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Protecting Workers: Exposure Limits to Exposure Controls

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Abstract

Occupational hygienists have used exposure limits as a trigger for remedial action, a target for engineering control efforts, and as a tool in selecting appropriate personal protective equipment. The limits have often been set in the absence of complete scientific understanding and with significant uncertainties. The formal processes for modifying existing limits or setting new limits are often controversial and slow to respond to changing conditions, such as the introduction of new materials or exposure situations, e.g. mixtures. Hygienists often use professional judgement when dealing with situations where exposure limits are inadequate or non-existent, for example for biological agents and nanomaterials. New systematic approaches to exposure control have been devised that use gross properties, qualitative exposure assessment, and categorical risk phrases to guide in the selection of appropriate control strategies. Applying these techniques along with appropriate professional judgement can be used to protect workers from potentially harmful exposures in the absence of complete scientific information.

1. Basis for Exposure Control

Workers are exposed on the job to a myriad of chemical substances, biological agents, physical agents, and other stressors, often in combination, that may create or increase the risk of death or serious physical harm to the worker. Occupational hygienists are responsible for assessing and managing these risks so that workers do not suffer physical harm while just trying to earn a living. Occupational hygienists often use established occupational exposure limits (OELs) to guide their decisions regarding the need for engineering controls, personal protective devices, or to answer the basic question, "is this work place safe?" However, limits do not exist for all substances and are often inadequate for dealing with mixed exposure settings which is a common occurrence. Strategies beyond reliance on OELs are needed for dealing with the 21st Century workplace.

2. Occupational Exposure Limits

Occupational exposure limits (OELs) were developed largely during the mid-20th century. In the United States, many OELs were originally developed by a private professional organization known as the American Conference of Governmental Industrial Hygienists (ACGIH) which was founded in 1938. The ACGIH first published a list of Maximum Allowable Concentrations for 63 substances in 1942. The ACGIH's list later became the Threshold Limit Values® or TLVs®. The TLV® list is published annually by the ACGIH, and includes updates and additions to the list of substances with a TLV® (ACGIH 2007). In the U.S., the Occupational Safety and Health Act of 1970 provided a 24-month period following enactment on December 29, 1970, when the newly-created Occupational Safety and Health Administration (OSHA) could adopt existing standards used by the government (U.S. Government 1970, Section 6 (a)). Using this authority, during 1971, the 1968 ACGIH TLV list was incorporated into U.S. regulations as Permissible Exposure

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Limits (PELs). Due to the cumbersome processes that evolved from the Act (U.S. Government 1970, Section 6 (b)), by regulation, and as a result of several landmark court decisions, changing existing PELs or establishing limits for new substances, the PELs have become stagnant for 37 years, with most currently enforced standards dating back to the ACGIH's 1968 TLV® list. Further, with the introduction of new materials into the work environment, and with the recognition of the hazardous properties of previously unregulated substances, the updating of old PELs and the creation of new PELs has proved challenging (Howard, 2005).

Private standard-setting organizations and consensus standards bodies have continued to develop new limits based on emerging scientific advances (ACGIH, 2007, AIHA, 2006). Yet there remain many substances and hazards such as biological hazards that have no enforceable exposure limits or recommended guidelines for safe exposure. Occupational health practitioners increasingly are relying on professional judgment and ad hoc standards of practice to advise employers, operators, and workers on necessary use of exposure controls including engineering controls, administrative controls, and personal protective equipment.

2. Assessing Risks Using OELs

The easiest situation for an occupational hygienist to assess is one in which workers are exposed to a single substance that has an established OEL. OELs are not fine-lines for determining between safe and unsafe conditions. They are not relative measures of toxicity between substances they are the levels at which the setting body believes that most workers can be exposed continuously without suffering material harm (ACGIH 2007). Even substances that have long-established and well known exposure limits, asbestos for example, has substantial uncertainties associated with its limit, how the measurement should be made, and how to interpret the result in comparison to the stated limits. Additionally, it is also recognized that significant risk remains even at the regulated limit. Research issues remain to be addressed (NIOSH, 2007).

Despite the limitations, an OEL is an important component of a risk management system. Without an OEL, measurement of a contaminant exposure has no reference scale to give it meaning. The normalized concentration in occupational settings is often referred to as the "severity" index, and measures the concentration in multiples of the OEL. This useful construct can be used to evaluate a mixture when two or more substances act in the same manner on the same organ system, when "additivity" can be assumed; i.e. in the absence of informion to the contrary or if known synergism exist (NIOSH 2004a). To compute the mixture severity under the additivity assumption, the severity index for each independent exposure is summed, and if the sum exceeds unity, then the mixture would be considered to exceed the mixture OEL, e.g.:

$$\text{Severity (Mixture)} = C(1) / OEL(1) + C(2) / OEL(2) + \ldots + C(n) / OEL(n)$$

OELs are used by enforcement agencies to ascertain compliance with legal exposure limits. As such they do provide a target for workplace exposure controls. The occupational hygienist can compute single agent severities, mixture severities when appropriate, or can consider other safety factors in order to recommend appropriate control strategies to keep the severity indices below 1. The severity computed from an OEL is used directly in the selection of respiratory protective equipment. The worst-case expected severity is estimated, and then a respirator class is selected that has an "assigned protection factor" greater than the expected worst-case severity (NIOSH, 2004b; OSHA, 2006).

3. Risk Management in the Absence of OELs

Exposures of concern for which established limits are lacking include those for biological aerosols, newly recognized hazards, and newly introduced chemicals and substances. Additionally, in recent times occupational hygienists have had to deal with controlling exposure to warfare agents, largely as potential exposures for emergency responders and site remediation workers in connection with terrorist events.

