EXPOSURE TO BIOLOGICAL AGENTS AND RELATED HEALTH EFFECTS IN THE WASTE MANAGEMENT AND WASTEWATER TREATMENT SECTORS

Health effects related to exposure to biological agents in the workplace

Between 2015 and 2017, the European Agency for Safety and Health at Work (EU-OSHA) carried out a project to address the lack of knowledge and awareness of exposure to biological agents and the related health problems, as well as the lack of a systematic approach to workplace prevention in relation to biological agents at work. In 2016, an extensive literature review was carried out on work-related diseases due to biological agents. The research found that people in the waste management and wastewater treatment sectors are at a high risk of exposure to biological agents. In addition to the literature review, expert survey and collection of data on health problems and exposure from monitoring systems, information on policy measures intended to reduce the risks posed by biological agents was obtained from interviews with experts and focus group sessions with workplace practitioners. Additional information was gained during a stakeholder workshop in 2017. This article focuses on health effects related to biological agents in the waste management and wastewater treatment sectors.

In the field of industrial, medical and domestic waste treatment, growing amounts of waste are generated in the EU. Workers in waste treatment include waste collectors, waste handlers, waste sorters, recycling workers, incineration workers, composting workers, biomass/bioenergy workers, landfill workers and wastewater treatment workers. As exposure to microorganisms in these workers is common, (OSHwiki article 'Exposure to dangerous substances in the waste management sector'([1])), health effects due to biological agents are a serious risk to workers.

- **Waste treatment**

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). Furthermore, working areas in waste facilities with air-conditioning systems, high humidity or systems containing stagnant warm water are amenable to the growth of *Legionella* (EU-OSHA, 2011).

([1]) See the OSHwiki article 'Exposure to dangerous substances in the waste management sector': https://oshwiki.eu/wiki/Exposure_to_dangerous_substances_in_the_waste_management_sector

During waste handling, accidents with sharp objects pose risks of infection from blood-borne viruses. These accidents happen during the separation of waste or when rubbish is collected, especially when rubbish bags (which tear easily) are used instead of containers. Not only needles but also glass and cans must be separated by hand. Generally, where the waste originates from is unknown.

- **Wastewater treatment**

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).

Leptospirosis (caused by *Leptospira* spp.) has also been reported among wastewater and sewage workers (Dutkiewicz et al., 2011). Wastewater treatment workers are also at particular risk of exposure to *Legionella* (EU-OSHA, 2011).

Table 1 provides an overview of reported occupations, biological agents and related diseases in of biological agents at the workplace reported in reviews published since 2010 (EU-OSHA, 2019).

Table 1: Overview of reported occupations, biological agents and reported related infectious and unspecific diseases in waste treatment workers (e.g. waste collectors, waste composting workers, waste handlers, waste sorters) and wastewater treatment workers

Biological agent	Occupation	Health effect
Bacteria		
Actinomycetes	Composting site worker	Actinomycosis
Acinetobacter	Waste worker	—
Brucella spp.	Waste worker	Brucellosis
Campylobacter	Waste worker	Campylobacter infection
Escherichia coli	Waste worker	Colibacteriosis
Legionella spp.	Biological treatment plant worker Waste worker Wastewater treatment worker	Legionellosis
Mycobacterium	Waste worker	Tuberculosis
Salmonella	Waste worker	Salmonellosis
Staphylococcus	Waste worker	—
Treponema pallidum	Waste worker	Syphilis
Fungi		

Biological agent	Occupation	Health effect
Aspergillus	Waste worker	Mycotic keratitis (cornea infection)
Cryptococcus	Waste worker	Cryptococcosis
Geotrichum	Waste worker	—
Rhodotorula	Waste worker	—
Trichoderma	Waste worker	—
Viruses		
Hepatitis A virus	Waste worker	Hepatitis A
Hepatitis B virus		Hepatitis B
Hepatitis C virus		Hepatitis C
Human immunodeficiency virus (HIV)	Waste worker	Acquired immune deficiency syndrome (AIDS)
Parasites		
Toxoplasma gondii	Waste worker	Toxoplasmosis
Mixtures		
Indoor moulds, fungi (mixture)	Waste worker	Sick building syndrome, asthma, upper respiratory diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, and irritation of the nose, throat, eyes and skin

Note: The literature review did not provide information on specific health effects for all causative biological agents. Where there was no information in the literature, health effects have been identified based on general knowledge if possible, that is, if the biological agent causes one specific disease; for those biological agents that cause a range of health effects, cells have been marked with a dash.

