to biological agents. In general, a reduction in the number of cases has been observed over the years (a downwards trend).
DE	Over the period 2012-2015, of the total number of notifications of suspected cases of occupational disease, 3-4 % were infectious diseases, around 5 % were respiratory disorders and obstructive airway diseases (of which 6-7 % were due to exposure to organic dust), and 34-38 % were occupational skin diseases. Notifications have increased recently, but confirmed cases do not show a proportional increase (although these too show a slight increase in recent years). The healthcare sector is a major sector with occupational infections.
FR	From 2001 to 2015, exposure to biological agents accounted for only a relatively small percentage of all reported work-related diseases (2 %). During this period, numbers of reported exposures to biological agents seem to have remained stable, with the exception of the categories of animal and plant material (exposures seem to be increasing and represent > 70 % of total exposures to biological agents). Work-related diseases due to exposure to one or more biological agents occurred in seven industry sectors (6-13 % of the total): food industries; health and social care; farming, hunting and ancillary services; retail trade and repair of household goods; construction; hotels and restaurants; and public administration. Reported work-related infectious diseases and diseases caused by parasites over the period 2001-2015 were mainly cases of tuberculosis, followed by mycoses and viral hepatitis. In addition, non-infectious diseases such as hypersensitivity pneumonitis due to exposure to organic dust (e.g. allergic alveolitis, farmer's lung, mushroom worker's lung) were reported. Farmer's lung represents one third of all hypersensitivity pneumonitis cases reported. A further subdivision of the cases of hypersensitivity pneumonitis shows that nearly half of all biological agents belong to the 'fungi, mould' category, followed by 'vertebrates', and that the main industry sectors concerned are farming, hunting and ancillary services, and food industries.
DK	In recent years, numbers of notifications of occupational diseases related to biological agents have been relatively stable (1-2 %). In general, the percentage of registered diseases caused by biological agents per sector has been relatively low and constant over the years (on average, 1.2-2 %). However, in some sectors, such as agriculture, forestry and fishing, the food and beverage industry, restaurants and bars, and hotels and camping (2-6%), this percentage is relatively high, indicating that biological agents are a risk factor that needs particular attention.

Country	Summary of available outputs from the evaluated monitoring system
FI	The numbers of cases of occupational disease reported have either remained stable or declined in recent years, with the number of suspected diseases being much larger than those that are finally recognised. The industry that produces the most cases is agriculture. The proportions of cases of allergic respiratory diseases and skin diseases are increasing owing to reductions in other conditions. With respect to occupational diseases due to exposure to biological agents, allergic diseases are reported most frequently (mainly allergic asthma and allergic rhinitis, and to a lesser degree also allergic alveolitis and laryngitis). Reported skin diseases do not seem to be closely related to biological hazards.

Link to prevention

The outputs from the systems are generally made available by means of annual reports and/or crude statistics, which may be publicly available and at least in some cases are also actively shared with relevant stakeholders, such as the government, employers' and workers' organisations, health and safety service providers, and healthcare providers and (para)medical professionals operating in the field of OSH. This is confirmed by the results from the questionnaire (see Section 4.5.3). However, in what way this information is actually used to target preventive measures does not seem to be sytematically evaluated. And since in general the level of detail of these annual reports is not very high, and the available information on exposure to biological agents in the workplace and the associated health risks is not very extensive, it remains at least questionable if this type of information is suitable for identifying and implementing the necessary preventive measures to deal with this type of exposure.

Although usually one of the aims of registration systems for occupational diseases is to systematically collect information to help target prevention of the most relevant issues and/or emerging risks, the extent to which the information gathered is actually used for this purpose remains unclear. Therefore, it is also unknown whether the information gathered through these monitoring systems with regard to exposure to biological agents in the workplace and related diseases is actually used to prevent these exposures from occurring, or at least to better control the exposure situations in the workplace and ensure that exposures to biological agents are as low as possible.

Under-reporting and under-recognition

In this review, under-reporting was identified as one of the weaknesses of most if not all of the monitoring systems evaluated. However, the exact level of under-reporting cannot be quantified. It is assumed that the actual number of work-related diseases, including diseases due to biological agents, is (much) higher than is reported in the various countries, but no precise figures are available. This is also the case for the sectors that have been identified as sectors/occupations of concern in this review, which are, for example, arable farming, animal breeding/caring/handling, waste management and healthcare. In this review, under-reporting was identified as an issue among healthcare workers, and this was thought to be a result of stressful situations and non-compliance with protocol. Another important factor contributing to under-reporting may be under-recognition.

Monitoring systems for occupational exposures

Of the European countries for which publicly available data from selected systems were collected (the Netherlands, the UK, Germany, France, Denmark and Finland), only in Germany, France and Finland were systems identified that monitor and register occupational exposures on a regular basis.

In comparison, in the questionnaire survey 30 respondents out of 20 from a total of 29 countries indicated that they were familiar with one or more exposure monitoring systems. Different types of systems were identified, including registration systems for exposures, surveillance studies/programmes (to study/monitor a specific topic in a specific group), exposure assessment and information systems (to collect/categorise/classify information) were most frequently mentioned. The data were mostly reported as being used for policy-making, prevention programmes and research. However, there seems to have been confusion between exposure monitoring systems and monitoring systems for occupational diseases operating in these countries (see Annex 4, Tables 4-2 and A4-3), and registration of occupational diseases was the main purpose of many of the exposure monitoring systems referred to by the respondents.

Because the relationship with exposure is recorded when registering a disease, valuable information about exposures is gathered, albeit in an indirect way, by people registering occupational diseases; this at least gives an idea of the types of exposures that are related to the observed health effects. If these people were provided with suitable information to determine the cause of the disease (i.e. the relevant exposure), it could then be recorded with a high level of detail and exposures would be monitored and investigated in more detail too. This could provide valuable input for the development of an effective prevention programme.

One of the systems that records both exposures and diseases is the French rnv3p system. As mentioned in Section 5.10.1, the French TOE used in the rnv3p system allows detailed classification of exposures that include biological agents and relates them to tasks. This approach could serve as an example for designing a system to record exposures and link them to cases of ill health, as well as systematising and improving existing systems.

Few workplace measurements: only in selected occupations and workplace situations

Regular and compulsory measurement of workplace exposures to biological agents is not common in the countries considered here. Therefore, very limited information on exposure is available to optimise prevention programmes. In those countries where exposure measurements for biological agents are being carried out, some guidance values are in place — for example the technical control value for spores of mesophilic moulds in the workplace air of waste handling facilities in Germany (ABAS/BAuA, 2018) — but formal OELs for biological agents are not.

In Germany, occupational exposures are monitored through research projects or as part of routine data collection conducted by the BAuA, the IFA or the DGUV, the accident insurance institutions, the employer's liability insurance associations and universities. These exposure measurements include the measurement of biological agents. However, measurements of occupational exposure to biological agents are not mandatory (in contrast to measurements of exposure to chemical agents), and there are no OELs for biological agents. Individual data collection strategies for biological agents are established by accident insurance institutions. Since 2000, data on exposure to biological agents have been stored in the MEGA database (whole colony counts (for bacteria and fungi), and data on single species of bacteria and fungi, and on endotoxins). The data are maintained and evaluated by the IFA to determine exposure in specific workplaces, for epidemiological studies, for retrospective exposure assessment and for prevention purposes. However, the MEGA database is accessible only to statutory accident insurance institutions and other selected stakeholders, and data are not publicly available. Nonetheless, there are some details in the German MEGA database on exposures related to the bioburden of contaminated water-miscible cutting coolants and on exposure to endotoxins in natural textile fibre processing and manufacturing, as well as in agricultural settings. An extract from the analysis of moulds and endotoxins has been published in TRBA 400 (ABAS/BAuA 2017). Another area that has been reported on is respiratory diseases in the sea transport sector. There is a large data pool available that could be further explored. Similarly, measurement of bioaerosols and endotoxins has been carried out in the Netherlands in an attempt to standardise exposure assessment. German BAuA projects have focused on health risks in poultry farming, the use of rRNA-gene libraries to characterise biological agents in the air in workplaces, exposure to biological agents in biogas production, antibiotic-resistant bacteria in emissions from industrial livestock farming, exposure of hatchery workers to airborne bacteria taking into account existing antibiotic resistance, and the detection of airborne biological agents under difficult analytical conditions. However, leaving aside these specific issues, no overviews of exposure data on biological agents are currently available.

In France, the INRS collects the results of air measurements in workplaces performed by eight French regional health insurance funds, inter-regional chemical laboratories and the INRS laboratories. These measurements are carried out in the context of occupational risk prevention and recorded in the COLCHIC database. The data collected in COLCHIC come from measurement campaigns performed in establishments under the national social security scheme. However, the focus of the measurements in COLCHIC seems to be on chemical substances, and no information is available that suggests that data on exposure to biological agents are also collected. In addition to the COLCHIC database, the occupational exposure database (SCOLA) results from the French requirement that measurements made during the assessment of compliance with regulatory OELs should be archived in a national register. The measurements stored in SCOLA are performed by certified laboratories, which are independent of the company being monitored. With regard to the SCOLA database, no information is available that suggests that data on exposure to biological agents are also collected. This is to be expected, as no OELs for biological agents are known to be in place in France.

In Finland, FIOH keeps records of exposure measurements made as part of the occupational hygiene services it provides to companies, performed to fulfil the legal requirements, based on EU law, for employers to take preventive action to prevent workplace risks. The biological agents measured are mainly endotoxins, moulds, bacteria and parasites in workplaces, and IgE and IgG antibodies in workers exposed at these workplaces are also measured. The data are collected in a database that is not publicly available and can be analysed only on request, and no publications are available describing these exposure data. However, based on this database, FIOH has developed FINJEM, which contains information on exposures to organic dust (e.g. animals, flour, plants, and softwood and hardwood dust) and exposures to microbiological agents (e.g. mould spores and Gram-negative bacteria of non-human origin); similar tools could also be valuable in other countries, as FINJEM records data on the level of the exposure.

Access to measurement data is limited

Thus, in some of the countries in which regular exposure monitoring is in place, embedded in a system in which exposure measurements are required for risk assessment and/or prevention and are the responsibility of employers, exposures to biological agents in the workplace are also measured. However, since the databases in which the exposure data are collected are not publicly available, and in general the data available in these databases are normally not described in any way, information on, for instance, levels of exposure to different biological agents and the occurrence of these exposures in various industries/sectors is lacking.

In addition, deriving European reference values for at least general markers of exposure to biological agents, and perhaps even OELs for some of the most prominent and/or dangerous biological agents, would enable better surveillance of these exposures by labour inspectorates.

Reporting obligations under public health provisions

As reported in the questionnaire survey (Annex 4, Tables A4-2-A4-4), some of the systems that record diseases linked to exposure to biological agents operate under public health provisions. For example, in Germany physicians are obliged to report cases of certain infectious diseases (from a list of infectious diseases) to the local authority. The diseases in question represent a particularly high risk to public health and, in the case of zoonoses, also to animal health. This information is gathered and published by the Robert Koch Institute.

Mandatory notification of infectious diseases also covers occupational infections, although these cases are not necessarily specifically described as work-related diseases. In Greece, the National Mandatory Notification System for Communicable Diseases, supported by the Hellenic Centre for Disease Control and Prevention, is responsible for the epidemiological surveillance of 45 infectious diseases. Some of the diseases covered by this system are caused by biological agents that may be work related (e.g. brucellosis, echinococcal disease, hepatitis B and C, HIV, rabies). In the Netherlands, this role is played by the OSIRIS system (see Section 5.1.1), while in Spain the EDO system (Enfermedades de Declaración Obligatoria) is the equivalent. Public Health England collects data on cases of Legionnaire´s disease under the national surveillance scheme established to collect enhanced surveillance data on all cases of legionellosis in residents of England and Wales. In Portugal, it is SINAVE (Sistema Nacional de Vigilância Epidemiológica, or National Surveillance System for Obligatory Notifiable Infectious Diseases) that collects data on notifiable infectious diseases, and in Slovakia it is the EPIS system.

