

Biological Risk and Occupational Health

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Abstract: Many work activities include hazards to workers, and among these biological risk is particularly important, mostly because of different types of exposure, contact with highly dangerous agents, lack of limit values able to compare all exposures, presence of workers with defective immune systems and therefore more susceptible to the risk. Bioaerosols and dust are considered important vehicles of microorganisms at workplaces and interaction with other occupational agents is assumed. Moreover, biological risk can be significant in countries with increasing economic development or particular habits and some biological agents are also classified as carcinogenic to human. Specific emerging biological risks have been recently pointed out by Risk Observatory of the European Agency for Safety and Health at work, and we must consider the worker's attitude and behaviour, influenced by his own perception of risk more than his real knowledge, that could over-underestimate the risk itself. Therefore, biological risk at work requires a complex approach in relation to risk assessment and risk management, made more difficult due to the wide variety of biological agents, working environments and working techniques that can determine the exposures.

Key words: Biological risk, Workplaces, Occupational medicine, Risk perception, Risk assessment

Introduction

Exposures to many risk factors are possible in workplaces. Occupational diseases can be caused by chemical, physical, biological and ergonomic risks and accidents can be caused by structural factors or incorrect procedures and maneuvers. Traditional risk factors, such as biological agents, still cause concern in workplaces, despite the advent of modern technologies, such as laser systems and other electromagnetic sources^{1,2}.

Modern Occupational Medicine pays constant attention to biological risk, with reference both to its assessment and its management. Such an interest is based either on the scientific progress in the field of infectious diseases, which

can increase the knowledge of the hazard, or on the high number of workers potentially exposed to it, including students in scientific faculties.

There are actually many professional activities involving a biological hazard in various fields (health care, agriculture, forestry, zootechny, food, veterinary, biotechnology, treatment and waste disposal), even if infectious agents, endotoxins and ways of exposure show differences related to the type of work and way of exposure.

Intentional and deliberate use of biological agents is involved in various workplaces (such as microbiological laboratories) and occupational exposure can be easily monitored and controlled. On the contrary, risk assessment is difficult in case of unintentional exposure in workplaces (such as agricultural activities) and exposure prevention and protection measures can be inappropriate. In addition, we must consider the spread of new pathogen agents, such as SARS and avian flu recently, issues involving not only public health but also occupational medicine, and

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bioterrorism which requires biodefence, even vaccination, for all the exposed subjects^{3,4}.

Exposure to bioaerosols is considered very dangerous in workplaces. Bioaerosols contain a variety of airborne microorganisms, including moulds and endotoxins, and various inflammatory and allergic diseases in exposed workers are attributed to their inhalation. Risk assessment presents many difficulties and is also influenced by the possible interaction of microorganisms with non-biological agents in working environment. Also the effects can be influenced by the interaction with other factors acting on the same target organs and mechanisms operating simultaneously are not known.

Workers may be also involved by inhalation of dust containing biological agents and particles size is an important determinant of fraction deposited in various regions of the respiratory system. In fact, the sedimentation of dust in airways is influenced by particles' aerodynamic diameter and particles are currently divided into inhalable fraction, thoracic fraction and respirable fraction. Particularly, occupational exposure to grain dust is documented in employees of grain and animal feed industries and occupational exposure limits are recommended in various countries⁵.

In substance, occupational exposure to biological agents in workplaces is associated with very different diseases, such as infections, chronic obstructive pulmonary disease (COPD), acute toxic effects, allergies and fetal harm. Actually, some biological agents are also classified as carcinogenic by International Agency for Research on Cancer (IARC). Exactly, the following agents are classified as *carcinogenic to human* (group 1) by the IARC⁶:

- 1) *Clonorchis sinensis* (infection with);
- 2) Epstein-Barr virus;
- 3) *Helicobacter pylori* (infection with);
- 4) Hepatitis B virus (chronic infection with);
- 5) Hepatitis C virus (chronic infection with);
- 6) Human immunodeficiency virus type 1 (infection with);
- 7) Human papillomavirus types 16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, 59 (in order of magnitude in risk for cervical cancer);
- 8) Human T-cell lymphotropic virus type 1;
- 9) Kaposi sarcoma herpesvirus;
- 10) *Opisthorchis viverrini* (infection with);
- 11) *Schistosoma haematobium* (infection with).

