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BIOLOGICAL RISKS IN THE WORKPLACE: STATE OF KNOWLEDGE – INTERNATIONAL CONFERENCE ON BIOLOGICAL RISKS HELD BY INRS

The responses to the Sumer 2017 survey indicate that 19.3% of workers consider themselves exposed to biological risks within the context of their jobs. The biological risks conference held in Nancy from 5 to 7 June 2019 brought together more than 200 participants from about twenty countries. Speakers reviewed these risks in the occupational environment, with four successive sessions addressing the effects of biological agents on the health of exposed workers, the methods and strategies for the qualitative and quantitative assessment of biological risks, the characteristics of exposure at workstations, and the preventive measures that can be implemented to reduce exposure. This article summarises the content of the oral contributions.

Nancy, France, 5 to 7 June 2019
Report on the "Biological Risks" conference organised by INRS

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**Contributions: Catherine Aubry, Sarah Burzoni, Benoît Courrier, Patricia Dirrenberger, Marie-Cécile Bayeux-Dunglas, Valérie Demange, Louis Laurent, Jean-Pierre Leclerc, Ronan Levilly, Pauline Loison, Sophie Ndaw, Xavier Simon, Isabelle Sponne (INRS).*

Effects of biological agents on the health of workers

Jean-François Gehanno (CHU Rouen) presented a review of the literature on infectious risks.

Healthcare personnel are particularly exposed to inter human transmission of viral and bacterial diseases (such as tuberculosis). Other workers that are also highly exposed include technicians performing biological analyses, in particular due to aerosolisation of microorganisms during routine operations.

People working in contact with animals (domestic, wild, farmed) are also at risk, as various microorganisms are transmissible between animals and humans.

Among the studies mentioned, several related to leptospirosis and Lyme disease. This review was completed by Isabelle Thaon (CHU Nancy), who spoke about immuno allergic and toxinic risks. Allergens (proteins, fungal species, bacteria), to which workers are exposed in the workplace can lead to a reaction of the immune system causing hypersensitivity pneumonitis, which is revealed by symptoms such as coughing or a sensation of difficulty breathing. Numerous cases of hypersensitivity pneumonitis have been observed in certain professions. For example, the food and agriculture sector is often mentioned, in particular in relation to "Farmer's lung" or "Cheesemaker's lung".

However, this is not the only sector concerned, and cases have been reported elsewhere (e.g., linked to contaminants of cutting oil in the mechanics industry, or in professional wind instrument players).

In addition, in the agricultural sector, in the population exposed to dusts containing organic matter, toxic syndromes linked to exposure to organic dusts have been observed. These syndromes emerge a few hours after exposure in the form of respiratory and flulike symptoms. Unlike the case of hypersensitivity pneumonitis, x-rays of the lungs or spirometry to explore respiratory function, reveal no anomalies *(See. 1 - For further information*).

Élisabeth Bouvet (HAS, University Paris-Diderot) presented the latest available data and the perspectives related to biological risks in healthcare workers. Thus, in industrialised countries, the risk of blood-borne transmission of the AIDS or hepatitis B and C viruses has strongly decreased, following the reduction of accidents exposing healthcare workers to blood, linked to the application of standard precautions, the use of protective materials, the availability of postexposure treatment, and vaccination to prevent

hepatitis B. In addition, thanks to effective treatments, patients present less of a contamination risk. While the risk of tuberculosis appears to be under control in the same countries, vigilance should nevertheless be maintained, given the multiple resistance to antibiotics of certain imported cases (1 to 2% of cases declared in France).

Influenza and measles need to be taken seriously, in particular by encouraging better compliance with vaccination programs of all healthcare professionals and the general public.

Dominique Abiteboul (INRS) reviewed cytomegalovirus (CMV) infection in those working with small children. This infection is often benign, but is of concern in immunosuppressed individuals and pregnant women. It corresponds to the most prevalent congenital infection in economically developed countries. A literature review revealed that in an occupational setting, women working in contact with young children have a higher risk of contracting a CMV infection. The only consensus recommendations are strict compliance with hygiene measures, and providing information to pregnant women. Screening for CMV infection is not recommended for the general public or as part of occupational monitoring, as the French authority on public health (Haut Conseil de santé publique) recalled in 2018.