Better use could be made of these data to improve the prevention of occupational diseases, and this is discussed further in the following section.

5.11 Classification of biological agents

An important aspect of monitoring exposures to agents in the workplace, including exposures to biological agents, is the categorisation and classification of these agents. The French TOE provides a dedicated classification system for exposures that includes biological agents.

The system of classification of biological agents into risk groups used in Germany by ABAS is also a practical example of a useful system. It is based on and expands the provisions of Directive 2000/54/EC, and provides different lists for bacteria, fungi, viruses and parasites. Particular attention is paid to both infection potential, which determines the classification, and the sensitising and toxic potential of biological agents. If biological agents have hazardous properties independent of their infection potential, this is noted through the use of additional labels. In addition to the biological agents listed in Annex III to Directive 2000/54/EC (classified in groups 2-4), the German classification system includes biological agents classified in Risk Group 1 (according to Directive 2000/54), which have no potential for infection according to current knowledge. The classification system for biological agents in Austria is linked to the German classification system, and Switzerland also has a classification system for biological agents. Furthermore, the classification of organisms used in genetic engineering may also be a useful source of information, such as the database on safety-assessed organisms of the Federal Office of Consumer Protection and Food Safety in Germany (BVL, undated).

The GESTIS Biological Agents Database maintained by the IFA in Germany is a good example of how available information can be organised and made public (see Section 5.4.4). This database is publicly available and contains information on, for example, important properties of the various biological agents, including their occurrence, typical exposures at work and pathogenic properties, and relates them to prevention measures. It contains data on about 15,000 biological agents.

6 Discussion, conclusions and recommendations

The objectives of this review were to:

- assess existing information on:
  - health problems related to exposure to biological agents (paying particular attention to vulnerable workers and covering infectious agents, airborne aerosols and allergen factors),
  - work-related health effects and diseases linked to exposure to biological agents at work,
  - biological agents (including those that are less known, and emerging exposures to biological agents in new professions and new industrial activities),
  - recognised and compensated occupational diseases linked to exposure to biological agents in Europe,
  - monitoring systems that record work-related diseases linked to biological agents and/or exposure to biological agents (including their limitations), and
  - major reviews related to the implementation of Directive 2000/54/EC on the protection of workers from risks related to occupational exposure to biological agents in the EU;
- identify databases and datasets that provide systematic information on biological agents and risks to workers; and
- identify gaps in data and knowledge.

This section contains a summary of and conclusions based on the results of the scientific literature review, the questionnaire survey and the evaluation of selected monitoring systems. It is organised around several themes that are considered important, identifies data gaps and includes recommendations for the future.

6.1 Biological agents, related health effects, emerging risks and occupations at risk

The main occupations, work-related health effects and diseases linked to biological agents

Chapter 4 of the report includes extensive tables of the biological risk factors and related diseases identified through the literature search, which also show the occupations and economic sectors affected. However, the extent to which a particular biological agent had been researched and reported in the literature varied considerably. Most commonly reported were health issues in the agricultural industry, and among workers dealing with animals, including veterinarians and slaughterhouse workers. Likewise, the characteristics of biological agent-related health issues in the healthcare sector (hepatitis, HIV, etc.), among sex workers (sexually transmissible infections), among forestry workers (tick-borne diseases) and among workers maintaining air-conditioning systems and similar systems (Legionaire´s disease), were well described, and associations between work-related diseases and biological agents were well established among these sectors and occupational groups. However, there was a paucity of literature on many occupations and sectors; sometimes, the search strategy retrieved only a single publication. These included the aquaculture sector, bone button makers, border guards, fertiliser workers and outdoor game managers.

For several occupations, a very broad spectrum of potential infections and related diseases was identified through the literature review, for example in occupations that involve contact with animals (e.g. agriculture, animal breeders/carers/handlers, veterinarians, zoo personnel), healthcare workers, laboratory personnel and waste workers. In general, veterinarians, livestock farmers and workers in other occupations that involve contact with animals are considered to be at increased risk of contracting zoonotic infectious diseases (diseases that are transmitted from animal to human).

Allergenic agents in the agricultural and fishery sectors and in the food industry (specifically the production and processing of food) appeared to be among the most researched topics by a large margin.

These were followed by allergens in laboratory animal personnel. Other well-researched areas included allergens in the woodworking and metalworking industries that had similar bacterial and fungal microorganisms as causative agents. Common to the abovementioned sectors and occupational groups were the health outcomes of asthma and farmer's lung (hypersensitivity pneumonitis) (Zacharisen and Fink, 2011; Burton et al., 2012). Other fairly well-studied sectors in connection with allergenic health complaints were waste management and composting, and, with the expectation of more green jobs in the future, one might expect to see an increased prevalence of sensitisation to biomass-related allergens. These diseases are registered by at least some of the registration systems evaluated in Chapter 5, but, except for farmer's lung, it is rather difficult to link an allergenic health complaint definitively to workplace exposure to a particular biological agent. The relatively sparse evidence base makes it difficult to set general priorities in policies for the prevention of allergens in the workplace, although some exceptions do exist (e.g. with regard to bakery workers (Meijster, 2009)).

Assuming that the amount of literature available on the association between a specific biological agent and an OSH issue is indicative of the relevance and extent of knowledge on that association, the knowledge of the various biological agent-work-related disease associations varies. Continued research on the well-described associations between biological agents and certain diseases should be encouraged (e.g. in relation to the healthcare sector and sex workers). However, particular attention is warranted when information is scarce, either in the literature or among experts in the field. A single publication on a biological agent-work-related disease link could either signal a bigger underlying issue or identify a biological agent-related health issue that may increase among an occupational group if not appropriately addressed at an early stage. Again, raising awareness among practitioners with the objective of keeping a close eye on increased incidence of known diseases in novel occupational settings would be a key mitigating strategy. Based on this review, the key sectors on which to focus appear to be the agricultural and fishery industries, the food industry and occupations in which workers purposely or inadvertently come into contact with animals. The healthcare sector is also an obvious area of concern, although, given its nature, it already enjoys considerable focus, and knowledge regarding its issues is fairly substantial.

Impact of the definition of biological agents on the identification and recognition of diseases

Based on the Directive 2000/54/EC's definition of biological agents, substances or structures that originate from living or dead organisms (e.g. exotoxins, endotoxins, glucans, mycotoxins and allergens) fall outside its legislative purview. This probably has implications for how well these may be considered in the national monitoring systems and health policies of Member States. However, there is no way of knowing precisely how this omission affects official reporting of illness and disease related to exposures to biological agents that fall outside the scope of the directive. The considerable literature on these exposures may suggest that it should be ensured that they are covered in the legislation incorporating the directive into national laws and guidance. Possibly that expansion of the directive's remit should be considered, particularly when one considers findings in the literature such as the high prevalence of rodent allergy (11-44 %) and insect allergy (26-35 %) among laboratory personnel, the relatively high rates of allergenic responses among vulnerable and/or inexperienced workers and the incidence of emergency treatment for anaphylactic shock in seafood workers.

Emerging risks in Europe and their risk factors

The concept of an emerging risk may cover a '(i) newly created risk; (ii) newly identified/noticed risk; (iii) increasing risk; (iv) or risk becoming widely known or established' (Flage and Aven, 2015); there is a slightly different definition by EU-OSHA (2007a):

> An 'emerging OSH risk' is any risk that is both new and increasing. New means that:
>
> - the risk was previously non-existent; or
> - a long-standing issue is now considered to be a risk due to new scientific knowledge or public perceptions.
>
> The risk is increasing if:

- the number of hazards leading to the risk is rising; or
- the likelihood of exposure is rising; or
- the effect of the hazard on workers' health is getting worse.

In the context of this review, 'newly created risk' pertains to new circumstances that facilitate increased incidence rates of diseases that have not previously been reported in Europe. This may be due to, for instance, climate change and/or increased travel between Europe and areas in which diseases not usually seen in Europe are endemic, or to known diseases appearing in (workplace) settings where they have never before been observed. There are nuances of meaning among the other categories of emerging risk, but most types that relate to biological agents in Europe fall within this first category of newly created risk, including new bacteria developed through bioengineering and increased exposure to bacteria and fungi due to an increase in the collection and separation of organic waste (EU-OSHA, 2013a, 2013b).

Climate change

Climate change is a significant factor with respect to newly created risks in that it influences the geographical range of the vectors (ticks, mosquitoes) of biological agents, thereby facilitating the spread of diseases that are new to the region. Among the diseases identified in this review are Rift Valley fever, yellow fever, malaria, dengue fever and chikungunya (Applebaum et al., 2016). Evidence has also been confirmed of Crimean-Congo haemorrhagic fever, which is endemic to the Balkans, in Spain and Portugal — a circumstance that suggests the possibility of further spread. Jenkins et al. (2013) highlighted the risk of a shift in occurrence of zoonotic parasites due to climate change.

Travelling and an increase in working abroad

Changing travelling patterns are also a major factor in emerging risks. Indeed, travelling was indicated by questionnaire respondents as a reason for paying more attention to certain biological agents and the illnesses they cause. Hepatitis E, for instance, is of particular concern in relation to vulnerable people and is associated with travel to endemic areas. Workers who are in contact with travellers (airline personnel, customs workers), global trade workers, workers in war zones, epidemic control (field) epidemiologists, and journalists and media professionals are likely to be at risk of contracting diseases that leisure and business travellers in general are at risk of contracting. This includes the risk of contracting avian influenza, Q fever, dengue fever, Ebola/Marburg virus infection, tularaemia, legionellosis, measles, tuberculosis, yellow fever, SARS, cholera or meningitis (EU-OSHA, 2007a).

Some workers whose jobs involve travel, for example professional drivers, should also be scrutinised for their risk of contracting diseases linked to exposure to biological agents. For example, fungal infections are reported (Seyfarth et al., 2010; Correia et al., 2010), possibly related to air conditioning. As no prevalence data are available and a significant number of workers may be concerned, the risks posed to professional drivers should be considered as a subject for future research.

Migration

Despite the greatly increased movement among populations from very diverse regions (including Asia, the Middle East and Africa) to Europe, research on the transfer of biological agent-related diseases from populations outside the region was limited to only one publication identified in this review, which described malaria transmitted in Europe by European-settled immigrants returning from visiting friends and family in their country of origin (Monge-Maillo and López-Vélez, 2012), without, however, an occupational context. Nonetheless, owing to the large migration flow that has been apparent in large parts of Europe in recent years, the transfer of biological agents from the Middle East and Africa may need to be given extra focus, especially among groups of workers who are in first contact with migrants (e.g. healthcare workers, social workers, rescue workers and customs workers). That there are vaccination programmes within EU Member States for diseases, such as pertussis and malaria, that are most commonly associated with developing countries suggests that some Member States (e.g. the UK, the Netherlands) recognise the importance of migration and (work) travel in relation to the distribution of diseases from outside the EU.

Other issues, such as surgical smoke

Other emerging diseases were seen in central and eastern Europe among veterinarians, with cases of human dirofilariasis noted as an emerging zoonosis (Dutkiewicz et al., 2011) and infections due to the fungus *Sporothrix schenckii* (inducing sporotrichosis) reported as a new risk category (Barros et al., 2011).

