

Topic: An Ergonomic Approach to Industrial Air Quality and the Release of Endotoxins

Introduction:

Industrial Air Quality (IAQ) has become a significant environmental issue. The number of related complaints has increased in recent years with increased building tightness, the growing use of synthetic materials, and energy conservation measures that reduce the amount of outside air supply. Modern office equipment (e.g., photocopiers, laser printers, and computers), cleaning products and outdoors air pollution can also increase the level of indoor air contamination. The reactions to these contaminants have led to the phenomenon of sick building syndrome (SBS).

The causes of occupant complaints are multi-factorial and often elusive. It can involve chemical, microbiological, physical and psychological mechanisms. However from a rational perspective, contaminant source control is the most effective general means to improve IAQ. Analysis of air samples may fail to reveal significant concentrations of any one contaminant, so the problem is often attributed to the combined effects of many pollutants at low concentrations, complicated by other environmental factors. For example, several factors influence thermal comfort, such as overheating, under-heating, humidity extremes, drafts, and lack of air circulation. Likewise, odors are often associated with a perception of poor air quality, whether or not they cause symptoms. Environmental stressors such as noise, vibration, and overcrowding, and poor workplace design and lighting can produce symptoms that may be confused with the effects of poor air quality. Further, physical discomfort or psychosocial problems (such as job stress) can reduce tolerance for substandard air.

One of the microbiological contaminants that are exposing the workers in their workplaces is endotoxin. Endotoxin is produced by Gram-negative bacteria, which are common in the environment, particularly in water or in water damaged conditions. It has been associated with many respiratory symptoms and complaints related to the indoor environment.

Discussion:

Overview of Endotoxins:

Endotoxin is a heat-resistant pyrogen (specifically a lipopolysaccharide) found in the cell walls of certain pathogenic (disease-producing) bacteria. Endotoxins are part of the outer cell wall of bacteria, invariably associated with Gram-negative bacteria as constituents of the outer membrane of the cell wall. Endotoxins are heat stable (boiling

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for 30 minutes does not destabilize endotoxin), but can be degraded by certain powerful oxidizing agents (super oxide, peroxide and hypochlorite). Therefore, even if a medical device has been sterilized, residual endotoxins may still be found on the device (Rylander, 1997).

Endotoxins are toxic to most mammals, and produce the same range of biological effects in the animal host. The Gram-negative bacteria does not have to be alive for endotoxins to be toxic to humans, therefore viable and non-viable Gram-negative bacteria containing endotoxins can have similar health effects. Routes of exposure to endotoxins are through inhalation, intestinal tract absorption, or via subcutaneous infections that may occur in situations such as surgical procedures. The pharmaceutical and medical device industries have developed routine analytical methods for detecting endotoxins due to their toxicity.

Gram-negative bacteria can be found almost everywhere in nature. Endotoxins have been linked to water systems (especially ones containing sewage or recycled water). Endotoxins have also been found in buildings with humidifiers and those with sewage or gray water incursions. Elevated airborne concentrations are prevalent in such industries as sewage treatment plants, swine operations, cotton textile mills, and poultry houses.

Studies indicate they also have been found to populate ventilation systems and humidification devices. The types of Gram-negative bacteria that contain endotoxins include but are not limited to *E. coli*, *Salmonella*, *Pseudomonas*, and *Haemophilis*. Endotoxins have been detected in the air, dust and water. However, typical exposures occur through the air. Endotoxin exposure is highest when the water containing the endotoxin is aerosolized. Significant exposure locations include sludge pressrooms or aeration tanks at wastewater treatment facilities. The processes in these areas tend to aerosolize water and create droplets that can be inhaled by workers (Rylander, 1997).

Health effects vary tremendously, depending on the individual, dosage, and route of exposure. However, once in the bloodstream at high enough levels, endotoxins may cause fever, shock or even death. They have been associated with many respiratory symptoms and complaints related to specific occupational environments. In particular, the wastewater industry routinely deals with bacteria and, as a result, endotoxins during the treatment of human waste and its by-products on a daily basis. The bacteria associated with those processes are often that which the human body is trying to rid itself of. Studies have indicated that daily exposure to these bacteria may not be healthy.