Gaëtan Deffontaines (CCMSA) presented the recommendations of a group of experts who met at the instigation of the Central French Agricultural Mutual Benefit Society (Caisse centrale de la mutualité sociale agricole) in 2018, relating to the medical monitoring of workers following exposure to bovine tuberculosis. Following the implementation of sanitary measures, the prevalence of bovine tuberculosis foci in French farms fell below the threshold of 0.1% in the 1990s. This prevalence has been on the increase for around 15 years, but the incidence of human cases of tuberculosis linked to *Mycobacterium bovis* remains very low in France. The measures implemented relate in particular to medical monitoring after exposure to an animal reservoir in bovine herds, abattoirs or in the hunting sector. For the exposed workers, given the low transmissibility of *M. bovis* to humans, there is no indication for screening during individualised medical monitoring, nor for preventive vaccination.

In one part of her presentation, Caroline Herr (Bavarian Health and Food Safety Authority) described a certain number of emerging risks which merit particular attention. In particular, she cited: exposure to Legionella in systems using water (such as vehicle washing stations), contamination by wild animals, open-air storage areas for materials destined for recycling, and the propagation of antibiotic-resistant bacteria in the animal husbandry sector.

Methods to qualitatively and quantitatively assess biological risks

Measuring exposure

Anne-Mette Madsen (NRCWE, Denmark) drew up a current state of knowledge relating to methods to quantitatively evaluate exposure to biological agents. The most common measurement methods rely on sampling by filtration and analysis of the culturable bacteria and moulds, as well as of the endotoxins present. These measurements are then used to objectively document exposure of workers in a large number of activity sectors. The identification of microorganisms present in the air in workplaces has become easier thanks to the emergence of new – faster and more exhaustive – technologies, such as Maldi-Tof mass spectrometry and high-throughput DNA sequencing, combined with bioinformatics analyses. Similarly, qPCR analysis [1] using specific oligonucleotides can be employed to quantify target microbial taxons. In the context of assessing exposure, it is also important to have access to data on the viability and growth capacity of microorganisms, as well as on their inflammatory properties. In all cases, the results of various approaches (concentration measurements, identification, inflammation markers, and deposition of particles in the airways) should ideally be combined with data on the occurrence of respiratory problems, nausea or diarrhoea to understand the complexity of exposure to bioaerosols in occupational environments.

Caroline Duchaine (Quebec Heart and Lung Institute, Canada) provided complementary information on methods to measure bioaerosols. The standard technique is the culture method, which should be favoured if results are to be compared to historical data. Recently, molecular techniques have emerged, such as qPCR, aiming to analyse the nucleic acids contained in the aerosols. These techniques make it possible to detect non-culturable species, to obtain results on mass samples in a short timeframe, and to better understand the composition of an aerosol. In contrast, minority taxons may not be detectable and the various physiological states of the microorganisms (dead, living, dormant, etc.) cannot be differentiated. In practice, the two techniques – culture and molecular biology – are complementary. The speaker drew attention to how the results of an analysis of bioaerosols are influenced by various

experimental choices: the sampling technique (liquid), the method to extract nucleic acids, the choice of primers for DNA amplification, the bioinformatics analysis, etc.

Caroline Herr (Bavarian Health and Food Safety Authority) spoke about the risks linked to bioaerosols in the workplace. The methods and tools to measure exposure must be improved: measurement protocols that are representative of the profile and duration of exposure, standardised assay methods, new analysis methods, etc. Her review of the literature also revealed a lack of standardisation in how health effects are measured. Once these difficulties have been overcome, it may be possible to establish exposure thresholds based on dose-response relationships.

Advances in and performance of methods

Clara Pogner (CHB, Austria) discussed to what extent tests carried out in the controlled conditions in the laboratory, in confined experimental chambers, could contribute to the assessment of new systems for the quantitative detection of bioaerosols. Various methods (counting under microscope, Mycometer, and culture) were implemented to quantify fungi in bioaerosols generated from mixed cultures containing three different species (*Aspergillus brasiliensis, Cladosporium sphaerospermum, Penicillium rubens*). The results underlined the usefulness of laboratory approaches to examine the characteristics of the methods used to measure bioaerosols, but validation in real-life exposure conditions remains necessary.