It is estimated that biological risk in workplaces is responsible for about 320,000 deaths per year worldwide and about 5,000 deaths in the European Union, where oc-

cupational diseases due to infections are about 0.8% of the total death toll, with a prevalence (65.21%) in health and social services^{7,8}.

Workers with defective immune systems and then more susceptible to biological risk have to be excluded from exposures⁹.

Consequently, biological risk at work requires a complex management approach in which is extremely important identifying the work sectors affected by the presence of such a risk.

Working Activities with Biological Risk

Exposure to biological agents can occur by contact of skin and mucous membranes with many matrices. At work, this contact is with natural or organic materials (e.g., soil, plant materials), organic dust (e.g., flour, paper), substances of animal origin, food, waste, wastewater and body fluids. Many working activities are involved by biological risk. Biological risk can be found in traditional work environments, such as agriculture, but also in workplaces with modern technologies, such as biotechnology industry, and the exposure can also be accidental.

Health care, laboratory, dentistry

Health care workers are considered at higher biological risk because they are permanently exposed to blood and body fluids. Their exposure to infectious agents is widely regarded as the most important occupational risk factor, even because of the high probability that accidents at work can increase the risk of exposure to infectious agents¹⁰⁻¹². In fact, it is widely documented the need to properly manage occupational accidents due to body fluids exposure, through the planning of prevention strategies and the management of prophylaxis and post-exposure^{13,14}.

It is well known that training and knowledge are able to reduce the risk of accidents by exposure to biological agents, as also confirmed by observations on nursing students. Accidents frequency is in fact higher among health care professionals with working seniority of less than 5 yr (59%), as evidenced by a retrospective study on 1,810 occupational accidents, and among nursing students attending first year than subsequent years, as a recent retrospective study on 2,215 nursing students enrolled in four Italian universities demonstrates^{15,16}. On the contrary, higher evidence of HBV and HCV infections has been reported in workers with more working seniority. Evidence of HBV and HCV infection has been reported in 37% of nurses with working seniority of 16–20 yr vs. 11.2% of

nurses with working seniority up to 5 yr¹⁷). Accidents at work increase the risk of infections, estimated for HBV 4.29 times higher¹⁸). HBV, HCV and HIV viruses are mostly involved in percutaneous occupational exposures. According to the WHO, in Europe percutaneous exposures in health care workers each year would be 304,000 with risk HBV, 149,000 with risk HCV, 22,000 with risk HIV and the probability of acquiring an infection after an occupational exposure would be < 0.3–4.4% for HIV, 0.5–39% for HCV and 18–37% for HBV^{19–21}). It has been estimated that HIV virus transmission is lower following the exposure of mucous membranes²²). Together with doctors and nurses, also obstetricians can be affected by biological risk and work-related HIV infections, especially during water births²³).

Tuberculosis too constitutes a risk to health care workers²⁴). Ong A. *et al.* reported in a perspective cohort study carried out for 11 yr, that among 2,510 cases of tuberculosis, 31 (1.2%) were health care workers, 10 of which work-related (including two workers, despite the use of negative-pressure isolation and an N95 mask, two after puncture by contaminated needle and three had lived in countries with tuberculosis high prevalence)²⁵). It is also reported the risk of infection by *Group A Streptococcus* (Lancefield serological classification, based on specific carbohydrate antigen into groups of haemolytic streptococci)^{26, 27}, *Staphylococcus aureus* and *Francisella tularensis*, whereas strictly related to geographical area is the association between hospital work environment and endemic diseases such as malaria^{28–30}).

Among health care workers, nurses appear to be more exposed to biological risk, included those who perform home care³¹). Retrospective studies indicate that a percentage between 45% and 46.74% includes work injuries, with prevalence of needlestick injuries (53–63.6%) mostly on hands (76.3%)^{32, 33}). Accidental exposures to blood and body fluids are also frequent among workers of operating theatre, where it has been shown a potential exposure to contaminated aerosols due to the use of high speed surgical instruments³⁴).

Occupational exposures to biological agents also affect laboratory workers' health and safety, as also reported in papers indicating two accidents with exposure to SARS virus (Singapore and Taiwan) and a case of cutaneous anthrax. Accidental exposure to SARS virus was caused by inadequate safety practises and probably by inhalation after the opening of a transporting chamber before that SARS virus was inactivated^{35, 36}). Cutaneous anthrax derived by contact of vials containing it, during transport without gloves³⁷).

