EXPOSURE SENSORS

Exposure levels are currently measured by occasionally taking samples from a limited number of employees. A logbook is kept of the activities being carried out while these measurements are being made. The samples are analysed in a laboratory and, together with the log book data, interpreted and provided to the company. This approach does not, however, provide insight into peak exposures or into variations over time. Moreover, measurement results are obtained long after the exposure has taken place. With sensors, measurements can be taken much more frequently and amongst more people. The results contain more useful information and are available in real time.

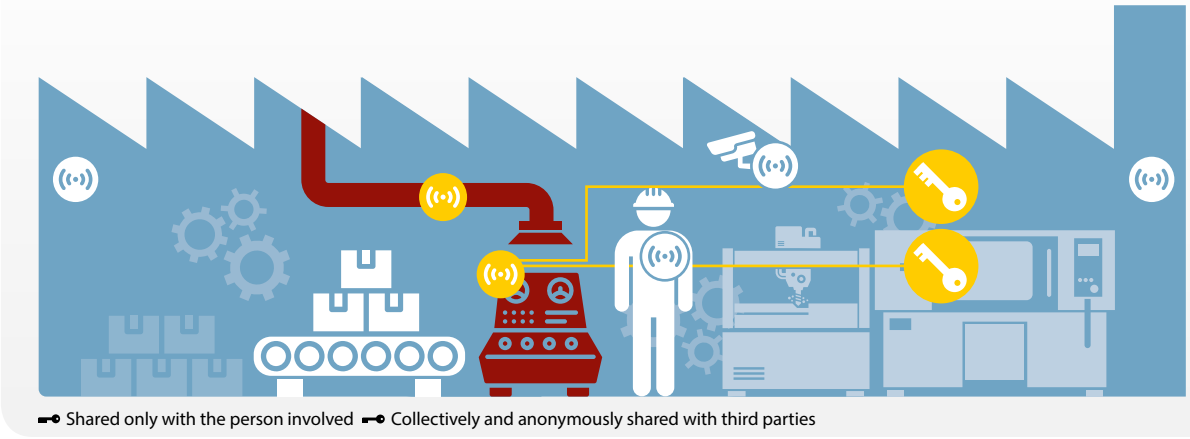
Advantages	Disadvantages
Sensors record a measurement every few seconds with as a result an all-day exposure profile (graph of concentration against time), which provides more useful information than an 8-hour time-weighted average (TWA): in combination with time-activity patterns, the activities that lead to elevated exposure are directly identifiable.	Most sensors are not yet as reliable as conventional methods, which means that they cannot yet be used to test compliance of measurement with limit values.
Sensors are smaller, lighter, and easier to attach than the pumps used in conventional measurement methods.	Regular testing is needed to determine whether recalibration is required; maintenance and recalibration instructions are in very short supply.
Real-time feedback of exposure levels makes it possible to intervene immediately if required.	Sensor measurement results are not directly legible; software is required to convert sensor data into understandable exposure levels.

ETHICS

Ethical values that could play a role in the introduction of workplace sensors include health/well-being, self-determination, privacy, trust, justice, and responsibility:

- Sensors can collect personal data that has to be shared with others, e.g. the occupational hygienist, in order to be useful *(privacy)*;
- The introduction of sensors can have negative side effects:
  - sensors can create a ‘Big Brother is watching you’ feeling *(well-being)*;
  - data can be used for other purposes, e.g. in an employees’ performance review *(trust)*;
- Sensors can be applied to people or objects. When applied to people, freedom of choice becomes important *(self-determination)*;
- Employers have working conditions obligations, while employees are exposed to materials or situations that might affect their health. The benefits and burdens of using sensors should therefore be fairly divided *(justice)*;
- The personalisation of exposure measurements could result in shifting responsibility for exposure reduction to employees themselves *(responsibility)*.

SENSORS AS DETECTOR



Sensors can be used to monitor the effectiveness of control measures or working procedures. This applies both to sensors measuring chemical substances and to so-called 'smart sensors' that measure physical quantities such as temperature, distance, orientation, vibration, pressure, etc. They are not applied to people but to equipment and machinery such as fume extractors. Examples would include:

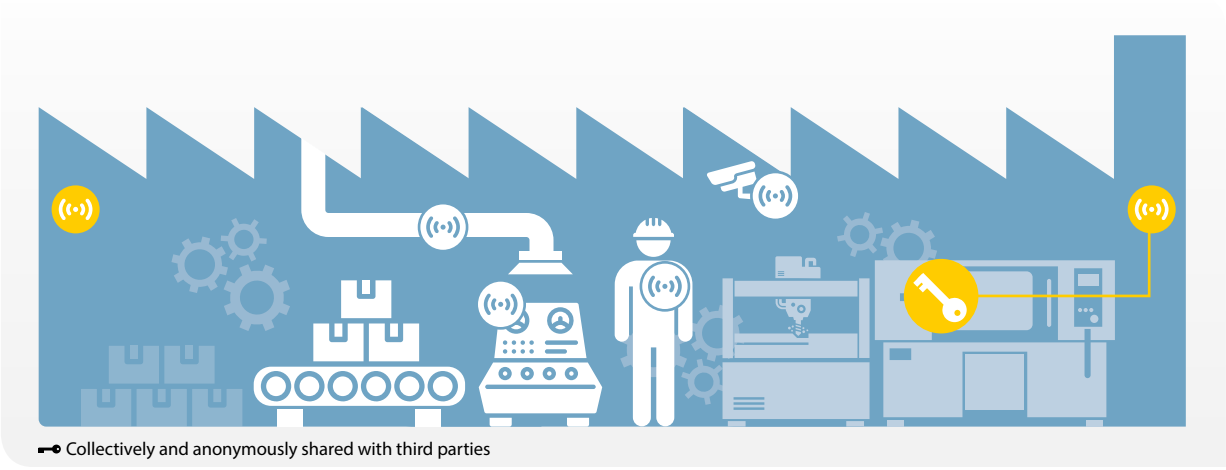
– automatically switching on an extraction system if too high a concentration of a given substance is detected;
– automatically giving a signal if a spray gun is incorrectly aimed at a surface, increasing the risk of high exposure levels.
– giving a signal when a filter of a vacuum cleaner is saturated.

Advantages	Disadvantages
Improving the functioning of existing control measures, e.g. automatic activation of control measures.	Generates no insight into employee exposure.
In the automatic control of exposure (e.g. automatic extraction), this control does not depend on human action.	Over-reliance on sensors can create a false sense of security.
The possibility of immediately modifying a control measure (e.g. close the sash of a fume cup board, or connect an extractor) if the sensor gives a signal.	The sensor signal does not indicate what the required modification is: instruction is required.

ETHICS

– The use of sensors as detector can optimise the effectiveness of control measures or of working procedures, thereby reducing potential exposure levels. The use of this technique therefore contributes towards several important values *(health/well-being, responsibility, justice)*, without jeopardising privacy.
– The introduction of sensors as detector can have negative side effects:
  – The signal generated by the non-optimal functioning of a control measure can be seen by the employee concerned, but also by others *(well-being, privacy)*;
  – The sensor signal frequency of non-optimal functioning of a control measure can be logged and used to say something about the behaviour and attitude of the employee concerned, for instance in an employees' performance review *(responsibility, trust)*.

STATIONARY EXPOSURE SENSORS



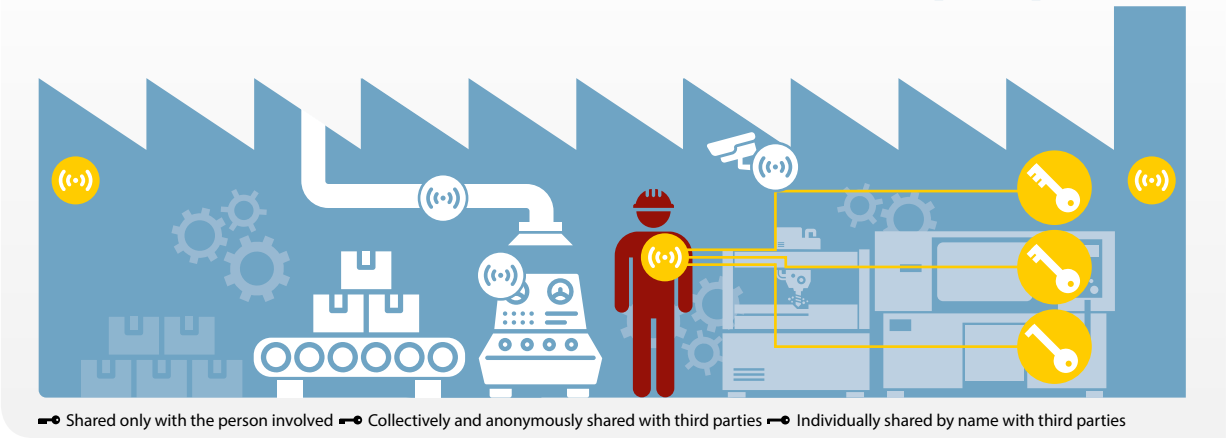
Stationary sensors are carefully distributed throughout the work environment. The concentration of a chemical substance is continuously measured. Modelling tools are used to draw a substance concentration map of the area, making high-concentration zones visible; this allows the location of a source to be identified.