The latter point was reinforced by the work presented by Xavier Simon (INRS, France), relating to the comparison of sampling methods on closed filter cassettes (CFC) [2] to methods involving liquid-phase biocollectors, to measure concentrations of culturable microorganisms. Comparative measurements were performed at fixed points in four occupational atmospheres presenting varied concentrations and microbial biodiversity. The results suggest the relevance of a filtration method such as CFC when seeking to measure concentrations of culturable fungi (hydrophobic spores that are resistant to environmentally-induced physiological damage). The concentrations of culturable bacteria measured by liquid phase biocollectors were close to or lower than those obtained with CFCs.

Two communications related to the comparison of two methods to assay endotoxins: the Limulus amaebocyte lysate (LAL) kinetic chromogenic test, and the recombinant factor C (rFC) method. Tests were performed on samples collected in companies. The data presented by Annette Kolk (IFA, Germany) correspond to around 850 samples analysed between 2007 and 2017. They revealed differences between the measurements performed using the two methods. In particular, there were variations depending on the sectors investigated; variations mainly appeared if the endotoxin concentrations were high with the two methods. Verena Liebers (IFA, Germany) presented the results from analysis of around 130 samples, and completed her study with laboratory tests. The latter indicated a significant correlation between the two methods, but the author underlined that the comparison of results obtained with the LAL and rFC methods could be misleading, because the concentration levels measured for the same sample may be different from one method to the next.

On this same subject of endotoxins, Olivier Schlosser (Suez, France) presented a study aiming to establish whether the concentration of inhalable dust particles could be an indicator of the airborne endotoxin concentration, and whether it could contribute to the assessment and management of risks linked to endotoxins. Measurements were performed in two waste-treatment sectors: composting of solid residue from water treatment plants (8 sites, 110 samples), and heat-induced drying of solid residues (8 sites, 81 samples). The results indicated that the level of dusts represents a highly significant determinant factor in the endotoxin concentration in the sectors investigated.

Thus, measurement of dust levels could efficiently help to select the preventive measures to implement to deal with risks linked to exposure to endotoxins in the occupational activities considered in the study. In contrast, measuring dusts cannot replace measurements of endotoxins in an approach assessing the risks, and the specific measurement of endotoxins remains necessary to assess exposure during composting and drying of solid residues.

The work of Carla Viegas (H&TRC, Portugal) showed that biomonitoring constitutes an alternative means to assess exposure to mycotoxins. This approach consists in detecting the parent compound (mycotoxin) and its metabolites in readily accessible biological fluids, such as blood or urine. The author presented data from several research projects undertaken in various occupational environments.

Her results indicated that exposure to mycotoxins can occur via the digestive route, and via other routes, and in specific occupational environments. Biomonitoring can help to reveal several relevant aspects of exposure, in particular the most common mixtures and the role of the occupational environment in total exposure to mycotoxins.

Assessing biological risks

In relation to the assessment of biological risks, Sarah Burzoni (INRS, France) presented a review of current knowledge and critically analysed the main approaches available for the qualitative assessment of biological risks in an occupational setting. To date, no approach integrates all the parameters required to perform a full assessment of biological risks. Nevertheless, this work allowed the author to define the components of an "ideal" approach. Our own experience on the implementation of a method to quantitatively assess biological risks in a company was proposed by two security coordinators working in a French group (Sanofi, France): Corine De Souza and Corinne Le Caër. They presented an assessment method adapted to Research and Development activities, which was implemented homogeneously across different sites. This risk assessment included several stages, which require a good understanding and description of the work activities undertaken, the biological agents manipulated and their mode of transmission, the preventive and protective measures applied, the frequency of exposure, the probability of occurrence of an accident scenario, etc. A computing tool, shared across the group, made it possible to record all of the modalities of this assessment, and to automatically calculate the risk score.

Stefan Mayer (BGHW, Germany) then presented a pragmatic method to assess biological risks, based on the analysis of exposure to bioaerosols in the workplace. This method relies on the fact that the risk increases with the level, duration and frequency of exposure. To rank the level of risk, he suggests using a table which integrates three levels of exposure ($< 10^5$, between 10^5 and 10^6, $> 10^6$ CFU/m^3 for culturable fungi; and $< 10^3$, between 10^3 and 10^4, $> 10^4$ EU/m^3 for endotoxins), with three exposure durations (short, medium, and long). Finally, Udo Jäckel (BAuA, Germany) provided elements for reflection on the contribution of quantitative measurements of exposure to bioaerosols when assessing biological risks. He underlined that the measurement methods available provide definitive elements on the levels to which workers are exposed to microbial entities. In contrast, the data collected provide no information on the risks linked to these exposures. Progress, which is still necessary in terms of the characterisation of exposure (frequency, duration and level) and on the measurement methods and strategies (analysis of microbial compounds, quantification of specific groups, and study of biodiversity), was evoked from examples derived from research undertaken in his Institute.