The Centers for Disease Control and Prevention (CDC) also report two cases of laboratory-acquired *West Nile virus* (WNV) infection, a neuropathogen commonly transmitted by mosquitoes, and two cases by laboratory-acquired *Neisseria meningitidis*^{38, 39}).

Sejvar *et al.* report sixteen cases of Meningococcal disease in the world among microbiologists from 1985 to 2001, including six in the United States from 1996 to 2001 (attack rate 13/100,000 microbiologists against 0.2/100,000 U.S. adults) and suppose the infectious role of droplet and aerosols, whose involvement is demonstrated in case of accidental events⁴⁰).

At present, indirect serological diagnosis procedures and prevalence of seroconversions make it possible to consider both HCV and HBV as relevant risk factors in the workplaces, together with *Mycobacterium tuberculosis*, in case of mycobacteriology laboratories^{41, 42}).

In histological laboratories it has also been reported spongiform encephalopathy risk⁴³). In presence of laboratory animals, we must also consider occupational risk for zoonotic diseases, whose rate of incidence in USA is estimated to be 45 cases per 10,000 workers-year at risk⁴⁴).

In dentistry it's well known the possibility of infections transmission from patient to dentist, from dentist to patient and from patient to patient, through blood and body fluids, saliva, infected aerosols, surgical instruments, water, even if the probability of transmission from dentist to patient is considered negligible^{45, 46}). Besides the possibility of infection by HBV and HIV, when present in blood and biological fluids, in case of percutaneous or mucous membranes exposure following an accident, the aerosols produced by high speed surgical instruments (ultrasonic scaler tip, bur on a high-speed handpiece) coming out from the patient mouth and mixing with the surrounding air are considered at significant biological risk⁴⁷). The presence of infectious agents can be a biological risk to dentists, but it can be reduced with specific mouth rinses by using 0.2% chlorhexidine gluconate for 1 min from the patient⁴⁸).

Small aerosols (<1 µm) during dental treatment can be considered an important occupational respiratory risk⁴⁹). Gram-negative biological agents and bacterial endotoxins have also been detected in dental unit waterlines and in water flowing from high-speed handpieces and it was suggested a potential risk of bronchial asthma in dentists^{50, 51}).

Controversial assessments regard the presence of Legionella, although commonly considered a risk in dental practices. Studies carried out in seven European Countries (UK, Ireland, Greece, Spain, Germany, Denmark and the Netherlands) showed that 51% of 237 dental unit

waterlines exceeded contaminations recommended by the American Dental Association (≤ 200 colony forming units (CFU)/ml) and showed the presence of *Legionella pneumophila*, *Mycobacterium spp* and lower frequency of oral streptococci, oral anaerobes, *Candida spp*⁵²). Biocontamination from *Legionella spp* was found in 33% of 102 Italian dental units and index of microbial air contamination (IMA) increase during work activities has been shown⁵³). Analyses performed on 208 water samples, of which 160 collected from dental chairs and 48 from cold incoming tap water, showed positivity for *Legionella spp* in 22.1% of the samples, of which 41.3% for *Legionella pneumophila*, 41.4% for *Pseudomonas aeruginosa*, and 0.96% for both in samples⁵⁴). The presence of *Legionella spp* in measured concentrations ($\geq 10^3$ CFU/ml) is considered a health risk. Other observations reveal a rather low level of *Legionella spp* in waterlines (0.37% on 266 tested) and evaluate a very low risk of occupational exposure for dentists, confirmed by the presence of antibodies anti-*Legionella pneumophila* lower than that observed in a comparable group of blood donors⁵⁵).

Farming and cattle-breeding

Also farming and cattle-breeding are considered at significant biological risk. Microbiological analyses performed on environmental dust, sampled during corn and soybeans harvesting and in animal confinements (swine, poultry and dairy), revealed higher concentrations of fungal spores during corn and soybeans harvesting ($3.4 \times 10^4 - (6.1 \pm 2.1) \times 10^6$ spore/m³ for total fungal spores, $8.2 \times 10^4 - (7.4 \pm 2.3) \times 10^6$ CFU/m³ for culturable fungal spores, $< \text{LOD} - (2.6 \pm 0.1) \times 10^4$ CFU/m³ for culturable actinomycetes), higher concentrations of culturable bacteria in swine confinements during summer (3.3×10^8 CFU/m³) and high production of particles between 2–10 μm formed by fungal spores⁵⁶).