Surgical smoke was another issue identified from several publications that warrants further examination. It is generated from the use of novel surgical instruments, such as laser devices, and it is estimated that about 95 % of all surgical processes create some degree of surgical smoke plume, which may contain living microorganisms such as multidrug-resistant tubercle bacilli, viral DNA of hepatitis viruses, HIV or human papillomavirus.

Re-emerging diseases (e.g. Q fever, tuberculosis and influenza) should also be considered among emerging risks, and the drivers for their re-emergence should be fully investigated.

The importance of case reports

Of special interest are first case reports, which may sometimes be indicative of a newly created risk. The first case reports identified in the literature search were predominantly concerned with the first cases of allergen-related occupational asthma, caused by a heterogeneous range of allergens. They were mainly observed in (roughly) three industries or types of occupation: the food industry; occupations in which workers purposely or inadvertently come into contact with animals; and occupations in which workers deal with plant products. It is not always easy to determine what exactly causes an allergic reaction, and the literature considers all allergens, irrespective of whether they originate from biological agents in the narrower sense of the term — that is, microorganisms — or from plants, animals or insects or even foodstuffs, for example. In quite a few cases, the exact causes of the allergy have not yet been elucidated, and very little is known about the role of microorganisms or their constituents, although fungi are increasingly recognised as an important cause of allergy. This is why it is important to record all exposures and why a broader approach has been chosen for this review.

In the food industry, first cases of occupational asthma have been seen, caused by *Chrysonilia sitophila* in the coffee industry; *Penicillium nalgiovensis* in sausage mould in semi-industrial pork butcheries; in connection with mushrooms at a greengrocer's; among seafood processing workers exposed to aerosolised octopus allergens and turbot; among olive oil and rice mill workers; and among machine operators at a malt company (Quirce and Bernstein, 2011; Quirce and Sastre, 2011). In occupations that involved contact with animals, the first cases of occupational asthma were observed among animal rehabilitation workers who dealt with roe deer, biologists who handled gerbils, greenhouse workers who were exposed to predatory mites and in an engineer who was exposed to caddis flies while working for an electric power company (Quirce and Bernstein, 2011; Quirce and Sastre, 2011). With respect to plant-related allergens, first cases were observed among plant breeders in connection with exposure to cauliflower and broccoli pollen; among greenhouse workers in connection with tomatoes; among herbal product traders; in a worker packing chamomile tea and among laboratory plant workers (*Arabidopsis thaliana*). Other notable first cases of occupational asthma concerned famers (cellar spider); exposure to wood among carpenters (cedrorana, chengal wood, *Arabidopsis thaliana*) and parquet floor layers (cabreuva wood); a chemist (linseed oilcake); a brush maker (tampico fibre); and pharmaceutical workers (papain). Rim et al. (2014) reviewed case reports of professions commonly known to be exposed to biological agents and rare infections, healthcare and laboratory workers, emergency responders, and workers in agriculture, fishery and forestry, as well as reports of outbreaks, for example of pertussis in an oncology department, or a hip prosthetic infection of a fishmonger.

The identification of emerging risks from biological agents and the factors that facilitate their emergence and spread is the first key step in the control of newly created, newly identified or re-emerging biological-related diseases. However, the nature of some emerging risks, in particular those linked to first case reports, makes mitigating measures challenging, since potential risk factors are difficult to identify. Robust monitoring systems, along with thorough incident investigation, are appropriate measures for determining if single cases may signal a larger threat in the future. In cases of emerging risks associated with larger issues such as climate change and increased movement of populations, mitigating strategies should focus on preventive measures. Furthermore, social issues such as human trafficking should be considered when addressing, for example, sexually transmissible infections and implementing prevention programmes to mitigate the effects and ensure social protection.

Other important data gaps include insufficient knowledge on the extent of the risk to zoo and wildlife veterinarians of contracting zoonotic diseases due to the transfer of animals from outside Europe to European animal parks and animal conservation centres for worldwide breeding programmes; limited research on the transfer of disease across borders mediated through travel staff; and the lack of prevalence data on fungal infections, possibly related to air conditioning, among professional drivers.

Comparing biological agents and diseases identified by experts and by the literature review

The agents and diseases identified by the expert respondents overlapped considerably with those identified through the literature search, although there was considerable heterogeneity in the questionnaire responses. Among the sectors/occupations identified as areas of concern were arable farming, animal breeding/caring/handling, waste management and healthcare. However, there was not always agreement with respect to the areas of concern for some of the biological agents and/or diseases.

Legionnaire´s disease, leptospirosis in farming and Q fever were identified as important issues by most of the questionnaire respondents as well as by the scientific literature search. However, for *Legionella*, the respondents indicated biological treatment plants, paper mills and healthcare as areas of concern, whereas based on the outcome of the literature search, workers in animal-related occupations, forestry workers, gardeners, maintenance workers, professional drivers and many others were also identified as at risk .

For leptospirosis, both the expert respondents and the literature search indicated agriculture as an area of concern, while only the literature search results referred to other workers in animal-related occupations and outdoor workers, as well as construction workers, dock workers, hunters, maintenance workers and pest control workers. Leptospirosis was also identified as an issue by the monitoring systems of France, the Netherlands and the UK.

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Moreover, while respondents considered hepatitis B virus, HIV and influenza to be the most important biological agents (see Section 4.4 responses to Question 17), they failed to report hepatitis B or HIV as areas of concern for healthcare workers, emergency services workers, mortuary workers, sex workers or waste workers, and nor did they report cases of (avian) influenza (see Section 4.4, responses to Question 15, and Annex 4, Table A4-10), although these were all reported in the literature selected for review.

Zika fever and epidemic nephritis in agriculture (farming) were the only diseases reported by respondents that were not identified in the literature.

The discrepancies between expert- and literature-sourced information on biological agents suggest that the approach of supplementing the literature review with input from experts has provided a more comprehensive overview of the associations among biological agents, work-related diseases and occupational settings than would have been obtained by considering only one information source. It also highlights the need for improvement in knowledge transfer between the research community and public health experts, as well as OSH practitioners, as it was clear that the literature offered the greater share of relevant information. Consequently, it is important to ensure that experts are privy to the wealth of information in the public health literature, as this will improve their awareness of the wide range of occupational settings in which specific biological agents could lead to work-related illness and disease.

Furthermore, the data extracted from the national systems included in this report confirm the findings of the literature review at least partially. They also highlight that it is important to reconsider regularly the lists of occupational diseases and the monitoring systems for exposure to cover the exposures and related health problems in workplaces, as well as prevention efforts. There are challenges ahead linked to the increase in tick-borne diseases and increased exposure to moulds. Another challenging area that is reflected in the monitoring systems is exposure to complex mixtures such as organic dust, and this is at least as challenging for workplace prevention and monitoring as exposures or mixtures of chemicals, because the composition of these dusts may vary greatly, given that they are composed of and produced by at least some living organisms. According to Ghosh et al. (2015), bioaerosol distribution in indoor environments is highly dependent on seasons and is found to be higher in summer and autumm and lowest in winter, so there may be great seasonal variations. The increase in green jobs and the increased use of natural construction materials may also increase exposure to these complex mixtures.

Vulnerable groups

A recurring theme in the literature review was the vulnerability of trainees and workers in their first job, who may be at higher risk than their more experienced colleagues; this may also be reflected by the fact that younger workers (< 21 years and 21-30 years) are slightly over-represented in prevalence reports on registered occupational diseases. Among those mentioned in the literature were trainee nurses and students starting career programmes, whose exposure to allergens resulted in a substantially higher frequency of sensitisation than their more experienced counterparts, as well as medical trainees at risk of contracting infectious diseases and of nosocomial transmission of blood-borne or body fluid-borne pathogens, with particular concern for those who work in resource-poor countries. This points to a need to improve training programmes for new workers in work sectors and occupational groups that are identified as being at high risk of biological agent- or allergen-related diseases. Also within this group of vulnerable workers are young cooks, who reportedly experience seafood allergy after a median of 1.7 years after beginning their employment, although in these cases natural susceptibility may also play a role in addition to their being workplace novices, since the majority experienced immediate sensitisation with a considerable proportion (16.7 %) succumbing to anaphylactic shock.

Pregnant workers are a particular group protected by the provisions of the pregnant workers Directive (Directive 92/85/EEC). The objective of this Directive is to protect the health and safety of women in the workplace when pregnant or after they have recently given birth and women who are breastfeeding. Under the Directive, a set of guidelines detail the assessment of the chemical, physical and biological agents and industrial processes considered dangerous for the health and safety of pregnant women or women who have just given birth and are breast feeding. This includes biological agents of risk groups 2, 3 and 4, in so far as it is known that such agents or the therapeutic measures necessitated by them endanger the health of pregnant women and the unborn child, and explicitly toxoplasma, and the rubella virus, unless the pregnant workers are proved to be adequately protected against such agents by immunization. Cytomegalovirus is another agent that should be addressed.

Another potentially vulnerable group identified by the literature review is immunocompromised people, for example in relation to fungal and viral infections. *Histoplasma*, *Coccidioides*, *Cryptococcus* and *Blastomyces* are fungi known to infect immunocompetent individuals, whereas immunocompromised patients are susceptible to infection with *Candida* and *Aspergillus* (Gerardi, 2010; Gangneux et al. 2012). Immunocompromised people (e.g. transplant recipients and HIV-infected patients) are also vulnerable to hepatitis E infections, as are pregnant women and patients with pre-existing liver disease.

Another vulnerable group for contracting for example zoonoses from contact with animals are people with peritoneal dialysis (Broughton et al., 2010).

As detailed below in Section 6.5.2, the critical doses and circumstances may be different for these groups, in particular immunocompromised people and pregnant workers, in relation to whom the effect on the unborn child needs to be considered too.

Another vulnerable group identified in the review is sex workers; prevention programmes targeting these workers need to take into account wider social issues such as the prevention of human trafficking and violence, and the social support schemes available to these workers.

For most occupations, no information was identified specifically on vulnerable groups, indicating an important data gap that should be addressed. It should be borne in mind, in addition, that EU OSH legislation has highlighted young workers and pregnant and breastfeeding women and their children as groups that warrant particular attention, and this applies in particular in relation to biological agents. This was confirmed by the literature review.

Other data gaps and recommendations

No data on prevalence except for a few occupations

With the exception of figures for the healthcare sector and the sex industry, prevalence data tended not to be reported in the literature. It was therefore difficult to distinguish between occupations with a (supposed) increased risk and those with an actual increased risk on the basis of comparisons of prevalence data on diseases between occupational groups and the general public. Consequently, it was not possible to verify whether an observed (work-related) biological agent-disease relationship was indicative of an actual higher disease rate or just an increased risk due to increased potential for exposure to the biological agent. In the absence of prevalence data, it can only be said that diseases are potential (as opposed to actual) work-related diseases, because of the greater risk of exposure when compared with the general population. An illustrative example is that of dentists, for whom a relation between their work and increased risk of hepatitis B or C infection is indicated. The highest prevalence of hepatitis B among healthcare workers is reported among dentists, which demonstrates an increased risk among dentists of contracting hepatitis B. However, the prevalence of hepatitis C among dentists was reportedly similar to or lower than that among the general population. This suggests that despite the greater potential for exposure, the protective measures in place among dentists is sufficient to ensure that disease prevalence is kept below the levels observed in the general population. Likewise, although Ebola and Marburg virus and other viral infections are indicated as a risk in several occupations, the underlying prevalence is likely to be very low. However, despite the paucity of prevalence data, the severity of health effects upon infection and the ease of disease transmission means that these biological agents are of a high priority for prevention.

Overall, the lack of prevalence data represents a significant data gap with respect to biological work-related diseases and robust health surveillance and registration systems (e.g. obligatory notification schemes) will be required if it is to be seriously addressed.