The session was also marked by the presentation of studies relating to the toxicology of microbial metabolites. Stefanie Klar (BAuA, Germany) presented an *in vitro* model to study the toxicity of bacterial metabolites. The methodology, based on real-time measurements of viability and cellular integrity by impedancemetry, was performed on a human lung cell line (NuLi1 strain) exposed to several bacterial strains, producing toxins or not. The results presented confirmed the relevance of the model and the analyses of impedancemetry and viability when assessing the toxicity of bacteria that may be present in an occupational setting. In addition, this method is transferable to other occupational bioaerosols.

Occupational exposure to biological agents

Knowledge of the biological agents present in the workplace, and to which workers are likely to be exposed, is essential for a better understanding of exposing situations, to assess risks, and to implement prevention strategies. Philippe Duquenne (INRS) introduced the session on the characteristics of bioaerosols at workstations by reminding listeners how much our understanding of exposing situations is key to the management of biological risks. The presentations were the occasion to review knowledge on the properties of bioaerosols and the factors influencing these properties. Data have been published for a broad range of activity sectors. The levels of contamination of work atmospheres and individual exposures are the best documented. Knowledge of the bioaerosol composition in terms of species and size distribution has progressed in recent years, but still requires development. Similarly, factors influencing exposure remain to be determined and, in general, we need to better understand exposing situations so as to manage the associated biological risks. It should be remembered that no OEL exists to interpret measurement results.

Although pragmatic guide values have been proposed (e.g., 200 and 1,000 EUculm^3 for endotoxins in France), there is no international consensus. The perspectives relating to the continuation of studies aiming to acquire a better understanding of this exposure, taking

into consideration multiple exposure and the possible consequences of various phenomena, such as the progression of antibiotic resistance or global warming.

The subsequent oral communications addressed several current topics. The presentation of the results of the Sumer survey (Medical monitoring of exposure of workers to occupational risks [3]), by Sigolène Morand and Sarah Memmi (French Labour Medical Inspectorate/Inspection médicale du travail – Dares, France), revealed an increase in the proportion of workers indicating they were exposed to biological agents between 1994 and 2017. This progression is particularly marked in the case of potential exposure ("*biological agents either are part of the activity itself, or are linked to the environment in which it takes place*"), compared to "deliberate" use ("*the industrial process requires the use of biological agents*"). One possible interpretation of this progression is that the biological risks are increasingly known by occupational health and safety prevention officers, and that workers are better able to identify them in companies. The responses to the survey also indicate that protective measures have improved. Nevertheless, numerous exposing situations persist, for which the measures implemented are not appropriate, even in the case of "deliberate" use. In any case, the results of the surveys can be used to define the populations of workers for which preventive actions appear to be necessary ("green" professions, homeworkers, etc.) and also to provide clear options for prevention.

Michèle Tremblay (Direction régionale de santé publique de Montréal, Canada) presented a study on monitoring of accidental occupational exposure to biological fluids, undertaken in Québec between 1999 and 2018 among municipal workers. The study exploited data produced from a questionnaire aiming to assess the postexposure risk and the prophylactic measures implemented to prevent exposure of workers to biological fluids. Over 14,000 cases were assessed. The study allowed the development of a project, with a view to identifying the municipal professions that were most at risk of contamination by pathogenic agents so as to reinforce the corresponding preventive messages. A similar approach should be undertaken in the healthcare sector, where greater risks exist.

Anne Straumfors (Stami, Norway) described exposure to moulds in the Norwegian cereal industry. Measurements were obtained from samples of air at fixed positions, collected for the duration of work shifts. The use of high-throughput sequencing (molecular biology approach) allowed the fungal biodiversity to be characterised.

The spatiotemporal variability was explored by performing measurements on three climatically distinct sites over two seasons (winter and autumn). Strong seasonal and climatic variations in the fungal communities were observed, with some taxons being more specific to certain seasons and climatic regions.

This first broad-spectrum image of fungal species observed at the workstation in the cereal industry opens numerous perspectives for future studies.