([a]) Toxins produced by certain bacteria and released upon destruction of the bacterial cell.

A causal relationship between exposure to non-infectious airborne biohazards endotoxins, (1-3)-betaD-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).

Increased exposures to endotoxins (EU-OSHA, 2007a; Ławniczek-Wałczyk and Górny, 2010; Duquenne et al., 2013), mycotoxins (Fromme et al., 2016), beta-glucans via organic dust (Ławniczek-Wałczyk and Górny, 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 thermotolerant/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)

Table 2 provides an overview of allergenic agents, toxins and related health problems identified in the literature review.

Table 2: Overview of occupations, allergenic agents, toxins and related health problems in waste management and wastewater treatment workers

Category	Agent	Occupation	Health effect
Arthropods	Sewer fly	Sewage plant worker	Asthma
Aspergillus fumigatus		Composting site worker	Pulmonary and respiratory diseases
Archaea	Archaea in bioaerosols	Wastewater treatment worker	Sensitisation (relevance to be determined)
Plant material	Kapok	Sewer worker	Asthma
Fungi	*Alternaria*	Waste worker	Asthma, hypersensitivity pneumonitis
Fungi	*Cladosporium*	Waste worker	Asthma, hypersensitivity pneumonitis
Fungi	*Penicillium*	Waste worker	Asthma, hypersensitivity pneumonitis

Category	Agent	Occupation	Health effect
Organic dust	Organic dust (beta glucans)	Waste worker	—
Organic dust (mixture)	Organic dust (endotoxins)	Waste worker	High fever, coughing, irritation of the respiratory system and chest congestion (inhalation exposure)
Organic dust, bioaerosols (mixture)	Organic dust, bioaerosols	Biomass power generation worker	Irritation (ocular, dermal)
Organic dust	Organic dust (bacteria, fungi, endotoxins ([a]), beta glucans)	Composting site worker	Cough, dyspnoea, eye irritation
Toxin/subcellular pathogen	Aflatoxins	Waste worker	Hepatotoxic, carcinogenic and immunosuppressive effects
Toxin/subcellular pathogen	Ochratoxin A	Waste worker	Carcinogenic, nephrotoxic, teratogenic and immunotoxic effects

Note: The literature review did not provide information on specific health effects for all causative biological agents. Where there was no information in the literature, health effects have been identified based on general knowledge if possible, that is, if the biological agent causes one specific disease; for those biological agents that cause a range of health effects, cells have been marked with a dash.

Exposure pattern, intentional versus unintentional use and available exposure limits

Waste materials in general contain a range of nutrients and are moist, which are good conditions for the growth of microorganisms. The age and composition of the waste, storage temperature and humidity affect the type and quantity of microorganisms in the waste, as well as the extent to which these microorganisms can survive and multiply. The most relevant routes of exposure to biological agents in this context are direct contact with waste materials and dust (mainly dermal and/or oral exposure) and inhalation of airborne biological agents ([2])] (EU-OSHA, 2019). A specific route of exposure to biological agents is through needlestick injuries, for example during manual sorting of waste.

Occupational exposure to biological agents can occur through the intentional use of specific microorganisms in the primary process, or as more or less accidental or unintentional exposure resulting from processes that involve many different microorganisms in environments in which biological agents occur naturally because the conditions are favourable for the growth of microorganisms. Intentional use occurs in the waste treatment sector when waste is decomposed using microorganisms, which happens in composting, for example, where naturally growing microorganisms decompose organic waste and the process is controlled to promote the growth of some of these decomposers. As the involvement of microorganisms is generally an essential part of, for instance, composting and sewage treatment processes, use of biological agents in these cases is considered intentional, but because of the significant variation in the microorganisms involved, it is still considered an issue of concern. In addition, in composting, for example, microorganisms are expected and intended to grow, but pathogens, for example in contaminated wastewater, or microorganisms that produce allergens, for example organic dust from waste, may also be present, and this is indeed unintentional.