It should be mentioned that medical personnel are to be regarded as a high-risk group at the same time as being the main reporters for work-related diseases linked to exposures to biological agents. This applies to occupational physicians, to general practitioners and other specialists, as well as dentists. They can therefore be regarded as important mediators of the prevention message, provided that they are well informed and stimulated to engage in improving the information provided about health problems and getting the prevention message across.

Lack of information on vaccination and refusal of vaccination among workers

A better understanding of the factors influencing low vaccination take-up among healthcare workers is an important subject for further research. It is not fully understood why there are low vaccination rates for example against influenza and *Bordetella pertussis* among healthcare workers, as pointed out in some of the research identified in this review, but vaccination rates may be important when it comes to protection of workers and patients. Kuster et al. (2011), for example, pointed out that healthcare workers are at a higher risk of asymptomatic but not of symptomatic influenza infection and this may mean a potentially increased risk of transfer of infections to their patients, and may also be important to consider in case of pandemic outbreaks. A higher rate of asymptomatic infection suggests past exposures that have lead to a certain degree of immunisation. While the healthcare workers may be at risk, they may also spread the disease. At the same time their infection rate would not be recognised, as it is asymptomatic. As the authors point out, a thorough assessment of influenza risk in healthcare workers, particularly those working in acute care, is needed to support decisions regarding priorities for influenza vaccination and antiviral treatment or prophylaxis during pandemics. Similarly, vaccination rates linked to other diseases may have to be considered to prevent spread of diseases, particularly to vulnerable populations, but also to limit risk to the workers themselves.

6.2 Rules and regulations and their implementation

As emerges from the questionnaire responses (Annex 4, ‘National policies, campaigns, networks and reports’), all the surveyed countries have regulations dedicated to prevention of harm from exposure to biological agents at work and many also have specific rules in relation to needlestick injuries and other related issues. Quite a few respondents also mentioned rules on health surveillance and mandatory reporting of exposures, or of accidental exposures or specific diseases.

Guidance documents may be sector-focused (e.g. focusing on waste management) or they may address specific issues such as the prevention of contamination (hand washing guidelines), needlestick injuries and the prevention of blood-borne infections in healthcare settings or the prevention of Legionnaire’s disease. Healthcare emerges as the best-covered sector as regards guidance and detailed rules. There are also rules or recommendations establishing vaccination regimes to better protect workers from infection with biological agents. Quite a few respondents referred to obligatory reporting and record-keeping of certain exposures to biological agents, in implementation of Article 11 of the Biological Agents Directive.

The most extensive set of rules was reported for Germany, where there is a dedicated committee dealing with classification and prevention and setting up technical rules for biological agents. A similar committee is the Advisory Committee on Dangerous Pathogens in the UK. The German respondent also cited the GESTIS Biological Agents Database and guidance on worker training. A similar approach was taken in France, the UK and Spain, with databases and information sheets providing information related to specific biological agents.

Several respondents reported on inspection and information campaigns (see Annex 4, ‘National policies, campaigns, networks and reports’) related to vaccination, the prevention of needlestick injuries, *Legionella* management, vector-borne diseases, MRSA prevention, prevention of *Mycobacterium bovis* infections in abattoir workers and prevention of HIV infection, or covering specific occupations and sectors such as childcare, cleaning, the emergency services, agriculture and waste management. Some of these were also linked to public health institutions.

6.3 Expert networks

The respondents to the questionnaire referred to several expert networks (see Annex 4), which focused either on a specific issue or occupation, such as needlestick injury prevention, MRSA in pig farms or tuberculosis prevention, or at a broader level on issues related to infections or exposure to biological agents. Most are networks of occupational physicians or hygienists within ministries, OSH institutes or occupational medicine or hygiene associations. In some countries, such as Spain, they are established at the Ministry of Health. Germany, as mentioned above, involves experts in an established committee on biological agents that issues technical regulations on biological agents and is heavily involved in the classification of biological agents. Experts from the Netherlands reported on several expert groups at different levels and dealing with very diverse issues. Austrian respondents reported on an ongoing transnational cooperation between experts from the statutory insurance institutions of Austria, Germany and Switzerland, namely AUVA, HVBG and SUVA.

The involvement of occupational physicians or hygienists therefore seems to be key for better monitoring and prevention in this area.

6.4 Monitoring systems for work-related and occupational diseases

Great variety between countries

The monitoring systems selected from the different countries and analysed in this review differed greatly in what they monitor, how frequently this is monitored, at what level of detail information is collected, and the accessibility of information from the system with regard to both availability to the public and accessibility in terms of the languages in which information is provided. Altogether, these differences present barriers to gaining an appreciation of the situation as regards work-related diseases cause by biological agents, identifying the most prevalent health problems in this area and achieving an overview of the trends over time across Europe. In addition, they are also an obstacle to the harmonisation of the monitoring of work-related diseases across the region. This is exacerbated by the lack of transparency about how these systems work. However, these systems do provide information on health problems related to exposure to biological agents that can be useful for prevention.

With regard to the lists of diseases used in the monitoring systems evaluated in this project, where specified, they were comparable with ICD-10 codes, although national system-specific lists are also used. All these lists contain at least a few diseases related to biological agents, but the exact number varies and can be very limited, and the types of diseases recorded vary.

The differences among the lists make it difficult to compare national data. In addition to differences in the coding of the registered diseases, there are differences in the coding of other aspects of the registration process, which may hamper the comparison of outputs from these systems.

However, Tables 77 and 78 below attempt to show where the lists coincide. However, regarding microorganisms, only for two countries was it possible to access information with sufficients datail.

Table 77: Microorganisms referred to in Chapter 5 in relation to the systems from five countries analysed

Microorganism/ biological agent	The Netherlands	France
Bacillus		X
Bacterial viruses (virus phages)		X
Borrelia *Borrelia burgdorferi*		X
Candida *Candida langeronii* *Candida stellatoidea*		X
Candida albicans	X	X
Cephalosporium (*Acremonium*)		X
Chikungunya virus		X
Chlamydia psittaci, avian or non-avian		X
Cladosporium		X
Coxiella burnetii		X
Cryptococcus neoformans gattii		X
Cytomegalovirus (human)		X
Dactylaria		X
Enterovirus (porcine)		X
Enterovirus 7c (acute haemorrhagic conjunctivitis virus)		X
Epstein-Barr virus		X
Francisella tularensis		X
Hantavirus		X
Helicobacter pylori		X
Hepatitis A, B, C and E viruses	X	X
Herpes simplex type 2 virus		

Microorganism/ biological agent	The Netherlands	France
HIV	X	X
Kingella kingae		X
Klebsiella pneumoniae	X	X
Legionella *Legionella pneumophila*		X
Leptospira	X	X
Mycobacterium	X	
Mycobacterium *Mycobacterium bovis*, *fortuitum fortuitum*, *marinum*, *microti*, *tuberculosis*, *xenopi*, *vaccae*		X
Onchocerca volvulus		X
Papillomavirus, including of animal origin		X
Parvovirus b19		X
Pasteurella aerogenes		X
Pichia guilliermondii		X
Plasmodium *Plasmodium falciparum*		X
Rickettsia	X	X
Salmonella	X	
Schistosoma mansoni		X
Scytalidium		X
Stachybotrys		X
Staphylococcus *Staphylococcus aureus*, *pneumoniae* (*pneumococcus*)		X
Staphylococcus aureus	X	

Microorganism/ biological agent	The Netherlands	France
Streptococcus	X	X
Trichophyton *Trichophyton raubitschekii*, *rubrum*	X	X
Trichostrongylus		X
Varicella virus		X
Actinobacillus actinomycetemcomitans		X
Actinomyces		X
Alternaria *Alternaria alternata*		X
Arthrobacter		X
Ascomycetes		
Aspergillus		X
Aspergillus fumigatus, *niger*	X	X
Basidiomycetes		X
Cladosporium		X
Cryptostroma		X
Fungi with ascospores formation		X
Lactobacillus		X
Micropolyspora faeni		X
Penicillium		X
Saccharomyces cerevisiae		X
Schizophylum		X
Sitophilus		X
Streptomyces		X
Thermoactinomyces		X

Microorganism/ biological agent	The Netherlands	France
Thermoactinomyces vulgaris		

Table 78: Diseases referred to in Chapter 5 in relation to the systems from five countries analysed

Disease/health effect	NL	UK	FR	DK	FI
Allergic diseases					
Allergic alveolitis (including farmer's lung)		X			
Anaphylaxis (natural rubber latex products used in healthcare)		X			
Bird fancier's lung/disease			X	X	
Farmer's lung		X	X	X	
Hypersensitivity pneumonitis due to organic dust			X		
Hypersensitivity pneumonitis due to unspecified organic dust			X		
Hypersensitivity pneumonitis due to other types of organic dust (cheese washer's lung, coffee worker's lung, fishmeal worker's lung, furrier's lung, sequoiosis)			X		
Mushroom worker's lung			X	X	
Work-related asthma	X	X		X	
Work-related rhinitis	X	X		X	
Bacterial diseases					
Anthrax			X		
Avian chlamydiosis (birds infected with *Chlamydia psittaci*)		X			
Brucellosis	X	X	X		

Disease/health effect	NL	UK	FR	DK	FI
Chlamydia infection			X		
Legionellosis	X				
Leptospirosis	X	X	X		
Lyme disease	X	X	X		
Ornithosis/psittacosis			X	X	
Pasteurelloses			X		
Rickettsioses			X		
Swine erysipelas			X		
Tetanus	X		X	X	
Tuberculosis	X	X			
Tuberculosis and other microbacterial infections			X	X	
Tularaemia			X		
Weil's disease				X	
Parasitic diseases					
Amoebiasis	X		X		
Ancylostomiasis			X		
Helminthiases			X		
Malaria	X			X	
Pediculosis, acariasis and other infestations	X				
Protozoal diseases			X		
Trypanosomiasis				X	
Q fever	X	X	X	X	
Viral diseases					
Arthropod-borne viral fevers and viral haemorrhagic fevers			X		

Disease/health effect	NL	UK	FR	DK	FI
Dengue fever				X	
Hantavirus infection			X		
Hepatitis (viral)	X	X	X	X	
Mycoses			X		
Mycosis (skin)	X		X		
Parvovirus	X			X	
Perionyxes and onyxes (fungal nail lesions)			X		
Poliomyelitis			X		
Rabies			X		
Viral diseases (other)			X		
Viral infections characterised by skin and mucous membrane lesions			X		
Viral infections of the central nervous system			X		
Viral keratoconjunctivitis			X		
Yellow fever				X	
Other, incl. groups of diseases					
Cancer after hepatitis infection				X	
Infections related to infectious agents encountered in hospital and during care at home			X		
Infectious diseases (other)			X		
Infectious or parasitic diseases transmitted to humans by animals or remains of animals	X				
Intestinal infections	X		X		

Disease/health effect	NL	UK	FR	DK	FI
RVP([35]): pertussis, measles	X				
Sequelae of infectious and parasitic diseases			X		
Toxic effects on the airways	X				
Toxic inhalation fever	X				
Traveller's diseases: shigella, dengue fever, chikungunya, giardiasis, parasite infection, rickettsia	X				
Work-related conjunctivitis				X	
Zoonoses	X		X		

Biological agent-related diseases integrated into occupational disease monitoring systems

The systems analysed and the questionnaire responses, as well as the literature review, suggest that, with the exception of some systems operating in healthcare establishments (e.g. to record needlestick injuries) and some systems for compulsory reporting of infectious diseases in the public health sphere (e.g. for hepatitis or tuberculosis), diseases due to biological agents are normally reported in generic occupational disease recording systems that do not specifically focus on biological agents.