Sophie Ndaw (INRS) presented a study relating to the biomonitoring of exposure to mycotoxins in workers in installations where grains are stored. Her team developed a method to analyse mycotoxins and their metabolites in urine, based on liquid chromatography coupled to high resolution mass spectrometry (LC-HRMS) after a hydrolysis step. The feasibility and performance of the method were then assessed on workers' urine samples. The results of the field study indicate that the most frequently detected contaminants are the mycotoxins deoxynivalenol (vomitoxin) and zearalenone (F-2 mycotoxin), as well as ochratoxin A. Aflatoxin B1, fumonisin B1, T-2 toxin and HT-2 toxin, are the most rarely detected mycotoxins. However, co-exposure is frequent in the sector investigated. Application of the method in the context of large-scale assessment studies will provide realistic exposure data for mycotoxins in an occupational setting.

Patricia Dirrenberger (INRS) presented the results of six measurement campaigns performed in five units of methanisation-composting located in France. The results revealed contrasting situations between companies, and within the same company, from one post to another. The ambient concentrations measured were between < 20 and 3000 EU/m^3 for endotoxins, between < 1x10^3 and 3x10^6 CFU/m^3 for mesophilic culturable bacteria and fungi, and less than 0.1 to 25 ppmv for ammonia. The study showed that 16% and 13% of individual exposures measured across all sites exceeded 10^6 CFU/m^3 for culturable mesophilic bacteria and fungi, respectively; 7% exceeded 10 ppmv for ammonia. At certain workstations, confirmed multiple exposure was observed.

The presentation by Dierk Poether (BAuA, Germany) on this same activity sector supported these concentration values. His presentation provided data relating to the biodiversity of the bioaerosols emitted in the companies visited, showing a dominance of

genre belonging to the *Bacillales* or *Lactobacillales* taxons for eubacteria (analysis of 16S rRNA sequences), and the *Aspergillus* and *Penicillium* genre for fungi.

In terms of occupational risk, attention was drawn to the fungal biodiversity and its variation over time in the waste methanisation sector.

Anne Oppliger (Unisanté, Switzerland) presented a study performed in Swiss pig farms. The aim was to study the influence of close contact between farmers and pigs, based on analysis of their nasal microbiota. Exposure was assessed using samples collected by nasopharyngeal swabbing, for two distinct families of microorganisms (moulds and bacteria). High-throughput sequencing was used to characterise exposure to bacterial communities. A novel "*single health*" approach was adopted: nasopharyngeal swabs were performed on pig farmers and animals, combined with sampling of the air at a fixed point.

The measurements performed revealed that the pig farmers had a greater microbial diversity than control individuals (who are not in contact with pigs). In addition, they presented a microbiota that was closer to that of the pigs and the air in the workplaces than microbiota for cow farmers or non-exposed populations.

A seasonal influence was also observed in the composition of the samples collected in farms.

Carla Viegas (H&TC, Portugal) reported on work relating to a study of the cork industry in Portugal. The fungal species in nasal samples were characterised by two analytical methods: culture and a molecular biology approach. In the latter case, the DNA from fungal species, known to cause hypersensitivity pneumonitis was specifically amplified by PCR. These two complementary approaches provided a more complete image of the nasal microbiota of these workers.

Prevention of biological risks in an occupational setting

Decontaminating air and surfaces

The means of protection with respect to aerosols containing infectious agents were discussed by Sergei Grinshpun (University of Cincinnati, United States). The main strategy consists either in treating the aerosol to destroy the microorganisms transported by it, or in eliminating the aerosol by filtration.

With respect to procedures to destroy microorganisms, the most effective include UV irradiation – which is relatively powerful, but has limits, such as loss of efficacy when the air is too humid or is displaced too rapidly – and thermal treatments. It should be noted that some microorganisms are present in the form of highly resistant spores which may require temperatures of around 400 °C to inactivate them. The other procedures, such as ozone treatment, photocatalytic oxidation, ionisation of the air, or microwaves, provide insufficient results. The presenter also discussed research aiming to inactivate a cloud charged with dangerous biological agents released for malevolent purposes. The principle consists in injecting a compound into the cloud that is capable of releasing a large amount of energy and also of producing biocidal compounds, e.g. an iodine/aluminium mixture.