([2]) See the OSHwiki article 'Exposure to dangerous substances in the waste management sector': https://oshwiki.eu/wiki/Exposure_to_dangerous_substances_in_the_waste_management_sector

Occupational exposure limits

The lack of knowledge about the full range of exposures and of (quantitative) data on the association between exposure and the related health effects (the exposure-effect relationship) hampers the derivation of occupational exposure limits (OELs) applicable to waste treatment and wastewater treatment. Currently, only Germany sets a technical control value for spores of mesophilic moulds in the workplace air of waste handling facilities: 5 x 10^4 spores per m^3 of respiratory air (BAuA, 2016). Although the recommendation is not specific to the waste treatment sector, and not implemented as an official OEL, the Netherlands has derived a health-based recommended OEL for endotoxin exposure (90 endotoxin units/m^3 of air, 8-hour time-weighted average ([3])) (Health Council of the Netherlands, 2010), which is also relevant to this sector. In Scandinavia, the Nordic Expert Group examined the health effects of moulds capable of producing toxic effects and calculated that the level of moulds in the air at which non-sensitised workers start to experience effects is about 10^5 spores/m^3 of air (Eduard, 2006, 2009).

However, based on the available scientific literature, the following threshold limits or reference values ([4]) are in use for bioaerosols in occupational environments, including waste management:

- Total bacteria: ≤ 1.0 x 10^3-7.0 x 10^3 colony-forming units (cfu)/m^3 for non-industrial workplaces, and ≤ 7.5 x 10^2-1.0 x 10^7 cfu/m^3 for manufacturing and industrial premises.
- Gram-negative bacteria: 1.0 x 10^3-2.0 x 10^4 cfu/m^3 for manufacturing and industrial premises
- Fungi: 1.0 x 10^1-1.0 x 10^4 cfu/m^3 for non-industrial workplaces and ≤ 1.0 x 10^2-1.0 x 10^7 cfu/m^3 for manufacturing and industrial premises.
- Bacterial endotoxins: 0.005-0.2 µg/m^3 for productive and industrial processes.
- There is no safe level of pathogenic microorganisms; the threshold limit should be 0 cfu/m^3.

Vulnerable groups

Some groups of workers can be considered 'inherently' vulnerable, the 'particularly sensitive risk groups' (e.g. ageing workers, young workers, female workers). In the case of workers with high levels of exposure, however, their vulnerability can be attributed to the job itself (and possibly to the fact that, in the sector in question, the high level of exposure is a result of OSH regulations not being properly implemented). However, there is an overlap between these groups, and the different conditions may interact. Consequently, differences in metabolism, pre-existing health problems — including those caused by work, such as respiratory disorders — the norms of the sector, its safety culture and employment conditions, and the specific conditions of the workplace need to be considered when identifying vulnerable groups.

In waste management and wastewater treatment, as in other sectors, trainees and workers in their first jobs, as well as temporary workers, are considered vulnerable groups, because they have less practical experience and are generally less aware of the risks. Pregnant women, elderly people, people with pre-existing diseases such as lung diseases, allergies, asthma and diabetes (because of the increased risk of infections), and people who have undergone immunosuppression as a treatment for chronic diseases are also considered vulnerable. Furthermore, temporary workers and undocumented (illegal) workers are considered particularly vulnerable in these jobs because they are often unaware of and uninformed about the risks that they are exposed to, and frequently do not receive appropriate training, instructions or vaccinations. The vulnerable groups mentioned above are a concern in many sectors, including the waste management and wastewater treatment sectors. Within these sectors, cleaning and maintenance are considered particularly high-risk jobs (EU-OSHA, 2020).

([3]) Endotoxin units are a measure of an endotoxin's activity.
([4]) See the OSHwiki article 'Bioaerosols and OSH': https://oshwiki.eu/wiki/Bioaerosols_and_OSH

Emerging risks

An 'emerging OSH risk' is any occupational risk that is considered to be new or increasing. Emerging risks include newly created or newly identified risks, increasing risks and risks that are becoming widely known or established.

The following are examples of emerging risks in the waste management and wastewater treatment sectors identified in the interviews with experts and focus groups.

The first emerging risk relates to the collection and separation of (organic) waste in households. This waste is nowadays often stored in (larger) plastic containers rather than in plastic bags, which can result in less frequent collection of waste. In the containers used for storage, the circumstances are generally optimal for the growth of microorganisms, and longer storage times in homes allow microorganisms more time to grow. This leads to an increased risk of unintentional exposure to bacteria and fungi among, for example, waste collectors and waste sorters.

Second, combined exposure to multiple risk factors (chemical, biological, physical), including a mixture of biological agents, is considered an emerging risk for waste treatment workers (EU-OSHA, 2009), as much is still unknown about the possible interactions that may increase or decrease the overall health effect (EU-OSHA, 2019).