Dust, biological agents and endotoxin have been reported during processing of peppermint and chamomile herbs, with a higher concentration of microorganisms ($895.1-6,015.8 \times 10^3$ CFU/m³, median $1,055 \times 10^3$ CFU/m³) and endotoxin ($1.53-208.33 \mu\text{g}/\text{m}^3$, median $57.3 \mu\text{g}/\text{m}^3$) in the first as to the second (microorganisms $0.88-295.6 \times 10^3$ CFU/m³, median 27.3×10^3 CFU/m³; endotoxins $0.005-2,604.19 \mu\text{g}/\text{m}^3$, median $0.96 \mu\text{g}/\text{m}^3$)⁵⁷). During processing of chamomile, among Gram-negative bacteria, prevalence of the species *Pantoea agglomerans* (synonyms: *herbicola amylovora*, *agglomerans Enterobacter*) with strong endotoxic and allergenic properties has been detected.

Exposure to dust, microorganisms such as thermophiles

and mesophilic Actinomycetes of the genus *Streptomyces*, *Corynebacterium*, Gram-negative bacteria (1.1×10^7 CFU/m³ – 4.2×10^6 CFU/m³) and endotoxins ($31.25-125.0 \mu\text{g}/\text{m}^3$) have also reported during grain and millet threshing and processing of valerian roots ($0.95-7,966 \times 10^3$ CFU/m³, endotoxins $0.15-24,448.2 \text{ mg}/\text{m}^3$)⁵⁸⁻⁶⁰). Microflora identified during threshing is made up of thermophilic and mesophilic Actinomycetes of the genus *Streptomyces*, *Corynebacterium*, Gram-negative bacteria and Gram-negative bacteria of the family Pseudomonadaceae (mainly *Stenotrophomonas maltophilia*, *Pseudomonas chlororaphis* and *Pseudomonas fluorescens*) and fungi (*Aspergillus fumigatus*) in processing of valerian. Observations on samples of grain and grain dust during threshing revealed presence of fungi genera (*Alternaria*, *Geotrichum*, *Cladosporium*, *Penicillium*, *Aspergillus*, *Fusarium*), with concentrations estimated between $5.0-520.0 \times 10^3$ CFU/g and $275.0-2,825.0 \times 10^3$ CFU/g, and mycotoxins (moniliformin; MON, deoxynivalenol; DON, ochratoxin A; OTA) with concentrations of $0.025-0.088 \mu\text{g}/\text{g}$ -MON, $0.015-0.068 \mu\text{g}/\text{g}$ -DON and $0.0004-0.0008 \mu\text{g}/\text{g}$ -OTA in samples of grain and $0.025-0.149 \mu\text{g}/\text{g}$ -MON, $0.015-0.215 \mu\text{g}/\text{g}$ -DON and $0.0004-0.0012 \mu\text{g}/\text{g}$ -OTA in grain dust⁶¹).

During processing of herbs (nettle, caraway, birch, chelidonia, marjoram, mint, peppermint, sage, calamus, yarrow) for production of medications, cosmetics and spices, microorganisms concentrations (bacteria and fungi) in air of $40.6-627.4 \times 10^3$ CFU/m³ (mean $231.4 \pm 181.0 \times 10^3$ CFU/m³) and endotoxin concentrations of $0.2-2,681.0 \mu\text{g}/\text{m}^3$ (median $16.0 \mu\text{g}/\text{m}^3$) have been reported⁶²). Environmental sampling carried out during processing of potatoes for production of various products (starch, meal, flakes, etc.) showed bacteria (*Corynebacterium spp*, *Arthrobacter spp*, *Microbacterium spp* and *Agromyces ramosus*), fungi (*Aspergillus niger*), with concentration of total airborne microorganisms of $28.3-93.1 \times 10^3$ CFU/m³ and respirable fraction of airborne microflora estimated between 25.3% and 73.2%, and endotoxin whose highest values were found of $45.9-1,893.9 \mu\text{g}/\text{m}^3$ ⁶³).