Advantages	Disadvantages
The distribution of substance concentrations in a work environment become visible.	The distribution of substance concentrations within an area says nothing about the exposure levels of individual employees.
High-concentration zones can be identified.	This insight does not automatically mean that employees in these zones would not be permitted or required to continue working.
Sources can be identified and control measures can be implemented accordingly.	The accuracy of modelled concentration maps is lower than that of the stationary measurements themselves.

ETHICS

- Concentration maps are not very accurate and this can give rise to a false sense of security *(trust)*;
- Decisions have to be made on the continuation of work activities in high-concentration zones *(responsibility)* and the affected employees *(justice, self-determination)*;
- Having to continue working in a high-concentration zone can feel uncomfortable *(well-being)*;
- The source of a problem may be identified as the behaviour or working methods of an employee; this information can be used to rectify employee behaviour *(responsibility, health)*, but could also be used in their assessment during an employees' performance reviews *(trust)*.

STATIONARY EXPOSURE SENSORS WITH INDOOR LOCATION TRACKING (ILT)



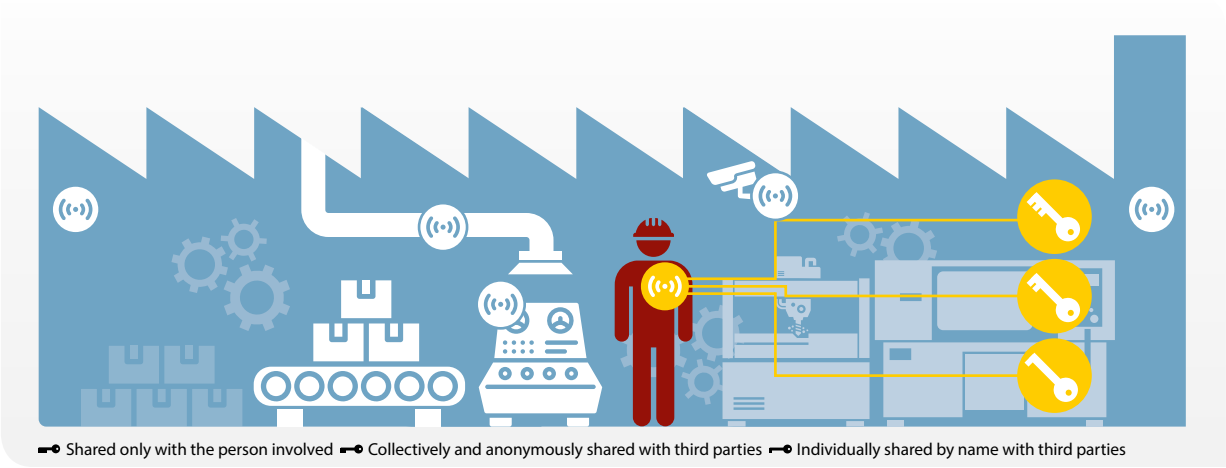
Stationary exposure sensors and modelling tools can be used to draw up concentration maps of workspaces. This can be done for more than one chemical substance simultaneously. If employees are fitted with an ILT device, individual exposure profiles can be developed by combining an individual's indoor location data with the concentration map data.

Advantages	Disadvantages
By monitoring the movements of an employee, they can be given a signal if they enter a high-concentration zone.	Wearing an ILT device means that all the movements of an employee during the day are visible, including how often they go outside (e.g. to smoke) or to the toilet.
If employees just wear an ILT device, individual exposure profiles can be generated for all substances subject using stationary monitoring data.	Because modelled concentration maps are less accurate than (personal) measurements, these exposure profiles are also less accurate.

ETHICS

- By combining ILT with stationary exposure sensors, an employee is only required to wear an ILT in order to develop exposure profiles for a variety of substances *(justice)*;
- Employees should have a say in whether or not they wear an ILT device *(self-determination, well-being)*;
- If ILT is coupled with GPS coordinates the data can be used to identify employees – which makes it personal data and privacy-sensitive *(privacy)*;
- The introduction of ILT can have negative side effects:
  - Stationary exposure sensors with ILT may contribute to a shift in responsibility to control high exposures onto employees themselves *(responsibility)*;
  - ILT data could also be used for other purposes, e.g. in an employees' performance review *(trust)*.