The expected increase in green jobs related to biomass use, waste and recycling may result in an increased prevalence of sensitisation to biomass-related allergens in the future. Biomass-related allergens are also a concern, as waste management and composting are associated with the occurrence of specific allergens.

Furthermore, *Aspergillus* in green waste recycling is considered an emerging risk, as this biological agent may be present in the bioaerosols released at these composting plants. Activities such as the shredding of fresh green waste, pile turning and the screening of mature compost may result in the release of significant amounts of bioaerosols and cause health effects in green waste recycling workers upon exposure.

EU-OSHA has also 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, 2013).

Another emerging risk relates to *Leptospira* spp., which cause Leptospirosis. *Leptospira* is often carried by rats and is secreted in their urine and climate change is expected to lead to an increase in the number of rats because rats thrive in warmer climates. Wastewater is frequently contaminated with rat urine, and therefore potentially contains *Leptospira,* which may infect wastewater treatment workers.

Proposals for OSH prevention in waste management and wastewater treatment

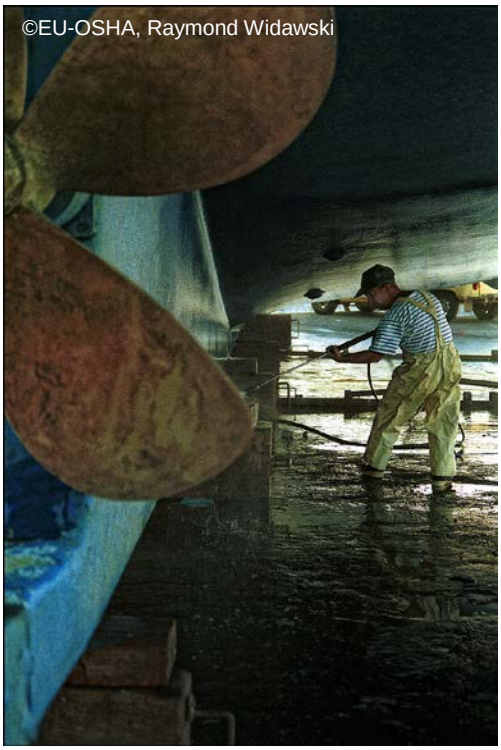
Many microorganisms and substances generated by them may affect workers in the sector, and their identification through workplace risk assessment may be difficult because of the variable nature of waste and wastewater and their composition. However, there are some tools available that provide guidance for workplaces and information on common exposure situations, for example the German rules for biological agents in the waste and wastewater management sectors (ABAS/BAuA 2010; ABAS/BAuA 2018) and the German GESTIS database (DGUV, 2017), which provides information about potential exposures and prevention measures (Förster, 2017).

- **Waste collection and treatment**

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 step-by-step 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.

As regards household waste, owing to an increase in the separation, different ways of storing waste and the less frequent collection of waste may have an influence on the exposure of workers to biological agents. Every step in the process should be considered when preventive measures are set to avoid exposures to workers. Consecutive steps to consider might be, for example, (1) the separation of waste in a household, (2) the collection of household waste by waste collectors and (3) the processing of household waste. Risks can relate to, for example, decreased frequency of waste collection, due to developments in the separation/recycling of waste and changes in how waste is stored. In the Netherlands, for example, household waste is increasingly separated at home where it is divided into smaller amounts to be collected from homes or taken to central waste storage facilities. This development increases the risk of exposure for workers collecting and handling the waste because the conditions of storage are generally optimal for the growth of microorganisms, and microorganisms have more time to grow. Where waste is collected/stored in central storage containers (mostly urban areas) instead of at people's homes it is generally collected more frequent and waste collection can be planned more efficiently.

New waste treatment plants are being built in Finland in which workers are separated from the waste stream in the treatment process. This may serve as an example of best practice. Technological innovations such as the use of robots for certain parts of the process — already common in green waste processing (e.g. composting) — are another possible solution to separate workers from waste and thus reduce their exposure to biological agents.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Another option would be to process some waste locally (i.e. at home). An example of this would be the use of a home waste management system that makes it possible to dispose of biodegradable plastic products using a cruncher connected to the local sewage system, where solid waste and wastewater are separated, and water is filtered.

An important issue in the waste treatment sector is that waste is often treated in open spaces in which aerosols are present. It is more difficult to contain biological agents in open spaces than it is in waste treatment facilities, where waste treatment processes are often much more contained and therefore more controllable. The focus in the waste treatment sector should therefore be on open spaces, where the risk is considered the highest (stakeholder workshop).