Endotoxin concentration in dust environment, between $0.36 \text{ ng}/\text{m}^3$ (in Spanish greenhouses) and $257.58 \text{ ng}/\text{m}^3$ (in poultry houses in Switzerland), has been reported in a study conducted in Europe on 213 crop and animal farming environments⁶⁴). By using the technique of quantitative polymerase (Q-PCR), a study carried out on 12 poultry houses in Switzerland has found very high concentrations of total bacteria in air (up to $53 \pm 2.6 \times 10^7$ cells m³), of the *Staphylococcus* species ($62 \pm 1.9 \times 10^6$ cells/m³) and endotoxin ($6,198 \pm 2.3 \text{ EU m}^3$ air) that was >6-fold higher than

Swiss occupational recommended value (1,000 EU m³)⁶⁵.

Other studies show various fungi (*Aspergillus oryzae*, *A. nidulans*, *Penicillium expansum*, *P. olivivoride*, *P. claviforme* and *Botryotrichum longibrachiatum*) in poultry houses⁶⁶. High values of endotoxin have been observed in German animal houses for different species (beef cattle, pigs, laying hens, turkeys, dairy cattle), where ranged from 16.9 EU/m³ (dairy cattle) to 1,902 EU/m³ (turkeys)⁶⁷. In rats exposed for 1, 5 and 20 d to air of swine barn with high concentration of endotoxin (15,361.75 ± 7,712.16 EU/m³) and then euthanized, induction of airway hyper-responsiveness to methacholine, lung inflammation, inflammatory cells in BALF with presence of mitotic cells (adaptive response) have been observed, compared to controls, in rats exposed for 20 d⁶⁸. In slaughterhouse workers, toxoplasma infection has been reported (19.20%)⁶⁹.

Exposures to other biological agents were considered cause of probable infections in other processes, such as Gram-negative bacteria, fungi and toxins infection in cotton workers (measured on various cotton lint concentrations of Gram-negative bacteria from 713 ± 212 to 216,830 ± 30,413 CFU/g, of fungal cells from 281 ± 29 to 9,250 ± 820 CFU/g, of endotoxin from 8.30 ± 0.89 to 137.89 ± 21.55 ng/g)⁷⁰.

During grinding grain, microbiological air contamination by mesophilic bacteria, psychrophilic bacteria and moulds in various areas (storage, cleaning unit, grinding unit, filling unit and laboratory) was found and microbial contamination was 11.41 times higher than that of external area⁷¹. *Campylobacter spp* infection was reported in dairy farms⁷².

Francisella tularensis infection has been studied in hunters and seroprevalence showed a significant risk in hunters living in endemic regions⁷³.

Mites infection of Acaridae, Glycyphagidae, Anoeidae, Pyroglyphidae families has been reported among zoo workers and is considered occupational risk for allergic diseases⁷⁴.

Hepatitis E infection was investigated in farmers who used untreated waste water for irrigation and anti-HEV seropositivity was reported in 34.8% of workers vs. 4.4% in the control group and acquiring hepatitis E risk was estimated 11.5 times higher in workers compared with controls⁷⁵.

It has also been studied the transfer of drug resistance from animals treated with antimicrobials to abattoir workers. *Escherichia coli* resistance to doxycycline, trimethoprim, sulphamethoxazole, ampicillin, fosfomicin, ceftriaxone and nalidixic acid in poultry abattoir workers

was attributed to the result of both animal and human antimicrobial drug usage (cross-resistance)⁷⁶.

Waste, wastewater, sewer, biotechnological industry and other workplaces

Biological hazard is identified in the treatment of solid waste (especially in composting plants) and wastewater and in sewer workers. Environmental sampling in waste disposal plants shows biological agents, especially in composting areas. Mesophilic bacteria and Actinomycetes were found in composting plants (up to 10⁴–10⁶ CFU/m³ and 10²–10⁵ CFU/m³, respectively), fungal spores in waste collection and sorting (up to 10⁴–10⁵ CFU/m³) and endotoxin during refuse collection (from 12 up to 59 UE/m³)^{77, 78}. In solid waste workers, prevalence of antibodies anti HBe and anti *Toxoplasma gondii* has been observed^{79, 80}.