Indoor air quality sampling for endotoxins should be considered when doing IAQ investigations involving gray or black water incursions or whenever elevated levels of Gram-negative bacteria are suspected.

Sampling And Analysis:

Air sampling for endotoxins consists of a sampling device equipped with an endotoxin-free, glass-fiber filter cassette. The sample is collected in the breathing zone (eight to ten inches from the nose and mouth) of the employee or in the area of the suspected exposure. At the conclusion of sample collection, the sampling cassette containing the filter is sent to a lab for analysis by Limulus ameobocyte lysate (LAL) kinetic chromogenic method. Sampling for endotoxins may also include placement of sampling water and dust into endotoxin-free containers (www.emsl.com, 2006).

Standards:

The Occupational Safety and Health Administration (OSHA), the National Institute of Occupational Safety and Health (NIOSH) or the American Conference of Governmental Industrial Hygienists (ACGIH) has established no enforceable standards to date. These organizations typically establish acceptable levels of exposure to occupational contaminants. Therefore, worker exposure results have to be compared to guidelines based on challenge studies and field studies.

Control Of Endotoxins:

Control of endotoxins in wastewater facilities can be difficult since they are naturally occurring in water and even more prevalent in wastewater. Uncontrolled flow of wastewater in areas populated by workers should be minimized and releases cleaned up quickly. Ventilation in these areas should be properly functioning to draw aerosolized water away from the breathing zone of the employee. HEPA filtration systems can be used to collect the airborne droplets. Wearing a respirator equipped with a dust, mist and fume cartridge in these areas can also offer protection to the employee.

Workplace and Endotoxin Release:

Biological air pollutants, such as endotoxin, are found to some degree in every home, school, and workplace. Sources include outdoor air and human occupants who shed viruses and bacteria, animal occupants (insects and other arthropods, mammals) that shed allergens, and indoor surfaces and water reservoirs

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where bacteria can grow, such as humidifiers, as already mentioned. A number of factors allow biological agents to grow and be released into the air. Especially important is high relative humidity, which encourages house dust mite populations to increase. Bacteria as well as other biological pollutants contamination can be caused by flooding, continually damp carpet (which may occur when carpet is installed on poorly ventilated concrete floors), inadequate exhaust of bathrooms, or kitchen-generated moisture.

Appliances such as humidifiers, dehumidifiers, air conditioners, and drip pans under cooling coils (as in refrigerators), support the growth of bacteria and fungi. Components of mechanical heating, ventilating, and air conditioning (HVAC) systems may also serve as reservoirs or sites of microbial amplification. These include air intakes near potential sources of contamination such as standing water, organic debris or bird droppings, or integral parts of the mechanical system itself, such as various humidification systems, cooling coils, or condensate drain pans. Dust and debris may be deposited in the ductwork or mixing boxes of the air handler.

Biological agents in indoor air are known to cause three types of human disease: infections, where pathogens invade human tissues; hypersensitivity diseases, where specific activation of the immune system causes disease; and toxicosis, where biologically produced chemical toxins cause direct toxic effects. In addition, exposure to conditions conducive to biological contamination (e.g., dampness, water damage) has been related to nonspecific upper and lower respiratory symptoms. Evidence is available that shows that some episodes of the group of nonspecific symptoms known as "sick building syndrome" may be related to microbial contamination in buildings.

What an exposure to edotoxin could cause?

There is one disease closely related with the exposure to endotoxins. Humidifier fever is a disease of uncertain etiology. It shares symptoms with hypersensitivity pneumonitis, but the high attack rate and short-term effects may indicate that toxins (e.g., bacterial endotoxins) are involved. Onset occurs a few hours after exposure. It is a flu-like illness marked by fever, headache, chills, myalgia, and malaise but without prominent pulmonary symptoms. It normally subsides within 24 hours without residual effects, and a physician is rarely consulted. Humidifier fever has been related to exposure to amoebae, bacteria, and fungi found in humidifier reservoirs, air conditioners, and aquaria. The attack rate within a workplace may be quite high, sometimes exceeding 25 percent.