The review, however, also describes systems that focused on specific diseases (e.g. THOR in the UK) and systems that have an alert function, such as the French rnv3p system or the SIGNAAL system developed by Belgium and the Netherlands.

Prescribed occupational diseases versus work-related diseases

According to the WHO, an 'occupational disease' is any disease contracted primarily as a result of an exposure to risk factors arising from work activity, whereas 'work-related diseases' have multiple causes, and work environment factors may play a role, together with other risk factors, in the development of such diseases (WHO, 2016). A recognised case of an occupational disease is a case accepted as such by a competent national authority in an administrative procedure (European Commission, 2008).

The types of diseases covered by the systems that were evaluated here vary from only prescribed occupational diseases to, in theory, all work-related diseases. However, only five systems address both work-related diseases and occupational diseases, and only the Danish system for the registry of occupational diseases stipulated 'recognised' occupational diseases.

The link to compensation — an obstacle to reporting

Carder et al. (2015) gathered structured information about the surveillance systems for occupational diseases in European countries, in which the countries included in this review were also covered (apart from Denmark). They identified compensation-based systems for monitoring of occupational diseases

([35]) The Netherlands has an extensive national immunisation programme to protect children against infectious diseases, the Rijksvaccinatieprogramma (RVP). The RVP offers vaccination against the following 12 diseases: cervical cancer (targeting the human papillomavirus (HPV) – only for girls aged 12/13), mumps, diphtheria, hepatitis B, Hib diseases (caused by Hib bacteria; these include infections of the upper respiratory system and meningitis), whooping cough, measles, meningitis C, pneumococcal infection, polio, rubella, tetanus.

in 11 out of the 20 countries. Of these, four also provided information for non-compensation-based systems (with at least one system in each country enabling the reporting of any type of disease). A further three countries provided information for non-compensation-based systems only. The type of data collected varied, but all collected diagnosis, age, gender, date reported and occupation (and/or industry), and most collected information on exposure. Among the countries not having a compensation-based system, two (the Netherlands and Macedonia) returned information to non-compensation-based systems. Among the 11 systems described in detail in this report, 5 are not part of a compensation-based system for workers: the UK's LFS and the THOR systems, France's rnv3p and the national notification and registration system of the Netherlands (Table 75).

A strong linkage to a compensation system has the disadvantage of the registry being tied to the country's social security regulations, which complicates the comparison of countries' results.

Type of diseases recorded

The European Commission has published a comprehensive report describing the current status of occupational disease systems in the EU (European Commission, 2012). One of the topics that this report addresses is the list of occupational diseases used within the European countries consulted.

It is not easy to determine exactly what diseases are recorded in the different countries from the analyses of the monitoring systems considered in this review and the data extracted, because reports are often available with information broken down only by very general categories or by classes of biological agents (i.e. bacteria, fungi, parasites, etc.) Furthermore, allergic diseases, and in particular respiratory diseases, may be reported within other categories and not be related by those who report to exposure to biological agents. This is complicated by the fact that information on the exact causal factors is limited even when the presence of and a causal link to biological agents are confirmed.

It is therefore difficult to provide an overview of the work-related or even the occupational diseases linked to these exposures. Equally, it is difficult, although Table 76 provides an overview of data trends, to assess whether such diseases are increasing or decreasing, and there are a lot of confounding factors outlined in this review.

However, what emerges from the review is the fact that diseases may be divided into infectious diseases and allergies. The findings also confirm a result of the literature survey, pointing to agriculture and healthcare as sectors where many diseases occur, in addition to food production, waste management and construction; tropical diseases imported by travellers and workers working abroad are also confirmed as an important issue. Farmer's lung, diseases in food production, hepatitis and baker's asthma are significant issues, as are smaller outbreaks of, for instance, zoonoses, which were also referred to in the questionnaire answers regarding case studies of diseases (Section 4.4, Table 37).

Respiratory and fungi-related diseases

Despite the fact that there was no direct access to the data collected in most of the monitoring systems evaluated, it can be assumed that those respiratory diseases that are traced to biological agents are only the tip of the iceberg, as in the Netherlands reportedly one third of the diseases recorded in the system are linked directly or indirectly to exposure to biological agents. It also seems that it is not easy to trace some diseases (mainly allergic diseases) to biological agents, although one of the countries mentioned IgE and IgG as parameters for assessing exposure (see Section 5.10.2). There is also an increasing awareness of fungi as a cause of disease to be observed, especially in those countries where moulds have been found to be a cause of disease and in newer occupations such as jobs in waste management; this awareness does not yet seem to be reflected in reporting and recognition practices, however. The German IFA and the Dutch authorities have developed measurement methods to allow for better identification of exposures and establish a better link between causal factor and disease, especially in cases of hypersensitivity reaction. Crivellaro et al. (2013) propose treatment when complete avoidance of exposure is not possible, in selected IgE-mediated disorders, including criteria for the prescription of allergen-specific immunotherapy to treat allergic rhinoconjunctivitis and asthma.

It can therefore be concluded that research into the causes of diseases, in particular allergenic diseases, and more comprehensive registration of exposures and potential causal factors — as permitted, for instance, by the French TOE, a dedicated classification system for exposures that includes biological agents and is a modified version of the European Classification of Causal Agents of Occupational Diseases — would improve the recording of diseases and enable an assessment of the real extent of the problem.

Under-reporting and under-recognition

In this review, under-reporting is considered a general issue, and is identified as one of the weaknesses of most if not all of the evaluated monitoring systems. However, the exact level of under-reporting is not easy to quantify, and therefore the actual number of work-related diseases in general, including diseases due to biological agents, will be (much) higher than that reported in the various countries; for now, the real extent of the issue must remain an educated guess at best.

Carder et al. (2015) mention that most systems surveyed were established to allow the reporting of occupational diseases from all geographical regions and from all economic sectors in the participating country. However, occupational diseases were under-reported (although to what extent was generally unknown or only partly known). One of the main factors contributing to under-reporting is under-recognition, that is, the individual and/or physician not associating the condition with work. This is of particular relevance for health problems linked to exposure to biological agents and this is why the next steps in the project will further explore the possibilities for improving knowledge and raising awareness among those reporting diseases, including experts and practitioners.

For the systems based on compensation, under-reporting may also occur because the individual is unaware of the availability of compensation or does not meet its eligibility criteria. For the systems based on physician reporting, the degree of under-reporting will also be affected by the level of physician participation. This will vary among different systems (and also over time), in part depending on the nature of reporting (i.e. voluntary or mandatory); other factors — for example physician workload, level of training in and interest in occupational health, or the area of specialism — will also play a role.

There may also be under-reporting of occupational diseases in specific sectors of the workforce. Participants in the Carder study most frequently responded that the self-employed were not covered, and that they accounted for around 15 % (and an increasing proportion) of the EU's working population. This finding is even more relevant for some of the sectors of concern identified in this review that have a high proportion of self-employed workers, such as farming; under-reporting is assumed to be high in this sector, considering the high proportion of self-employed and family workers.

Other systems reported limited coverage of specific sectors of the workforce. For example, access to an occupational physician in the UK is known to be easier in the public sector and larger industries, and this is reflected in the cases reported to the UK surveillance system by occupational physicians. However, with regard to some systems, respondents reported that steps had been taken to quantify the population (denominator) covered by the system, thus enabling the calculation of more accurate incidence rates (Carder et al., 2015).

Better training and guidance required

Most of the registration systems that were evaluated in this project were mandatory but did not provide much guidance and training for those who had to register cases. Providing more guidance and training may result in less under-reporting, and thus a better overview of the occurrence of occupational diseases in Europe, including occupational diseases due to exposure to biological agents in the workplace. Taking this into account, policies should be directed at making sufficient information accessible to all stakeholders and putting forward a standard key set of parameters that need to be monitored, and guidance should be given on what level of detail this should have. Finally, providing at least some information in English may help to facilitate the exchange of data and experiences.

The value of sentinel systems vs. national registries

Spreeuwers et al. (2008) investigated whether a sentinel surveillance project comprising motivated and guided occupational physicians would provide higher quality information for a policy to prevent occupational diseases than a national registry. The number of notifications per occupational physician, the proportion of incorrect notifications and the overall reported incidence of occupational diseases were compared. The sentinel surveillance group, consisting of motivated and guided occupational physicians, reported a substantially higher disease incidence and a lower proportion of incorrect notifications than the occupational physicians operating in the national registry. They concluded that notification projects that use the same notification forms and the same evidence-based guidelines for diagnosing and reporting, with the same quality standards, in combination with surveillance schemes with a sample of motivated reporting physicians, may be easier to manage and provide better quality results than nationwide registries (Spreeuwers et al., 2010). In addition, in the Netherlands, it was decided to focus on further strengthening the intrinsic motivation of occupational physicians by sharing knowledge and feedback on reporting, facilitating easy access to electronic reporting and supporting the balance of work-related and other causes. This has led (among other things) to an update to the step-by-step plan for the systematic investigation of whether a disease is actually an occupational disease or not.

Identification of new and emerging risks

For some of the systems evaluated in this project, such as rnv3p or SIGNAAL, as well as the THOR systems, the identification of new and/or emerging occupational diseases (or risks) is part of the registration system, and in most cases involves a process of evaluation by a group of experts. New work-related diseases were also raised by a European Commission report on occupational diseases (2012). It was concluded that detecting new OSH risks requires different instruments from those used for monitoring known occupational diseases. The choice of instrument is determined by the characteristics of the health problems, such as their nature, their seriousness and the strength of the causal link with the possible cause. It is not possible to detect new OSH risks using a single method, thus several complementary methods are required. Two major tools for this are the sentinel case approach, and epidemiological studies and health surveillance.

According to the respondents to the questionnaire (Annex 4, Table A4-4), sentinel or alert systems were most commonly used as an input for prevention programmes, policy-making and research, although several of the sentinel or alert systems mentioned by the respondents concerned a specific agent or disease (mainly infectious diseases but also occupational cancer). However, more systems focused on biological agents in general. As some of the respondents also mentioned, compulsory recording of exposure to biological agents may be an effective way in which to gather information that is necessary for effectively controlling diseases due to biological agents, and a better link could be established between occupational disease recording and public health systems based on compulsory recording.

As well as identifying selected problems linked to changing work processes and industrial structures, such as the rise in the green economy, which has brought about new jobs with potentially high exposures in waste management and wastewater handling, systems should also take account of other trends identified in the literature survey, such as the changes in travelling behaviour and issues such as the recent migration waves into Europe. Another factor that needs to be considered in the design of recording systems is climate change and its consequences, such as the spread of microorganisms or their vectors across Europe, or rising temperatures that change seasonal exposure patterns. All of these issues need to be considered when revising the coding categories, or with regard to procedural issues such as intervals between revisions to the existing structures. For all of this, it would be beneficial to maintain an expert structure such as those set up in some of the countries whose systems were reviewed, be it a stable committee, as in Germany, or a network of OSH experts operating in the field, as in France.

Enhancing expert cooperation

Better use could be made of these experts and the expert networks identified in the questionnaire survey (Annex 4, Table A4-8) for the identification of health problems and prevention at an earlier stage. As can be seen from the responses to the questionnaires (see Section 6.3), the example of the cooperation among German-speaking countries or the rnv3p system, which links expertise from occupational physicians reporting health problems into a database that is available to a prevention network and issues alerts, could serve as examples for improvements that could enhance reporting and prevention at the same time and ensure that interventions are timely and effective, by introducing an alert function into existing systems and making better use of available expertise. This is confirmed by a report on alert and sentinel systems (EU-OSHA, 2018). As mentioned earlier (Section 5.10.1), the French TOE, for example, which was developed by an expert network, allows for a level of detail that is higher than Annex III to the Biological Agents Directive, as well as the recording of links between cause and health effect, and plausibility checks on alerts.