During wastewater treatment, have been identified several species of fungi (especially *Aspergillus fumigatus*, but also *Mucor*, *Penicillium*, *Alternaria*, *Trichophyton*, *Geotrichum candidum*, *Cladosporium* with mean concentrations up to 2,331 ± 858 CFU/m³ in summer and up to 329 ± 95 CFU/m³ in winter), bacteria genera (*Pseudomonas*, *Acinetobacter*, *Stenotrophomonas*, *Burkholderia*, *Shewanella*, *Enterococcus* with concentrations between 10² CFU/m³ and 10⁵ CFU/m³) and endotoxin (between 0.6 UE/m³ and 2,093 UE/m³)^{81–83}. The highest levels have been found in sewage sludge bioaerosols and biological agents have shown a different seasonal variability⁸⁴.

Bioaerosols exposure has also been assessed in sewer workers. Estimates made next to the sewer manhole, inside the sewer and at effluent discharge point indicate concentrations of fungi (*Aspergillus fumigatus* and *Penicillium*) higher (1,0 × 10² CFU/m³) at effluent discharge point and bacteria (*Staphylococcus lentus* and *Enterococcus faecalis*) inside the sewer (5,0 × 10² CFU/m³)⁸⁵.

Workers are exposed to biological hazards in many other work activities. In recent decades for instance, biotechnological industry has had an enormous development in various fields (medical, pharmaceutical, alimentary, chemical, energetic) where exposure to even less common organisms can occur. Accidents and unforeseeable causes may determine exposure, as in case of eosinophilia-myalgia syndrome spreading. This syndrome was described for the first time in 1989 and is caused by contamination of tryptophan with toxic substances produced by *Bacillus amyloliquefaciens*, used during biotechnological process⁸⁶.

Furniture production and work in sawmill are considered work activities with respiratory hazard for inhalation of gram-negative bacteria (*Acinetobacter calcoaceticus*,

Alcaligenes faecalis, *Enterobacter* spp., *Pantoea agglomerans*, *Rahnella aquatilis*, *R. spp.*, *Pseudomonas maltophilia*, *P. marginalis*, *Pseudomonas* spp., *P. boiseopolis* and *Sanguibacter keddiei*), bacilli (*Bacillus cereus*, *B. megaterium*, *B. subtilis*, *B. licheniformis* and *B. spp.*), Corynebacteria (*Arthrobacter globiformis*, *A. spp.*, *Brevibacterium linens*, *B. helvolum*, *Corynebacterium pseudodiphtheriticum*, *C. xerosis*, *C. spp.*, *Microbacterium lacticum*), other mesophilic bacteria (*Lactobacillus* spp., *Micrococcus luteus*, *M. roseus*, *M. spp.*, *Nocardia* spp., *Rodococcus* spp., *Staphylococcus epidermidis*, *S. spp.*, *Streptococcus lactis*, *S. spp.*, *Streptomyces albus*, *S. spp.*), Thermophilic actinomycetes (*Saccharomonospora viridis*, *Saccharopolyspora rectivirgula*, *Micropolyspora faeni*, *Thermoactinomyces vulgaris*) and fungi (mostly *Aspergillus fumigatus* and *Penicillium* spp.) contained in wood, with higher concentrations in coniferous logs respect to the processing of deciduous wood^{87, 88}.

Biofuels production (especially the storage of wood chips and straw) involves a biological risk to workers, as well as cigarette and cigar manufacturing^{89, 90}. Gram-negative bacteria, mesophilic fungi, thermophilic actinomycetes and endotoxins was greater in production of cigars.

Biological risk for military and prison personnel is well known. Risk behaviours of prisoners are considered as potential causes of HCV, HBV and HIV infections in prisons, where available estimates indicate prevalence rates between 16.2% and 56% for HCV, between 20% and 27% for HBV, between 0 and 13.9% for HIV^{91–93}.

Legionella pneumophila risk has been reported in bus drivers (seropositivity rate of 19%), higher in personnel who were travelling to hot climates (seropositivity rate of 27.8%) than those who travel to cold climates (seropositivity rate of 4.6%), caused by contaminated water sources such as air conditioners⁹⁴.