Bacterial and fungal organisms can be emitted from impeller (cool mist) and ultrasonic humidifiers. Mesophilic fungi, thermophilic bacteria, and thermophilic actinomycetes, all of which are associated with development of allergic responses, have been isolated from humidifiers built into the forced-air heating system as well as separate console units. Airborne concentrations of microorganisms are noted during operation and might be quite high for individuals using ultrasonic or cool mist units. Drying and chemical disinfections with bleach or 3% hydrogen peroxide solution are effective remedial measures over a short period, but cannot be considered as reliable maintenance. Only rigorous, daily, and end-of-season cleaning regimens, coupled with disinfections, have been shown to be effective. Manual cleaning of contaminated reservoirs can cause exposure to allergens and pathogens.

Ergonomics intervention on IAQ:

Indoor air quality is a major concern to businesses, building managers, tenants, and employees because it can impact the health, comfort, well being, and productivity of building occupants. Most Americans spend up to 90% of their time indoors and many spend most of their working hours in an office environment. Studies conducted by the U.S. Environmental Protection Agency (EPA) and others show that indoor environments sometimes can have levels of pollutants that are actually higher than levels found outside.

Pollutants can be generated by outdoor or indoor sources, including building maintenance activities, pest control, housekeeping, renovation or remodeling, new furnishings or finishes, and building occupant activities. One important goal of an indoor air quality program is to minimize people's exposure to pollutants from these sources. Pollutants in our indoor environment can increase the risk of illness. Several studies by EPA, states, and independent scientific panels have consistently ranked indoor air pollution as an important environmental health problem. While most buildings do not have severe indoor air quality problems, even well run buildings can sometimes experience episodes of poor indoor air quality. A 1989 EPA Report to Congress concluded that improved indoor air quality can result in higher productivity and fewer lost workdays. EPA estimates that poor indoor air may cost the nation tens of billions of dollars each year in lost productivity and medical care.

Indoor air quality is not a simple, easily defined concept like a desk or a leaky faucet. It is a constantly changing interaction of complex factors that affect the types, levels, and importance of pollutants in indoor environments. These factors include: sources of pollutants or odors; design, maintenance and operation of

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building ventilation systems; moisture and humidity; and occupant perceptions and susceptibilities. In addition, there are many other factors that affect comfort or perception of indoor air quality.

Controlling indoor air quality involves integrating three main strategies. First, manage the sources of pollutants either by removing them from the building or isolating them from people through physical barriers, air pressure relationships, or by controlling the timing of their use. Second, dilute pollutants and remove them from the building through ventilation. Third, use filtration to clean the air of pollutants.

HFE Intervention:

To prevent biological hazards, changing the type of collection or respiratory protection could be done to improve a better air quality in the workplace, free of pollutant like endotoxins. There are some factors that are key in trying to improve and provide a better air to breath in the workplace such as:

- **Ventilation:** Inadequate ventilation can enable airborne contaminants to accumulate. This may happen when contaminants are not captured and exhausted near their point of release, or when contaminated air is recirculated by a heating-ventilating-air-conditioning (**HVAC**) system. Because ventilation also plays a role in controlling temperature, moisture and humidity, it can also influence rate of release and distribution of bothersome chemicals.

The American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) provides standards for issues such as how much fresh air should be introduced, recommended temperature and relative humidity ranges, how much air flow there should be per room occupant, etc. Like building codes, ASHRAE standards are subject to change over time. Though a ventilation system may have been designed to meet the standards when built, the system may not be meeting current standards. Further, it is not uncommon for systems to be modified during construction, no longer meeting the requirements of the design specifications. Likewise, modification to the system when new construction occurs, or new needs arise often results in alteration of airflow. Often, some areas get more air than they should, while other areas get less than intended. Readjustment of the system, particularly by uncomfortable, unqualified occupants (who should instead contact qualified maintenance staff), can further affect operation of the system. Further, it is not uncommon to discover that dampers that regulate entry of fresh air into the system have been adjusted so less fresh air is delivered. IAQ investigations involving measurement of airflow, temperature, and humidity often reveal that the air handling system is not operating as designed.