3.1 Biological Agents

Mold has been a recognized hazard since biblical times, yet specific criteria for assessment such as established OELs are lacking. The need for assessments increased dramatically in the U.S. following the hurricane Katrina disaster of 2005. A related issue is the development of appropriate risk management plans for dealing with health care workers potentially exposed to airborne infectious agents such as tuberculosis, SARS, and more recently avian and or pandemic influenza. A lively debate exists between infection control specialists and occupational safety and health specialists on the selection of appropriate respiratory protection. However, most agree that the primary control measures should be prevention through administrative controls that limit the extent of contact with infectious patients, i.e., rapid identification of infectious patients combined with isolation; and also through engineering controls such as negative pressure rooms and ultraviolet germicidal irradiation (ACOEM 1998). Without OELs for mold or infectious agents, it is not possible to use the quantitative respiratory protection algorithm described above based on the severity index. Instead other methods are used based on professional judgment and epidemiological experience (Lenhart, 2004).

3.2 Nanotechnology

Another category of exposures without established exposure limits is new substances introduced that have the potential to produce adverse health effects. A recent example is the introduction into commerce of products based on nano-sized materials. Nanomaterials are defined as those substances that have characteristic dimensions smaller than 100 nm. These include substances that have limited adverse health effects when they exist as macro-sized particles, but have the potential for unexpected health consequences when produced in nanometer size. For example, ultrafine-sized particles of titanium dioxide have been observed to have higher carcinogenic activity than fine-sized particles in toxicology studies using rats.

With respect to nano-sized materials, an occupational hygienist must consider the following issues when developing a worker protection program:Are workers being exposed to the material?

- What is the concentrations to which workers are exposed?
- Are there potential adverse health effects from the new material?
- What controls are available?
- How effective are the controls?

Worker risks can also be assessed prospectively, by considering the characteristics of potential new hazards and projecting potential health effects. Nanotechnologies are increasingly being used in applications ranging from electronics and medicine to cosmetics and clothing. With their extremely small size and large surface area, understanding the chemical, physical, and biological properties of engineered nanoparticles compared with larger counterparts is essential to understanding associated risks. That is, while nanoparticles can offer significant health benefits, such as crossing the blood-brain barrier to deliver therapeutic cancer drugs, they could also pose new health risks. Recent studies using mice with pharyngeal aspiration of single-walled carbon nanotubes produced increased pulmonary toxicity including acute inflammation, fibrosis and granulomas a month after exposure to low doses. Equal doses of ultrafine carbon black particles or fine crystalline silica (SiO_2) did not induce granulomas or alveolar wall thickening and caused a significantly weaker pulmonary inflammation and damage (Shvedova, 2005). Studies to date have been limited to a few nanoparticle types used in some workplaces, so substantial knowledge gaps remain.

Because the earliest, most extensive exposures to nanoparticles will likely be in the workplace, timely research is crucial. In fact, billions of dollars are being poured into nanotechnology research and development to bring the best assessment and mitigation approaches to bear on health and environmental protection (Bartis 2006). The National Institute for Occupational Safety and Health (NIOSH) established the

Nanotechnology Research Center in 2004 to coordinate and facilitate research in support of workplace safety, and this Center collaborates with the Organization for Economic Cooperation and Development to enhance international coordination and communication. The goals of ongoing NIOSH nanotechnology activities are:

- Determine if nanoparticles and nanomaterials pose risks for work-related injuries and illnesses.
- Conduct research on the application of nanotechnology for the prevention of work-related injuries and illnesses (i.e., harness the benefits, such as via better sensors, filters, and protective materials).
- Promote healthy workplaces through interventions, recommendations, and capacity building.
- Enhance global workplace safety and health through national and international collaborations on nanotechnology research and guidance.

Practicing occupational hygienists dealing with new substances like nanomaterials need to use professional judgment when recommending exposure limiting controls until research on the potential hazards clarifies the situation permitting science-based risk management recommendations.

3.3 Flavoring Agents

In August 2000, the Missouri Department of Health and Senior Services requested technical assistance from NIOSH in an investigation of bronchiolitis obliterans in former workers of a microwave popcorn plant in Jasper, Missouri. Bronchiolitis obliterans is a serious lung disease that is irreversible. Based on studies of case clusters in workers from several plants where butter flavoring chemicals were used, recommendations for limiting worker exposure were developed including: substituting alternative flavoring agents, engineering controls, administrative controls and the use of personal protective equipment (NIOSH, 2004c). While it will take additional research to establish science-based exposure limits for diacetyl and other agents in the flavorings mixtures, practical steps can be taken in the absence of full information to reduce or eliminate exposure, thus reducing or eliminating disease potential.

4. Approaches for Managing Occupational Risks

To cope with the uncertainties of such ongoing and emerging exposure situations, occupational health professionals have developed various systems for risk management that do not require existence of precise occupational exposure limits. Techniques such as control banding provide a logical rubric for exposure control based on the amounts of materials present, the probability of those materials resulting in exposure, and the relative toxicity of the agent (HSE, 2007). Alternative judgment-based methods also exist.

5. Conclusions

In summary, occupational health professionals are faced with challenges of updating response information from old agents of concern as well as from new exposure agents. Techniques have been developed for managing risks that can be used in the absence of data and full scientific understanding. Ideally, these approaches would rely on extensive evaluation and integration of multiple types of data, ranging from exposure conditions and variability in human susceptibility across the population groups exposed to the hazards themselves – including physical, chemical, and biological characteristics and behaviors of mixtures and new materials. When data are limited, management techniques must tap qualitative approaches that incorporate available information to guide worker protection programs, with a process for updating these measures as new information becomes available.

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