Office work may also result in biohazard and bioaerosols can cause sick building syndrome (SBS) and allergy⁹⁵. Up to 501 bacterial strains have been isolated and bacterial contaminations have been detected on surfaces (ranged from 1–1,000, with 33 CFU/25 cm² as median value), on carpets (ranged from 0.73–185 × 10⁵ CFU/g, with 33 CFU/25 cm² as median value) together with endotoxin concentrations in dust from 4.6–116.2 EU/mg, with a median value of 20.3 EU/mg⁹⁶.

Accidental biological risk was confirmed in four workers from postal facility in Washington in 2001 because of aerosol produced by passing through a sorting machine of two envelopes containing *Bacillus anthracis* spores⁹⁷.

Discussion

Literature data show a variety of working activities with biological risk affecting a large number of workers. Available data mainly concern the detection and estimation of biological agents in different processes, but data on work-related diseases are lacking. Nevertheless the attention of international organisms against biological risk is high. As part of Community Strategy for 2002–2006, a survey carried out by the European Risk Observatory of the European Agency for Safety and Health at Work has in fact identified the following ten emerging biological risks⁹⁸:

- 1) occupational risks related to global epidemics;
- 2) difficult assessment of biological risks;
- 3) workers exposure to drug-resistant microorganisms;
- 4) lack of information on biological risks;
- 5) poor maintenance of air-conditioning and water systems;
- 6) inadequate OSH (Occupational Safety Health) training of local authorities staff;
- 7) biohazards in waste treatment plants;
- 8) combined exposure to bioaerosols and chemicals;
- 9) endotoxins;
- 10) moulds in indoor workplaces.

European Union has also regulated the risk of occupational exposure to biological agents with the Directive of 18th September, 2000 (*On the Protection of Workers from risks related to exposure to biological agents at work*)⁹⁹.

Finally, there are several institutions that deal with biological risk, both European (European Centre for Disease and Control, ECDC; Health and Safety Executive, HSE) and International (World Health Organization, WHO; Centre for Disease Prevention and Control, CDC; The National Institute for Occupational Safety and Health, NIOSH; The Occupational Safety and Health Administration, OSHA; Food and Agriculture Organization of the United Nations, FAO; International Labour Organization, ILO).

Data on workers' attitude towards biological risk are also poor. Several comments relate to detect the "perception" of biological risk, but substantially detect only knowledge. Actually "*Risk is More Than Just a Number*", as recalled by F. Passchier, Chairman of the Committee Risk Measures and Risk Assessment of the Health Council, and the mechanisms of risk perception are essentially emotional mechanisms¹⁰⁰. In them, rational component is not relevant while strong is the influence of emotional component, known as an offense (*outrage*) that such a risk represents to the individual. Then, perception of risk does not arise

from lack of knowledge and according to P. Sandman's "Risk = Hazard + Outrage", namely risk includes other aspects than those that are purely technical¹⁰¹. Detecting these individual differences towards risk certainly allows a more complete assessment of it, with positive effects in decision making and management strategies. It is in fact testified that there is the perception of an insignificant risk on the basis of the failure to report about an exposure to biological agents^{102, 103}.

It is well-known that the perception of high risk is particularly pronounced in relation to involuntary exposures and in relation to risk factors which are difficult to see and smell, such as radiation and biological agents, especially if involved in serious diseases, such as AIDS and HIV¹⁰⁴. Perception is also affected by stress, by the occurrence of disasters (Fukushima, Chernobyl, Seveso), possibility of threats, as in case of bioterrorism, war events, as reported by a longitudinal cohort study on 1,250 soldiers of the Gulf War, according to which soldiers with greater number of combat exposures and combat stress were more likely to believe they were exposed to chemical and biological weapons¹⁰⁵. Actually, many workers are also exposed to biological risk and emerging infectious diseases (SARS, Ebola virus and Avian flu), disasters and bioterrorism involve mainly health care workers. Among the various causes impeding a reduction of diseases and accidents caused by biological agents is considered the global shortage of health care workers in many areas¹⁰⁶.

Organizational factors and infection control training are considered fundamental to implement prevention among health care workers. A study conducted on nurses in the Union States shows low prevalence of training (85% had received annual training and 8.5% had not received any training in the previous year) and high rate of underreporting of needlesticks and other exposure accidents (48.9%)¹⁰⁷. The problem of underreporting is particularly investigated in Japan and the rate of underreporting is estimated about of 20%^{108, 109}. However, a study among Japanese nurses reveal a higher percentage (64.1%) of needlesticks and sharp injuries underreported and shows the importance of interactions between needlesticks, psychosocial factors and safety climate (56% reported much responsibility in their work)¹¹⁰.