With regard to procedures based on filtration, the speaker addressed two questions relating to masks:

• Procedures to certify their efficacy. He underlined the importance of taking into consideration the mask as a whole and not just the filter element, so as to account for leakage between the mask and the skin. To perform this type of certification, a mannequin has been developed linked to a pump simulating breathing. The speaker described masks with an improved design which increased airtightness at the level of the skin;

• The capacity of the filter to retain or eliminate biological agents. There are various methods, based on the incorporation of biocidal substances in the filter, the use of microwaves (or even a microwave oven), or infrared sources, or even electrical charging of the fibres, if the aim is to eliminate a virus.

The subsequent presentations provided further enlightenment on these questions. Alan Beswick (HSL, United Kingdom) addressed the issue of procedures to decontaminate surfaces, often implemented with a view to reducing workers' exposure to infectious microorganisms. In particular he presented studies relating to the performance of methods used to decontaminate laboratory equipment (ozone treatment, formaldehyde-based fumigation, hydrogen peroxide treatment, etc.). These studies indicate that fumigation remains necessary in certain work situations and that such treatments are possible, with new less voluminous and cheaper systems. It is essential to validate the efficacy of each system with respect to the target microorganisms, using appropriate microbial models and realistic test scenarios. Deterioration of the material due to application of biocidal substances should also be

taken into account. These data were completed by Marie-Ève Dubuis (Université Laval, Canada) who presented her research on the inactivation of airborne viruses using ozone. Ozone is a gas with a significant disinfectant power in water and the study aimed to investigate the effect of the gas concentration and the relative humidity (HR) of the air on model viral aerosols produced in the laboratory. The first tests, undertaken using for model phages (Phi6, PhiX174, PR772 and MS2) at an ozone concentration of 1.13 ppm, were used to validate the exposure system; they also showed that the most extensive inactivation occurred with a HR of 85%. Other tests, undertaken with the murine norovirus (MNV-1), showed a combined effect of the ozone concentration, the relative humidity, and the duration of exposure on virus inactivation. The experimental system developed provides information to improve knowledge relating to the effect of ozone on the inactivation of airborne viruses and opens promising perspectives for the assessment of the performance of air decontamination methods in general.

Respiratory protective equipment

The selection and adjustment of respiratory protective equipment (RPE) was discussed initially by Marie-Cécile Bayeux (INRS). The importance of selecting masks adapted to the shape of the face and their correct adjustment was shown. Unfortunately, today many hospital centres only stock a single model of mask, and no adjustment tests are performed. It would be useful to help institutions to choose appropriate models in line with the morphology of their healthcare workers. We can also ask the question of the availability of a simplified test protocol, to take into account the constraints in care institutions, and to encourage the performance of an adjustment test for healthcare workers looking after patients with inhalation-transmissible infections.

On this same theme, Alex Birrel (*Clean Space Technology Pty Ltd*) presented a new type of assisted ventilation RPE, equipped with a system to continuously verify the quality of the adjustment, performing 100 measurements of the pressure per second. The performance of this RPE is quantified in the form of an experimental correlation, between the variation in pressure inside and outside the mask and the values of a *fit test* [4] using a particle collector.

Examples of measures deployed in companies to prevent biological risks

The end of the session was devoted to the presentation of three examples of implementation of measures to prevent biological risks. Isabelle Balty (INRS) presented a study involving workers attaching poultry to conveyor systems in around 15 abattoirs, so as to measure their exposure and in parallel assess the aeraulic characteristics of the zones where this step in meat processing is performed. Indeed, attachment generates dusts contaminated by bacteria in the air in work areas. Inhalation of these dusts can affect the general health status of the workers, leading to respiratory symptoms such as infections (ornithosis), inflammatory effects, acute respiratory symptoms, and irreversible alterations of the respiratory function. The results of the measurement campaigns indicate exposure levels often exceeding 5 mg/m$_3$ for inhalable dusts and several thousands of EU/m^3 for endotoxins. These levels of exposure require the implementation of preventive measures in the work areas considered.

The study allowed the identification of appropriate preventive techniques and also suggested approaches to sensitise and inform the workers both with regard to the biological risks, in particular ornithosis, and on the steps to take if symptoms occur (see Find out more).

In waste-sorting centres, in real-life situations, Brigitte Falcon (Cramif) showed that preventive measures were sufficient to strongly limit exposure to biological agents, and in particular to bioaerosols. The recommendations included:

• Reducing the time that waste is stored and improving the quality of the storage areas, so as to limit microbial proliferation;

• Limitation of dust dispersion, by confining emission sources (hoppers, conveyors, bins) and localised capture, improving ventilation and work organisation, as well as providing operator training.