Harmonisation of monitoring systems across the EU region

Harmonisation of data and reports

Although lists of occupational diseases mainly aid recognition and compensation, the EU and national lists nevertheless help indirectly in improving the prevention of occupational diseases. According to the abovementioned Commission report (European Commission, 2012), to enable comparison of the outputs from the various national systems, it is important to compile reports on occupational diseases — for instance Commission and Member State statistics — using common standardised structures and wording. It was recommended that each country should report to the European Commission regularly on how their occupational disease system works; the transparency of the national system; how information regarding occupational diseases covered by their national system is provided; and how they deal with new knowledge on the causation of diseases by working conditions.

In future, a more harmonised way of collecting data on occupational diseases may result in a better understanding of the differences in the incidence and prevalence of occupational diseases in Europe, and of what causes these differences. This may provide valuable information with regard to prevention. Harmonisation of the coding of important parameters with regard to the registration of cases of work-related disease and/or occupational disease would benefit the surveillance of the health of the working population in Europe.

For example, in general, the classification system used for causal agents in occupational diseases, including biological agents, is very limited. However, in the rnv3p system operated in France, the French TOE is an example of a coding system that could be more widely used. The level of detail that the system allows contrasts with the classification of exposures in some other systems, which can use very broad categories, of which biological agents is one (as in Denmark, for instance).

Carder et al. (2015) confirm that the identification of a 'core' system' with common reporting fields and coding systems would help to optimise the surveillance of occupational diseases on a European scale, which would be beneficial for researchers who may want to carry out collaborative or comparative studies. They observed that the key variables common to most (if not all) of the systems they surveyed were diagnosis, date reported, gender, age, occupation, economic sector and probable causal agent. They stated that these variables represented the minimum information required to ensure reliable, meaningful surveillance of occupational diseases on a large scale for policy-making and research on occupational health trends, and could therefore be viewed as the 'core variables' needed to meet this key objective, although systems with other aims, for example sentinel systems to capture 'new and emerging risks', may require additional variables. They also stressed the importance of the codification used to record these core variables when relevant, which is essential to make reliable transnational comparisons possible.

Limited public availability of data

As can be seen in Chapter 5 of this review, some of the available data from the systems analysed are very limited and do not by any means meet the recommended requirements set out in the abovementioned Carder et al. study (data by gender, age, occupation, economic sector and probable causal agent), in particular as concerns exposures. With respect to availability, a certain minimum requirement for what should be publicly available could be implemented in a bid to facilitate the analysis of trends across the region.

The relevant databases mentioned in the scientific literature, were identified mainly related to monitoring diseases, such as the French rnv3p system and the German and Taiwanese systems related to national health insurance (including compensation of occupational diseases). Furthermore, specific topics such as occupational asthma, blood-borne diseases among healthcare workers and, to a lesser extent, sexually transmissible diseases among sex workers are mentioned, although no specific databases could be located. Broadly, these databases can be sorted into two groups: large-scale (government) surveillance (rnv3p), and small-scale databases set up by, among others, individual clinics, hospitals, companies or humanitarian initiatives. However, both groups are under-represented in the scientific literature, possibly because such databases are rarely described in scientific journals.

Assessing the usefulness of a system

In addition, Spreeuwers et al. (2009) developed a tool for the quality assessment of occupational disease registries with respect to their ability to provide appropriate information for preventive policies on a national level, called ‘ODIT’. This instrument can serve as a starting point for a quality improvement process. The tool has defined indicators, and for each one, criteria were assessed to demarcate high and low quality. The following indicators have been defined:

- structural preconditions:
    - completeness of notification form
        - diagnosis
        - exposure
        - occupation
        - economic sector
        - susceptibility
        - probability of causal relation
        - age of worker
        - sex of worker
        - other causes;
    - coverage of registration;
    - guidelines or criteria for notification;
    - education and training;
- diagnosis and notification process:
    - completeness of registration;
    - statistical methods used;
    - investigation of special cases;
- output:
    - presentation of alert information;
    - presentation of monitoring information;
        - occupational disease incidence rates and distribution;
            - incidence rates of specific occupational diseases for the total working population
            - incidence rates of specific occupational diseases by sector or by occupation
            - distribution of occupational diseases by sociodemographic variables, age and sex;
    - additional information;
    - validity of incidence rates.

Spreeuwers et al. (2010) used the ODIT tool to evaluate the occupational disease registries of six EU Member States: their ability to provide appropriate information for preventive policy, their usefulness for determining compensation, how they provide statistics, and their usefuleness for prevention and research. The average quality of the systems for monitoring occupational diseases and identifying new risks was low, which was mainly due to inadequate education and training of physicians and the poor participation of notifying physicians.

Information needs to be made available to prevention actors more broadly. Although monitoring systems for occupational diseases, including sentinel systems, should be linked to prevention, in general this does not seem to be the case. As well as differences in the coding of the registered diseases, there are also differences in the coding of other aspects of the registration process. All these differences may hamper the comparison of outputs from these systems, and, for instance, make it difficult to obtain an overview of the number of reported diseases due to biological agents on the basis of the outputs from the systems. Furthermore, the available outputs from the systems could not be analysed with regard to gender or age, with the exception of those from the Dutch system, and limited information was available on industry and occupation. This is a major obstacle to targeted, gender- and age-sensitive prevention and should be flagged up for future improvement of the systems, as well as for research.

The dissemination of the results of the registries to workplaces and labour safety authorities is essential for effective use of the information for prevention. The respondents to the questionnaire indicated that the information collected by the disease monitoring systems is generally used to provide input into policy-making, prevention programmes or research, and to a lesser extent for disease surveillance in order to keep track of the prevalence and incidence rates of diseases, for warning and control systems and inspections, for compensation, educational purposes, enforcement, and diagnostics or treatment. Although respondents to the questionnaire referred to several expert networks that make use of such information, it could be beneficial to make available more detailed data from the systems to a broader OSH audience.

Furthermore, the outputs from the systems are made available in annual reports or as crude statistics and some are shared with relevant actors, such as the authorities and social partners, other OSH actors, and occupational physicians and other medical professions. However, there is no assessment of the actual use of the information and there does not seem to be a debate ongoing about the public availability and usefulness of available data. It would be worth considering whether a minimum set of available data and a regular revision process involving important actors might help improve prevention. There are countries that have established a stable network or commission that addresses issues related to diseases caused by biological agents and their prevention (as referred to in Section 6.3 and Annex 4, Table A4-8) or an alert system that enables physicians to record emerging diseases (as referred to in Sections 4.5.3 and 5.10.1 and Annex 4, Table A4-4), and these examples could be followed in other countries.

A better link to public health

As revealed in the responses to the questions put to respondents on monitoring systems and discussed in Section 4.4, an additional source of information on the occurrence of diseases due to biological agents could be the information that is collected as part of public health systems, especially with regard to diseases for which the relation to exposure in the work environment is not always clear to the worker and/or the employer. In some countries, general practitioners are also involved in the registration of occupational diseases and could, for instance, cover the cases that are not picked up by occupational physicians and other occupational health professionals. These systems cover specific infections, in particular zoonoses, and some coincide with priorities identified in the occupational field, such as he increase in tuberculosis infections and tropical diseases, or the increasing number of outbreaks of legionellosis. Some of these systems were installed in the public health field to improve prevention for groups of workers that are not well covered by occupational disease registration systems. This is the case for systems that record cases of brucellosis, for example, which are relevant for agriculture, a sector with a high proportion of self-employed and family workers.

Another source of information could be regional health authorities (e.g. involved in vaccination programmes for travellers) and microbiological laboratories that encounter, for instance, cases of infectious diseases for which a relation to work might be expected. A more direct link between public health systems and OSH systems could enable the collection of valuable information that could be used to target the prevention of exposure to biological agents in the workplace. However, to be able to use the information from both sources in an efficient manner, some level of harmonisation of the registered information, a structural way of communicating and processing information from both types of systems, and a legal framework for cooperation and exchange of information and data between both areas would be necessary. It seems that such a framework has been established in some countries, where occupational health and/or health surveillance is part of public health provision, and the examples of those countries that have reported such synergies could be followed.

6.5 Monitoring exposure to biological agents and deriving occupational exposure limits for biological agents

Although a large number of the respondents to the questionnaire survey indicated that they were familiar with monitoring systems for occupational exposures to substances (including biological agents), exposure measurements for biological agents are usually integrated into general measurement databases. In their answers, the respondents referred to occupational disease recognition systems in those countries where no measurement databases seem to exist. Nonetheless, the systems that monitor diseases do provide valuable information on exposures in a more indirect way, which at least gives an idea of the types of exposures that are related to health effects. If the registrants are provided with suitable information to be able to determine the cause of the disease they encounter (i.e. the exposure), which can then also be registered with a high level of detail, the exposures causing the diseases can also be monitored and investigated in more detail. This can provide valuable input into the development of an effective prevention programme. Those databases that were identified through the literature review and the measurement databases described in Chapter 5 are in many instances only presumed to include biological agents, as the available descriptions are on a very general level

Measurements in a few countries and in selected occupations, with limited access

Although, in contrast to the requirements in relation to chemical exposures, there are no compulsory measurements for exposures to biological agents at work, several systems for recording exposures to biological agents were identified in the review, namely those in France, Finland and Germany. The Netherlands is also assumed to have carried out measurements because of the limit values laid down in particular for endotoxins.

Measurements are available from studies by the German statutory insurance institutions and the research institution BAuA, as well as the OSH research institutions in France and Finland.

The studies cover some of the professions identified in the literature as at risk, and specific exposures, namely:

- agricultural workers in livestock raising facilities, such as poultry farms and hatcheries, in relation to exposure to bioaerosols and antibiotic-resistant bacteria;
- biogas production;
- composting plants;
- waste recycling and paper production;
- the bioburden of water-miscible cutting coolants;
- endotoxin exposure in natural fibre processing and manufacturing, agriculture, the wholesale trade and warehousing, and waste incinerators;
- the sea transport sector

Regarding methodologies, the following topics were addressed:

- the use of rRNA gene libraries to characterise biological agents in the air in workplaces;
- the detection of airborne biological agents under difficult analytical conditions;
- the development of a gene-based detection system for bacteria as causative organisms for respiratory problems due to bioaerosols;
- a fluorescence microscopy method for analysing bioaerosol samples from workplaces;
- culture-independent microscopic quantification techniques based on DNA staining;
- DNA sequencing for identification;
- various air sampling devices;
- measurement of endotoxins, moulds, bacteria and parasites in workplaces, and IgE and IgG antibodies in workers exposed.

Data from these databases could be further explored, and transnational use of these data could help characterise exposures in specific workplaces. An exchange between the data holders would therefore be very beneficial.

Furthermore, in Finland, the FINJEM job-exposure matrix has been developed; it contains information on exposures to organic dust (e.g. animals, flour, plants, and softwood and hardwood dust) and exposures to microbiological agents (e.g. mould spores and Gram-negative bacteria of non-human origin), and similar tools could be valuable in other countries, as it records data on the level of exposure.

Methodological challenges in relation to workplace measurements of biological agents

The quantification of exposure to biological agents is complex, and certain issues should be paid special attention when measuring exposure to biological agents (Health Council of the Netherlands, 2012).

- **Fluctuation in exposure:** biological agents often relate to living organisms. Because they can grow themselves, multiply and die, exposure to biological agents varies more over time than exposure to chemical agents. A single exposure measurement is only a snapshot of the concentration of biological agents in the air. Thus, to get an accurate picture of the exposure, repeated measurements are needed. In addition, exposure concentration is highly dependent on the season, and the place in which it is measured. This complicates generating a representative picture of exposure via the air.