A life-cycle approach is also recommended as a general measure. Since the waste treatment sector is generally at the end of a value chain, certain risks that occur during waste treatment may be better tackled earlier in the chain. An example of these sector-transcending risks is needlestick injuries during the collection and sorting of waste: pharmacists and distributors could (better) inform consumers who buy needles of how to dispose of them without risks to both themselves and waste treatment workers. This would result in fewer accidents with sharp objects during waste handling and thus reduce the risk of infection with blood-borne viruses among these workers.

- **Training**

Because of the general lack of awareness and knowledge in this sector, wide-ranging training on the risks of exposure to biological pathogenic agents for OSH experts at company level (e.g. health and safety committee members) is warranted, as would highly specialised training for waste treatment workers, to inform them of the type of risks they face when handling a specific type of waste. It is also important to ensure sufficient information and training for temporary or external staff who are hired through subcontracting companies. One suggested measure is offering a course to workers when they first start their job, one that would instruct them on the (biological) risks related to waste treatment with specific reference to new employees (identified as a vulnerable group).

More information on preventive measures applicable to the waste treatment sector is presented in the OSHwiki article 'Exposure to dangerous substances in the waste management sector' ([5]).

Wastewater treatment

The prevention measures for the wastewater management sector should follow the hierarchy of control measures and prioritise technical over personal protective measures. Constructive measures should have been implemented in the planning phase of the plants to avoid the formation of bioaerosols in wastewater plants. In particular.

As in waste treatment, in addition, general hygiene measures are recommended in wastewater treatment and maintenance and repair of wastewater and sewerage installations. These include storage for work clothing separate from street clothing, including shoes, procedures for washing hands and separation of rest and work areas, as well as guidelines for storage and cleaning of work clothing. PPE should be stored separately and PPE should be provided to workers where exposure cannot be avoided or is to be expected. One policy is the so-called black and white policy, which sets out rules for separating black (contaminated) areas, equipment, and clothing from white (clean, non-contaminated) ones. Appropriate washing facilities should also be provided to workers.

Maintenance and cleaning are regarded as particularly dirty tasks in this sector and bear a high risk of exposure, although they are routinely applied in this sector. Risk assessment and prevention measures need to include these tasks and set out specific measures for them. To prevent gastrointestinal illnesses, for example, ,guidelines on sewage handling in some Member states, such as Denmark, include recommendation to avoid bioaerosol formation for example not using high-pressure water for cleaning.

Another measure to avoid infections are vaccination programmes for wastewater workers, which have been implemented in France against leptospirosis and in Denmark to prevent hepatitis and tetanus.

Conclusion

It is clear that workers in waste treatment and wastewater treatment are exposed to a variety of risks due to unintentional exposure to bacteria, viruses and fungi and their constituents as well as potential exposure to bioaerosols and organic dust. These exposures can lead to infections, irritative and toxic effects, as well as allergies and a range of other effects such as nausea or gastrointestinal disorders, or even immunological effects. Diseases that frequently occur in waste collection workers are asthma and hepatitis infection. Wastewater workers are at particular risk of legionellosis and leptospirosis. Cleaners and maintenance workers in waste treatment and wastewater treatment are vulnerable groups; another group at risk is temporary and subcontracted workers. Immunosuppressed workers may also be at risk as they may be potentially exposed to a broad range of (unknown) biological agents. Emerging issues that may lead to increased risk are increases in waste separation in households promoting the growth of mocroorganisms, combined exposure (mixtures), increased risk of contracting leptospirosis due to climate change and the potentially increasing exposure to biomass-related allergens in a greening economy. In addition to a number of specific technical measures following the hierarchy of prevention measures set out in OSH legislation (e.g. eliminating risk by separating workers from waste in recycling plants to avoid exposure and specific hygienic measures such as the separation

([5]) https://oshwiki.eu/wiki/Exposure_to_dangerous_substances_in_the_waste_management_sector

of contaminated and non-contaminated work areas, equipment and clothing (black-white policy)), policy measures identified in this research include vaccination programmes, targeted awareness-raising, training and instruction programmes, and a life-cycle approach that takes into account new ways of collecting waste. To reduce the risk of infection from biological agents, it would be helpful if sector-specific OELs could be derived, taking into account the distinct groups of waste treatment workers and wastewater treatment workers and the particular risks they are exposed to.

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