Perception of occupational risk from emerging infectious diseases (avian flu) has been studied in Japanese health care workers. As to the perceived impact on personal life and work in the event of pandemic avian flu, a high percentage perceives that they feel that people would avoid them (60.1%) or their family (48.7%) because of

their profession and shows higher perception (72.8%) of work overtime¹¹¹.

Emerging biological risks involve countries with increasing economic development, as in China. Recently, AIDS emergency has been reported in contemporary China, especially in areas with drug use, high number of migrating workers and increased commercial sex work, even for influx of tourists during Olympic Games. This new emergency involves a high number of Chinese health care workers and increases their occupational risk, especially caused by sharps and needlesticks. Improvement of knowledge is recommended in health care workers and reduction of accidents underreported (10% of injuries underreported by Chinese physicians) is suggested¹¹².

Currently, no Occupational Exposure Limits have been available for biological agents¹¹³. Dose-response relationships for most biological agents have not been established and risk assessment is influenced from the lack of valid methods to assess exposure quantitatively. Some European Union Member States have set limits only for some endotoxins, recognised as biologically active components in most organic dust¹¹⁴. Occupational Exposure Limits have been established for wood dust and flour dust in some countries to protect workers from adverse effects. Subtilisins are bacterial enzymes usually produced from *Bacillus subtilis* and TLV (ceiling concentration) of 0.00006 mg/m³ for workplace airborne exposure have been established by American Conference of Governmental Industrial Hygienists (ACGIH). Gram negative bacterial endotoxin and (1-3) beta, D-glucan are biologically derived agents under study by Bioaerosols Committee of ACGIH¹¹⁵.

An integrated prevention, including targeted training for workers against biological risk inherent the specific work activity, is the first important thing to consider. In fact, biological risk is also attributable to specific habits in workplaces, as in case of foot injuries among Japanese health care workers. A comparison between Japanese and American data shows in Japanese workers a higher percentage (1.5% vs 0.6%) of foot injuries, attributable to the use of slippers inside hospital, which are usually soft-sided and often open-toed¹¹⁶.

Conclusion

Biological risk can be considered a risk in evolution, concerning both new and old workplaces. Moreover, emerging risk is widely documented in most traditional workplaces.

Emergency management involves problems not easy

to solve, because of the impact perceived by workers and the social stigmatization perceived by health care workers. Health workers are considered at higher biological risk and this risk can't be estimated. In fact, health care workers are exposed to the patient population whose prevalence may differ significantly to that of general population.

Biological risk can be significant in countries with increasing economic development and advanced technologies or particular habits. Therefore, biological risk can concern health professions as biotechnology, showing specific variations.

Ability to reproduce of biological agents is considered an essential difference between their and other hazardous agents and the interaction of bioaerosols with other occupational agents is assumed. Moreover, organic particles are generated also from sources very represented among general population and associated with other risks. In fact, production of biological particles was studied in presence of tobacco smoke and re-suspension of particles with inhalation risk for exposed has been observed¹¹⁷.

In addition, very different diseases are caused by biological agents (infections, allergies, poisoning, cancer and foetal harm) and work-related transmission can also occur by different systems (respiratory apparatus, skin and digestive apparatus). Individual susceptibility of workers and the transfer of drug resistance from animals treated with antimicrobials must also be considered in the workplaces with biological risk.

Nevertheless biological risk assessment, associated to the lack of Occupational Exposure Limit for all the occupational exposures, which prevents proper estimates of risk itself and of its effects, turns out to be difficult. Moreover, we must also remember that, in addition to the lack of definition of Occupational Exposure Limit of biological agents, a little is known about infectious doses.

Consequently, risk assessment presents many difficulties and in prevention management there is an unanimous agreement on the importance of workers knowledge. Knowledge is however influenced by perceived risk and training plays a key role to avoid upper and lower estimates of risk itself and provide appropriate behaviours.

It is also important to improve workers' knowledge and skills in order to help them acquire a less distorted perception of risk. In such a context it is particularly important that any doctor would be able to recognize the possible occupational origin of infectious diseases seen in patients, also in order to contribute to workers' educational training leading to appropriate and targeted behaviours.

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