European Agency for Safety and Health at Work

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

European Risk Observatory
Executive summary

European Agency for Safety and Health at Work

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Cataloguing data can be found on the cover of this publication.

Luxembourg: Publications Office of the European Union, 2019

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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.

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

[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.

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[2] 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.

Legal requirements

Directive 2000/54/EC[3] 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

[2] **Protection of workers Directive 2000/54/EC of the European Parliament and of the Council of 18 September 2000**. Available at: https://osha.europa.eu/es/legislation/directives/exposure-to-biological-agents/77

[3] **Framework Directive**: **Directive 89/391 - OSH "Framework Directive"** of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work. The European Framework Directive on Safety and Health at Work (Directive 89/391 EEC) adopted in 1989 was a substantial milestone in improving safety and health at work. It guarantees minimum safety and health requirements throughout Europe while Member States are allowed to maintain or establish more stringent measures. For more information see https://osha.europa.eu/en/legislation/directives/the-osh-framework-directive/1

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.

1.1.1 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.


Dragan LEKIC/Libre arbitre

1.1.2 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.

1.1.3 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.

1.1.4 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.


Sandra Milosevic

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.

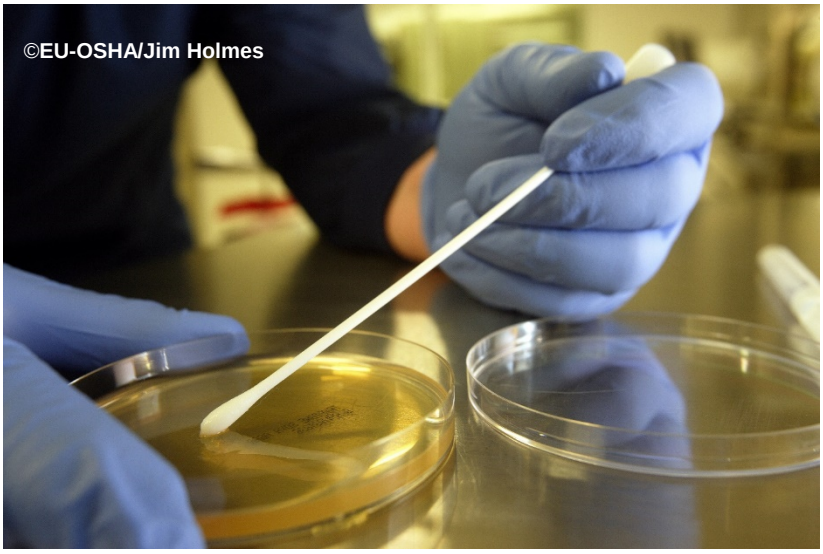
For the detection of new occupational health risks, instruments other than those used for the monitoring of known occupational diseases may be needed. Information that is routinely collected by public health systems could possibly be used to this end, especially when it is not directly clear to the worker/and 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[4], 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.

[4] **Rnv3p** - The French rnv3p network, set up in 2001, draws together 31 work-related disease consultation centres in hospitals where occupational health physicians investigate the suspected WRDs and collect data into a permanent national database. The network has developed a specific thesaurus of exposures and uses specific methods for the detection of new WRDs. It can generate three types of alerts, from a notification to an internal group to alerting the OSH and public health authorities for potential action at the national level. For more information see https://osha.europa.eu/en/publications/alert-and-sentinel-systems-rnv3p-france/view



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.

1.1.5 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.

1.1.6 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.

1.1.7 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[5]. 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.

[5] The German **GESTIS** Biological Agents Database is part of GESTIS (hazardous substance information system of the German Social Accident Insurance). It holds data for almost 15,000 biological agents on the classification in one of the four risk groups and the basic technical, organisational and personal protective measures during activities in laboratories, biotechnology and keeping of experimental animals. For an increasing number of biological agents, datasheets with extended information provide more detail, e.g. on the relevant sectors and activities, protective measures for specific pathogens, decontamination, first aid measures, preventive health care, morphology and physiology, natural distribution, occurrence, pathogenicity, disease, epidemiology, resistance and legal principles. Datasheets are issued not only on biological agents, but also on activities, such as waste management, or agriculture and forestry. For more information, see https://oshwiki.eu/wiki/The_GESTIS_Biological_Agents_Database_%E2%80%93_compact_information_for_occupational_safety_and_health_protection

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-borne diseases; sex workers, who are prone to sexually transmissible infections; workers	Ensure broad coverage of professions that are potentially exposed to biological agents, especially professions that involve contact with people, animals, food or plants, as regards monitoring and prevention	

Findings	Recommendations	Remarks
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	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
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	Alert systems such as the rnv3p system established in France, following a pharmacological vigilance approach, could be helpful

Findings	Recommendations	Remarks
	Cooperation with public health institutions could help in monitoring the spread of diseases and outbreaks	
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*))	Enhance research and monitoring in exposed professions	
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 respiratory syndrome (SARS), cholera or meningitis	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
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	

Findings	Recommendations	Remarks
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 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	

Findings	Recommendations	Remarks
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	
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	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	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

Findings	Recommendations	Remarks
part of registrants, as a result of inadequate guidance and training	physician to notify a disease that they suspect could be linked to work	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
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

Findings	Recommendations	Remarks
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

The European Agency for Safety and Health at Work (EU-OSHA) contributes to making Europe a safer, healthier and more productive place to work. The Agency researches, develops, and distributes reliable, balanced, and impartial safety and health information and organises pan-European awareness raising campaigns. Set up by the European Union in 1994 and based in Bilbao, Spain, the Agency brings together representatives from the European Commission, Member State governments, employers' and workers' organisations, as well as leading experts in each of the EU Member States and beyond.

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