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- **Temperature:** Maintain the ambient temperature between 18°C and 21°C. An overheated environment provokes sleepiness and dries the air.
- **Humidity level:** Maintain the relative humidity level between 50% and 70%. Note that the eyes and skin are particularly sensitive to ambient dryness. This factor, combined with the drying effects of working with a screen, can considerably affect your vision and comfort.

There are some other factors that may be useful to evaluate the situation when encountering an endotoxins release in the environment. These are:

- Is the case related to the workplace, home, or other location?
- Does the location have a reservoir or disseminator of biological that may logically lead to exposure?
- Is the relative humidity in the home or workplace consistently above 50 percent?
- Are humidifiers or other water-spray systems in use? How often are they cleaned? Are they cleaned appropriately?
- Has there been flooding or leaks?
- Is there evidence of mold growth (visible growth or odors)?
- Are organic materials handled in the workplace?
- Is carpet installed on unventilated concrete (e.g., slab on grade) floors?
- Is adequate outdoor air being provided?
- Is the relative humidity in the home or workplace above 50 percent or below 30 percent?
- Are humidifiers or other water-spray systems in use?
 - Are bacterial odors present (fishy or locker-room smells)?

HFE benefits of improved indoor environmental quality:

The benefits are many. They include improved occupant health and reduced absenteeism, resulting in improved worker satisfaction, job retention, and overall productivity. Savings may be seen in Workers Compensation premiums, as well.

Ergonomics Countermeasures:

- Provide adequate outdoor air ventilation to dilute human source aerosols.

- Keep equipment water reservoirs clean and potable water systems adequately chlorinated, according to manufacturer instructions. Be sure there is no standing water in air conditioners. Maintain humidifiers and dehumidifiers according to manufacturer instructions.
- Repair leaks and seepage. Thoroughly clean and dry water-damaged carpets and building materials within 24 hours of damage, or consider removal and replacement.
- Keep relative humidity below 50 percent. Use exhaust fans in bathrooms and kitchens, and vent clothes dryers to outside.
- Vacuum carpets and upholstered furniture regularly. *Note:* While it is important to keep an area as dust-free as possible, cleaning activities often re-suspend fine particles during and immediately after the activity.
- Sensitive individuals should be cautioned to avoid such exposure, and have others perform the vacuuming, or use a commercially available HEPA (High Efficiency Particulate Air) filtered vacuum.

Conclusion:

Coverage of the full range of work undertaken by environmental ergonomics goes well beyond the limited scope of this paper. Here, the focus has been on presenting how an endotoxin release into the workplace can affect the principles and value of environmental ergonomics and the ways that this can contribute to improving the design of the everyday places where the majority of people need to live and work in healthful and comfortable conditions. At the new millennium it would be wise not to overlook or underestimate the critical role that the physical environment conditions in which we live and work continue to play in shaping behavior, and ultimately in determining the success or failure of any physical setting as a person-technology system.

References:

1. Hedge, A., Where are we in understanding the effects of where we are? Journal of Ergonomics, 2000, 43:7.
2. Kennedy, M., Creation Ideal Facilities. American School & University Journal. 2002, 74:5.
3. Rylander, R., Endotoxins in the environment: A criteria document. Occupational And Environmental Health Journal. 1997, 3:1
4. Stellman JM, Air Quality and ergonomics in the office: survey results and methodology issues. American Industrial Hygiene Association Journal. 1985 46:5, pp. 286-93;
5. The Environmental Protection Agency, Indoor Air Pollution: An Introduction for Health Professionals, U.S Government Printing Office Publication, 1994, 1194:523
6. The Environmental Protection Agency, An Office Building Occupant's Guide to Indoors Quality. Indoor Environmental Division, 1997.
7. www.emsl.com accessed on March 30, 2006