- **Different routes of exposure:** Available measurement methods often focus on measuring biological agents in the air. Skin exposure to biological agents in the work environment has hardly been studied. However, in many situations oral or dermal exposure (hand-foot, hand-nose contact) are also considered relevant due to surface contamination, although standardised measurement methods do not exist for these exposure routes. The review has identified a number of infections (mainly fungal infections) that should be assessed. Furthermore, contamination of the of hands can favour the spread of disease and increase the infection risk of an individual. Paying attention to good hand hygiene is one way in which to minimise transmission via these routes and several campaigns have been mentioned in the survey that promote it (Cheng et al., 2011b).
- **Available measurement methods:** Only a few standardised methods for biological agents are described. However, no m ethods are available for the measurement of exposure to specific microorganisms in the air. Most methods are labour intensive and can be performed only by specialised laboratories
    - EN 13098 provides general principles for the measurement of microorganisms in the air (NEN-EN, 2000).
    - The 'viable' methods are based on the culturing of the viable organisms isolated from the air and measuring the number of colony forming units (CFUs), for which the result is expressed in a plate count (CFU/m^3). These methods only detect viable parts of the microorganism, but do not help quantify the (non-viable) toxic or allergenic components of biological agents, which can be contained in dead microorganisms or fragments of microorganisms.
    - An alternative are the 'non-viable' methods, which determine microorganisms by (electron) microscopic counting or map exposure to specific agents. For instance, EN 14031 is a standardised measurement method for determining the concentration of endotoxins in the air (NEN-EN, 2003).
    - Methods that also make use of the genetic information of specific microorganisms are becoming increasingly available. For instance, polymerase chain reaction technologies make it possible to measure small amounts of DNA to enable quicker and more specific detection (Wéry, 2014).
    - In addition, more and more IgE antibodies are available to quantify exposure via enzyme-linked immunosorbent assays, or ELISAs (tests that use antibodies and colour change to identify a substance).
    - It is to be expected that the methods would need to be combined to get a full overview of potential exposures: In a review in 2012, Eduard et al. referred to three different measurement methods for constituents of biological agents: endotoxins and beta(1→ 3)-glucans, enzymes and mycotoxins.

Some of the countries, such as Germany, have reported on research into this measurement methods (see section 5.4.1 of this report). It is recommended that the development of measurement and analytical methods for biological agents be further stimulated, as this of great importance for a better understanding of exposure to biological agents at work and to enable effective control or prevention of such exposures. National or European requirements for regular exposure measurements of biological agents would enhance the collection of this type of data and would be very valuable for exposure and risk assessment. The results could also be used for the development of exposure models.

Owing to the large variety of microorganisms potentially present in workplaces, and the fact that most require a specialised measurement and/or analytical method, assessment of exposure to individual species is, however, challenging.

The first step would be to measure whole colony counts (for total bacteria, Gram-negative and Gram-positive bacteria, fungi) and, for instance, markers of microbial exposure such as endotoxins or beta-glucans, to get an idea of the overall exposure to biological agents in the workplace.

Furthermore, measurements and analytical methods need to be standardised to ensure that the quality of the exposure data collected is good and that exposure data can be compared. Many biological agents are ubiquitous in the environment and can grow and proliferate, but their presence and growth is dependent on environmental factors such as substrate availability, water availability and temperature, so levels of biological agents in soil, air and water can vary greatly. Variability in measured exposure levels is to be expected and needs to be considered when designing a measurement strategy. However, this should not prevent the measurement of exposure to biological agents in the workplace, which can at least offer an indication of actual exposure.

Prioritise measurement for respiratory and skin diseases and important sectors

As respiratory and skin diseases are important groups of diseases caused by biological agents, the focus of workplace measurements should preferably be on enhancing methods that cover the biological agents that cause these diseases. First attempts have been made through endotoxin and mould measurements in workplaces (in, for instance, Germany and Finland), to the point that there have been a few exposure guidance values set based on these measurements. In Finland, for example, IgE and IgG antibodies are measured among workers. As indicators of worker exposure, IgE measurements and others, for example relating to microbes, are made and the data stored for individuals. IgG measurements are only used, and the data stored at group or workplace level because of the amount of variation at individual level.

Furthermore, workplace measurements of biological agents should be further developed for important sectors and occupations, such as those identified as sectors/occupations of concern in this review, including arable farming, animal breeding/caring/handling, waste management and healthcare. Some of the exposure studies conducted by BAuA (see Section 5.4.1) provide valuable information on exposure to biological agents in, for instance, livestock workers and waste workers.

Develop synergies with chemical exposure measurement

As occurrence of respiratory (allergenic) diseases, as well as skin diseases, are also important triggers for the performance of workplace measurements for chemical substances, it would be beneficial to design measurement strategies that cover both biological and chemical substances and provide data on exposure to both in specific occupations and sectors.

Lavoie et al. (2013) propose a control banding method for selecting respiratory protection against infectious and non-infectious bioaerosols applicable to all workplaces and intended for occupational hygienists and other occupational health and safety practitioners, as well as for experts who are members of learned societies. This model, which is a follow-up to the Guide on Respiratory Protection against Bioaerosols , published by the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) in 2007, is based on bioaerosol-related knowledge and on approaches to control banding developed mainly for chemical contaminants and nanoparticles. The model is presented in the form of a matrix consisting of the four risk groups used in biosafety and of five exposure levels. The cross-tabulation of a risk group and a given exposure level corresponds to an assigned protection factor that allows the user to choose an appropriate respirator.

Better coverage of occupational exposures and a better link to public health

Many of the data on the effects of exposure to infectious microorganisms are obtained after outbreaks of diseases, in which the main focus is on public health and the prevention of pandemics, and workers' health may be overlooked. More research on the potential for occupational exposure and the effects on health is therefore required, and new methods need to be developed to support the monitoring and evaluation of changes in occupational exposure. Furthermore, knowledge and measurement methods that are available in the field of infectious diseases and public health should be made more generally accessible to OSH actors, to achieve improved working conditions (Health Council of the Netherlands, 2012).

The development of reliable methods to measure or monitor exposure and the availability of immunological tests also deserves attention. Early detection of sensitised workers by means of periodic screening can potentially be a valuable tool. However, the feasibility of periodic screening should be considered on a case-by-case basis, because periodic screening is of value only when accurate and reliable tests are available. Such tests are available for certain well-known allergens (e.g. flour dust, urine of laboratory animals and latex) but need to be developed for others. In addition, periodic screening should be applied cost-effectively (Health Council of the Netherlands, 2008), and there are ethical considerations in its application.

Occupational exposure limits for biological agents and their by-products

With regard to infectious biological agents, specific OELs or reference values are not available. As the variety of biological agents that give rise to infectious diseases is wide, determining one overall effective OEL to apply to all such biological agents is not possible. Although considerable advances are being made in the quantification of exposure, knowledge regarding biological agents in these fields is currently still limited. As quantitative information on exposure, pathogenicity, the disease and the relationship between them is needed to determine health-based recommended OELs for individual agents, it is not very likely that it will be possible in the short term to determine OELs for biological agents that lead to infectious diseases. In the meantime, a precautionary approach to these agents should be taken, in which exposure is avoided or kept as low as reasonably or feasibly possible. The exact threshold below which exposure levels should be kept varies from one agent to the next. In addition, it should be noted that for viable agents, which may replicate upon infection, the minimum infection leading to adversity may very much depend on person to person variation (e.g. in the case of immunocompromised persons). Moreover, for some agents, a minimum infection grade leading to a disease may be very low, depending on the pathogenicity of the organism.

Guidance values for toxic effects

In principle, it is possible to derive OELs for biological agents that primarily cause toxic effects in the same way as is done for other non-carcinogenic substances (using methods such as the no-observed-adverse-effect-level method ([36]), the benchmark dose method ([37]) or another, similar statistical model for human data). However, the lack of good (quantitative) data on exposure and associated toxic effects (the exposure-effect relationship), hampers the actual derivation of such OELs in practice.

Nevertheless, in the Netherlands, a health-based recommended OEL was derived for endotoxin exposure (90 EU/m^3 8-hour time-weighted average (TWA)) (Health Council of the Netherlands, 2010). A health-based recommended OEL for inhalable grain dust of 1.5 mg/m^3 (8-hour TWA) was also considered sufficient protection for workers with acute, short-term and chronic exposure (compared with the threshold limit value derived by the American Conference of Governmental Industrial Hygienists (ACGIH) in the US of 4 mg/m^3 for total grain dust (wheat, oats, barley) and a workplace exposure limit for grain dust of 10 mg/m^3, as established by HSE in the UK) (Health Council of the Netherlands, 2011). In Scandinavia, the Nordic Expert Group has examined the effects on health of moulds capable of producing toxic effects. The level of moulds in the air at which non-sensitised workers start to experience effects was calculated to be about 10^5 spores/m^3 air. However, no recommendations for an OEL were made (Eduard, 2006, 2009). [38]For endotoxins, a health-based OEL of 90 endotoxin units/m^3 has been

([36]) The no-observed-adverse-effect level (NOAEL) is the level of exposure of an organism, found by experiment or observation, at which there is no biologically or statistically significant increase in the frequency or severity of any adverse effects. In toxicology, it is the highest tested dose or concentration of a substance (i.e. a drug or chemical) or agent (e.g. radiation) at which no such adverse effect is found in exposed test organisms where higher doses or concentrations resulted in an adverse effect. See also Regulation (EC) No 440/2008 of 30 May 2008 laying down test methods pursuant to Regulation (EC) No 907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

([37]) The benchmark dose (BMD) method has been proposed as an alternative to the NOAEL approach for assessing non-cancer risks associated with hazardous compounds. It makes use of all of the dose-response data to estimate the shape of the overall dose-response relationship for a particular endpoint. The BMD is a dose level, estimated from the fitted dose-response curve, associated with a specified change in response, the benchmark response (BMR). See also the EFSA Scientific Committee guidance document 'Use of the benchmark dose approach in risk assessment', https://www.efsa.europa.eu/en/efsajournal/pub/4658.

proposed in the Netherlands. A criteria document for fungal spores proposed a lowest observed effect level of 100,000 spores/m³ for non-pathogenic and non-mycotoxin producing species based on inflammatory respiratory effects (Eduard et al., 2012).

Guidance values for allergenic effects

As it is suggested that a threshold level exists for inhaled allergens, OELs could be calculated in the same way as they are for other non-carcinogenic substances. However, the relevant threshold levels for allergens in general may be too low to be measured using the techniques presently available. If deriving an OEL is not possible, reference values (i.e. exposure levels that correspond to predefined accepted levels of risk of allergic sensitisation) can serve as an alternative. These reference values can then be used as a basis for deriving OELs, in which case the concept of an acceptable risk would need to be applied instead of deriving an OEL below which no health effects are expected to occur (see for example Basketter et al., 2010). However, at the moment, sufficient toxicity and effectiveness studies are only available for a small number of allergens. For this reason, it is important to stimulate research on other allergens.

As far as is known, currently only a limited number of limit or reference values for allergens are available. In the Netherlands, reference values of 0.012 mg inhalable flour dust/m³ (8-hour TWA) for occupational exposure to wheat and other cereal flour dusts, 0.9 ng enzyme/m³ (8-hour TWA) for occupational exposure to fungal alpha-amylase, and 0.1 µg inhalable soy antigen/m³ (8-hour TWA) for occupational exposure to dust from processed de-hulled soybean flour are derived, related to a sensitisation risk of 1 % compared to the background risk of the general population (Health Council of the Netherlands, 2004, 2014, 2016). In the case of flour dust, Sweden has recommended a level limit value of 3 mg/m³ (8-hour TWA), the UK a maximum exposure level of 10 mg/m³ (8-hour TWA) and of 30 mg/m³ (15-min TWA), and the ACGIH in the US has recommended a threshold limit value (TLV) for inhalable flour dust of 0.5 mg/m³ (8-hour TWA). The ACGIH has also established a TLV for subtilisin, an enzyme of bacterial origin that is used as, for example, a detergent and is produced with the aid of GMOs.