PERSONAL EXPOSURE SENSORS



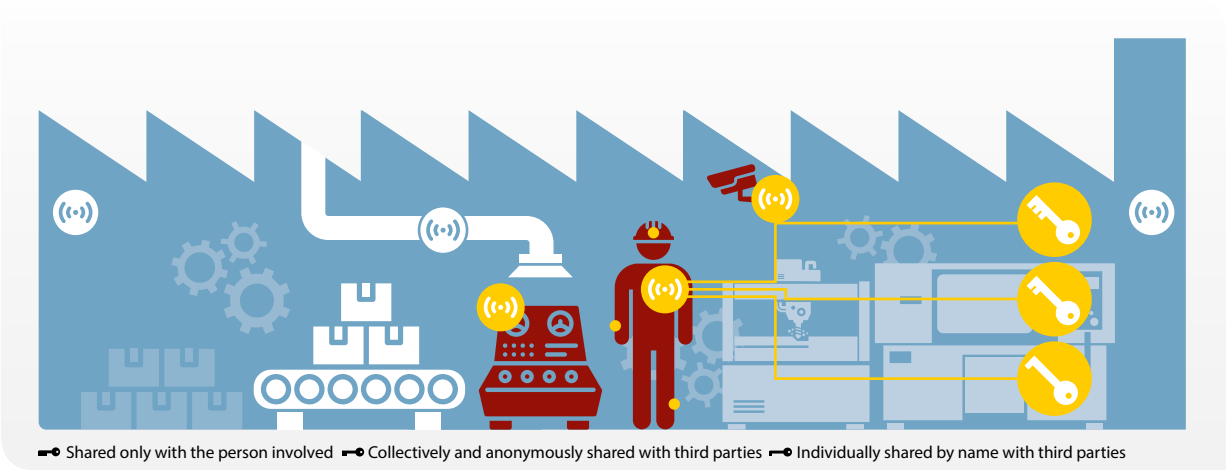
Exposure sensors can be worn by employees on the chest or shoulder to measure their personal exposure levels. Sensors often record a measurement every few seconds, yielding an exposure profile (time series) for the entire working day. This can be presented to the employees themselves in real time, e.g. using an app. It can be visualized as an exposure profile, the average daily exposure, or (non) compliance of the exposure level in relation to an exposure limit.

Advantages	Disadvantages
Real time insight into personal exposure, enabling immediate intervention.	The sensor may become a distraction that the employee is constantly checking.
A warning signal can be given if the exposure level is too high.	It has to be clear what exposure level is ‘too high’.
The sensor can indicate the total daily exposure compared with the exposure limit.	It is not immediately clear how this information can be applied.
The system can function without data storage, ruling out data abuse.	If data are not stored, employees themselves are responsible for responding adequately to excessive exposure. Without data storage it will not be possible to establish a link between exposure and health problems.
The system can also function with data storage. Data can be analysed collectively to identify appropriate control measures for the company (the responsibility of the HSE manager).	If data are stored, the data can be abused.

ETHICS

- Employees should have a say in whether they wear a sensor or not *(self-determination, well-being)*;
- Employer needs knowledge in order to fulfil their responsibilities, but employee’s knowledge also brings responsibilities *(responsibility)*;
- Possible negative side effect: an employer may ask employees to perform work associated with high exposures because they have not yet reached their ‘maximum exposure’ for a given work shift *(justice)*;
- Personal exposure data could be stored in an exposure register, allowing health complaints to be traced back to related exposures *(health, privacy, responsibility, liability)*;
- Personal data could also be used in a negative way: included in an employees’ performance review, or shared with potential new employers *(trust, responsibility)*.

PERSONAL EXPOSURE SENSORS WITH CONTEXT-MEASURING TECHNIQUES



An exposure profile based on a personal exposure sensor is not easy to interpret. To understand what is causing peak or elevated exposures, insight is needed into what an employee has done, in what way, and under what circumstances, i.e. the context. This context can also be measured - in part - using sensors and other techniques, such as indoor location tracking, video cameras, and smart sensors that measure a person's posture or movement.

Advantages	Disadvantages
Combining context-measuring techniques with personal exposure sensor data helps to identify the most efficient control strategies.	A great deal of data needs to be collected, which is only useful when analysed as a whole. Software is needed to synchronise and interpret this data.
Offers the possibility of effective personal prevention.	Employees are obliged to wear one or multiple (light-weight) devices.
Offers the possibility of effective group-level prevention.	Data has to be shared between employees and the HSE manager.

ETHICS

- Sensors and other techniques can give people a 'Big Brother is watching you' feeling *(well-being)*;
- Much of this data is personal *(privacy)*;
- Employees should have a say in whether these techniques are used or not *(self-determination)*;
- These techniques collect data that has to be shared with others to be effective, e.g. the occupational hygienist *(privacy)*;
- Because a person's behaviour can be derived from this data, it could also be used in a negative way *(trust)*;
- The personalisation of exposure measurements could result in shifting responsibility for exposure reduction to employees themselves *(responsibility)*.