In a similar sector, Christine David (INRS) addressed the theme of potentially infectious medical waste (PIMW) which is dealt with in a dedicated treatment line. Nevertheless, PIMW can be found in centres where household waste is treated, where it can lead to pricks or cuts in workers. Increasing the visibility of PIMW on manual sorting belts, regulation of the flow of waste to be sorted, training of operators to recognise this type of waste, and implementation of a procedure in case of discovery of a PIMW can help to reduce the risks associated with this type of waste.

Conclusion

At the end of the conference, Louis Laurent and Philippe Duquenne (INRS) wished to recall a few major points evoked on several occasions during the presentations.

Biological risks are shared by numerous activity sectors. They are as old as human activity, in particular in the food and agriculture, care, and waste treatment sectors. To these "historic" risks, which are still clearly present, must be added more recent concerns, such as the effect of climate change, the increase in power of "green professions", the development of antibiotic resistance, and the emergence of new diseases.

Biological risk is distinguished from chemical risk by a certain number of characteristics. Its perception in companies is progressing but remains insufficient. This is due to various factors, such as the "natural" nature of certain sources of exposure, the fact that the effects of biological agents may go unnoticed or not be attributed to the exposure, to the sometimes unexpected nature of the contaminants, to the absence of a clearly established dose-effect relationship. Thus, the link between exposure and effects on health remains complex. Although in many presentations, measurements of exposure were considered, it remains difficult to define occupational exposure limits, on the basis of studies of the dose-response relationship. In terms of prevention, most frequently occupational monitoring is based on comparisons between mean exposure values in an activity sector.

It is in this context that a certain number of presentations described methodologies to assess the risk, when biological agents are present.

Assessment of exposure is a very active area of study, with the inherent difficulties linked to the variety of biological agents present and the variability which characterises living systems. Various studies related to methodological developments aiming, if not to standardise measurement methods, at least to better understand the differences between the results obtained by different techniques. Thus, several presentations dealt with assays for endotoxins, methods to sample biological agents, culture- or DNA-based analysis tools. Particular emphasis was placed on molecular biology tools. While traditional methods, based on the capacity of microorganisms to develop in culture remain the standard to assess exposure to biological agents, molecular tools have shown advantages for the characterisation of exposure to microorganisms, and for the analysis of their biodiversity. These methods can provide rich pickings when seeking to characterise the origin of exposure.

This conference was also the occasion to discuss prevention practices in occupational settings or technical developments to reduce exposure. In general, given the complexity of biological risks, a systemic approach is necessary.

Optimisation of activities to reduce exposure, the adoption of good practices to avoid contamination in the healthcare sector (linked to the patient and to the treatment of contaminated waste), vaccination in the case of identified infectious risk, the use of technical measures to eliminate or neutralise infectious agents, should all be taken into consideration.

1. Quantitative PCR (qPCR), or real-time PCR, is a specific polymerase chain reaction method which can be used to measure the initial quantity of DNA in a given sample of microorganisms (source Wiki).
2. With respect to "closed cassette" sampling: see the article (technical note) on this subject in the previous issue of this journal.
3. In relation to the SUMER 2017 survey, see: Références en santé au travail, Sept. 2019, 159, pp. 53-78.
4. The "fit test" is an adjustment test, the aim of which is to verify – based on common work scenarios – whether the mask is well adapted (shape, size, etc.) to the morphology of the person wearing it.

FOR FURTHER INFORMATION

1. Paris C. — Le syndrome toxique des poussières organiques. [Organic dust toxic syndrome] *Références en santé au travail*, 2014, 140, TR 57, pp. 109-124.
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2. Balty I. *et al.* — Étude de cas : exposition aux poussières émises par les volailles aux postes d'accrochage en abattoirs. [Case study: exposure to dusts emitted by poultry at attachment posts in abattoirs.] *Hygiène et sécurité du travail*, December 2017, 249, pp. 72-76. Accessible through: www.inrs.fr
3. Duquenne P. *et al.* — Dossier : les risques biologiques au travail. [Biological risks in the workplace] *Hygiène et sécurité du travail*, September 2018, 252, pp. 22-52. Accessible through: www.inrs.fr (HST journal).