Technical guidance values

In some cases, upper limits are given for the occurrence of the agent in the environment. This applies, for example, to *Legionella* spp. in stagnant water (in fire hoses, boilers, etc.). While these limits do help to limit the concentration or even the occurrence of the agent in the working environment, they are not directly related to health effects (or the relationship between exposure and effect).

6.6 Other reporting and monitoring obligations

Several respondents to the questionnaire also referred to the obligation to notify activities with biological agents, in particular those classified in Groups 3 and 4 to the authorities before the start of the activities, which is based on a provision set out in the Biological Agents Directive (Annex 4, Tables A4-3-A4-5). One respondent (from Estonia) mentioned the registration of activities with GMOs in a database.

Biomonitoring and health surveillance were also mentioned as a source of monitoring and disease information by several respondents, notably from Austria, Finland, France, Germany, Italy, Latvia, the Netherlands, Portugal, Slovakia and Spain (including a regional surveillance system in Valencia).

Data from these systems could be combined with data from disease and exposure measurement systems to provide a better overview of the situation and implement better prevention in specific workplaces. On the one hand, the information on diseases and exposures regarding the variables sector, occupation, age and gender could be improved, creating a clearer picture and enabling the identification of groups that are particularly at risk, and, on the other hand, targeted prevention could be implemented in specific enterprises.

6.7 EU Directive 2000/54/EC on biological agents

In contrast to what was expected, only a limited number of publications were retrieved in the literature search that discussed the implementation of Directive 2000/54/EC. An evaluation of the EU OSH directives has been carried out, and it provides some information related to diseases (European Commission, 2017a). Data from the European Working Conditions Survey show that workers exposed to infectious agents more often report that their health is negatively affected by work. Moreover, sickness absence is higher among workers exposed to infectious agents. Finally, the data also indicate that workers exposed to infectious agents more often report skin problems, headaches, respiratory problems and injuries. However, the analyses do not allow causal inferences and no firm conclusions about the health effects of the Biological Agents Directive can be drawn. The evaluation also recommends including in the directive the obligation to inform workers on how to detect health effects caused by exposure and how to report them as required under the Chemical Agents Directive, although Article 9 “Information and training of workers” of Directive 2000/54/EC envisages among others measures, information and instructions concerning steps to be taken by workers in the case of incidents and potential risks to health. As in general much more attention is paid to (the prevention of) exposure to chemical agents than to biological agents, although the Biological Agents Directive came into force as recently as 2000, it is very likely that its implementation is less well developed and understood than the equivalent legislation on chemical agents. However, article 10 “Worker information in particular cases” of the directive puts an obligation on workers to “immediately report any accident or incident involving the handling of a biological agent to the person in charge, or to the person responsible for safety and healthy at work”, and awareness should be raised about these obligations for employers and workers.

Current focus on sectors with intentional use

One of the main focuses of the directive is on the sectors in which working with biological agents is either part of the primary process (industrial processes, laboratories and animal rooms) or in which workers come into contact with human or animal patients (health and veterinary care facilities), on which specific articles focus (Articles 15 and 16) and for which indications concerning containment measures and containment levels (Annex V) and containment for industrial processes (Annex VI) are specified. It should be noted that, probably at least partly due to this directive, these sectors are known for their high level of regulation, control and preventive measures, and in general the workers active in these sectors are trained and assumed to be relatively well aware of the risks they are potentially exposed to. The containment measures set out in these annexes could at least partially be implemented in other sectors, but in many sectors in which exposure to biological agents is not part of the primary process or part of a stringent control/prevention strategy, but still an inherent part of everyday working practice, these containment measures are not easy to put into place.

There is a need for global harmonisation of national regulations in the biosafety and biosecurity fields, as risk management is better documented for processes in which handling biological agents is part of the primary process (e.g. for GMOs) than when dealing with naturally occurring biological agents (Bielecka and Mohammadi, 2014). This finding is supported by the evaluation of the Biological Agents Directive (European Commission, 2017a), which found that compliance with the Biological Agents Directive varies from sector to sector, as establishments that are intentional users or handlers of biological agents have a much higher level of compliance than establishments that do not have biological agents as their core business. Furthermore, the implementation of control measures has to be engineered step-by-step to reduce exposure pathways; the experience that specialists have already gained in the process industries can be used for this. In addition, the directive contains a requirement according to which health surveillance should be carried out before work starts and those responsible for the health surveillance must be familiar with the exposure conditions or circumstances of each worker. Owing to the large variation among sectors/industries in which biological agents pose a potential risk for workers, however, a ‘one size fits all’ solution is unlikely to be found.

The general focus on healthcare and laboratory settings is also observed in the responses of the questionnaire respondents. The types of policy beyond the minimum regulations laid down in Directive 2000/54/EC mentioned by the respondents were described as regulations, legislation or guidance/guidelines, mainly aiming at classification, prevention and/or vaccination. When a specific sector or subject was mentioned, most of the policies were aimed at the healthcare sector (and then mainly in relation to needlestick injuries). Although most referred to regulation or legislation on biological agents in general, several focused on a specific biological agent or disease, namely *Legionella* (specific regulations or the provision of information), spongiform encephalopathies (regulations), viruses (guidance or regulations) and tuberculosis (surveillance). Around 47 % of the respondents, representing about half of the countries, indicated that they were familiar with one or more campaigns/strategies that focused on the risks posed by biological agents at work. These types of campaigns were generally described and categorised as (workplace) inspections and campaigns, although, for instance, vaccination programmes were also mentioned. These national or local campaigns frequently focused on a specific agent or disease, such as *Legionella*, tuberculosis, tetanus, hepatitis, HIV, flu, bird flu, Lyme disease or MRSA. If a specific sector or job was mentioned, it was the healthcare sector, although abattoirs, education, childcare, agriculture, biosafety, laboratories and reception centres were also mentioned. Specified topics mainly concerned needlestick injuries.

Classification systems for biological agents

An important aspect of monitoring exposures to agents in the workplace, including exposure to biological agents, is the categorisation and classification of these agents. Both in France and in Germany, classification systems are in use that can serve as practical examples of harmonisation. These systems, such as the GESTIS database, may be integrated with prevention measures and be used to improve prevention. Furthermore, they could function as useful tools in planning an update to the annexes to the Biological Agents Directive. It should be noted in this context that according to the evaluation of the directive, the annexed list of biological agents was assessed as outdated by several Member States (European Commission, 2017b).

Expert networks

Although not directly related to the directive, around 42 % of the respondents (representing about half of the countries involved) indicated that they were familiar with one or more expert networks dealing with biological agents, mostly an organisation of occupational physicians or hygienists, operating either on a general level over various sectors or more specifically in a particular sector (e.g. hospitals) or in a particular group of OSH professionals (e.g. via a national association). An example of the integration of expert networks with regard to monitoring diseases is the French rnv3p system, in which ANSES coordinates a network of ODCs and OSHs. These expert networks could be valuable information sources for the implementation of the directive and on potential adaptations, as well for an update to the directive to take into account emerging issues. A Dutch expert network has contributed to the characterisation of multiresistant microorganisms and issued assessments of the risk levels, and other networks directly contribute to prevention and to new legislation. It is important to note that the assessments of microorganisms are carried out by different ministries in some Member States (European Commission, 2017b), notably the ministries of health, and a collaboration between public health and OSH experts (and their networks) should be ensured to maximise the benefit from their knowledge and input.

Conclusions

Based on this review, it can be concluded that biological agents, as well as occupations for which exposure to biological agents is relevant, are immensely diverse, and that a directive in which a generalised approach is applied cannot be expected to cover all possible situations in which exposure to biological agents, possibly resulting in related health effects, can occur. A reliable classification of all biological agents according to their level of risk would require a study and subsequent risk assessment of each individual biological agent, which is not possible for all biological agents, as, for some, data are simply unavailable. The measures set out in the directive are related to generalised broad risk categories, and the containment measures that are mentioned mainly focus on laboratory work. Therefore, some work environments in which exposure to biological agents frequently occurs are not covered, for example sectors in which exposure to biological agents is not a good fit with these containment measures (e.g. arable farming, animal breeders/carers/handlers, zoos, professions that involve travelling or contact with travellers or migrants).

The main focus of the directive is on microorganisms in relation to infectious diseases, whereas the definition of biological agents used in various Member States is much broader. It is recommended that a wider definition of biological agents be considered in implementing the directive: in addition to living (micro)organisms (e.g. bacteria, viruses, fungi, yeasts and prions), substances or structures that originate from living or dead organisms (e.g. exotoxins, endotoxins, glucans, mycotoxins), allergens (originating from living or dead organisms, and possibly also plants or animals) and carriers of a variety of biological agents (e.g. organic dust and bioaerosols) contribute significantly to exposure to biological agents in work environments, and should therefore also be addressed. This wider definition would help in enabling the prevention of toxic and allergenic or irritative effects related to these substances. The interface and overlap between biological and chemical agents needs to be clarified and addressed by national legislation or guidance implementing the directive, in relation to the assessment of exposures, but also to ensure that all possible uptake routes are explored; that the exposures are identified and their effects traced to their exact cause; and that potentially work-related diseases are monitored and their prevention enhanced.

The health effects related to biological agents are a significant burden on the working population. In relation to allergenic agents and respiratory diseases in particular, a lot still remains to be done, and the prevention framework needs to ensure that they can be unequivocally addressed in research, monitoring, recording, legislation, inspection and prevention. Equally, mixtures of biological agents such as organic dust and toxins emanating from biological agents, which have a high potential to cause irreversible effects such as sensitisation, effects on the immune system and even cancer, need to be covered by this framework, be it in chemical or biological agents-related provisions.

A wider range of occupations than those considered in the directive should be considered ‘at risk’, and also it is recommended that they be considered more specifically in EU legislation, to make sure, for example, that these are also tackled by prevention measures in the relevant professions. The information provided by means of the scientific literature review, the questionnaire survey, the evaluation of selected monitoring systems, and the interviews with experts (Task 2 of this project) could be useful sources to take into account for a possible update to the directive and its annexes in order to address the whole range of biological agents and the related health effects identified in both research and practice.

Furthermore, the evaluation of the Biological Agents Directive (European Commission, 2017a) recommends incorporating into the directive provisions from the Chemical Agents Directive, such as:

- the obligation during the risk assessment to
    - take into account the effect of preventive measures,
    - obtain additional information from suppliers,
    - take into account conclusions to be drawn from health surveillance,
    - include activities with foreseeable exposures in the risk assessment and include a justification by the employer that the nature and extent of the risks make a further detailed assessment unnecessary;
- the obligation to update the health record;
- the obligation to inform workers on how to detect health effects of exposure and how to report them as required under certain physical agent directives .

These provisions could support a better knowledge base for risk assessment and consequently could also help in implementing better prevention, in particular in those workplaces where prevention needs to be enhanced, as in many sectors where unintentional exposure takes place.

It is also recommended that sectoral organisations and workplace actors direct more attention towards the directive, by providing guidance on how to control/prevent exposure in work environments (e.g. agriculture) and also during medical emergencies. Biological agents that require specialised precautions, such as *Legionella*, should also receive more attention.

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