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SHORT COMMUNICATION

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The role of odor and irritation, as well as risk perception, in the setting of occupational exposure limits

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Abstract *Objective*: This paper reviews current research regarding the relationship between odor perception or irritation and setting an occupational exposure limit (OEL). Special focus was directed at those settings where a small fraction of persons report unacceptable responses to concentrations well below the OEL. *Methods*: We evaluated the published literature on the topic of irritation and olfactory response to exposure to industrial chemicals. More than a dozen researchers have been active in this area over the past 10 years. *Results*: It was found that for some chemicals, even when one maintains airborne concentrations below a particular OEL, this level of exposure may not be adequate to prevent all persons from reporting an appreciable adverse response. In some cases, worker's pre-existing belief systems about the source of an odor may be sufficient to require that they have not be exposed to any detectable concentration. In addition, detection of odors by workers may tap into the person's aversion to odors, in general. In both situations, it is often necessary to address these specific issues through risk communication and dealing directly with risk perception. *Conclusions*: For practical reasons, the current objective of organizations charged with setting OELs for chemicals is to identify concentrations that do not cause irritation or widespread reports of unpleasant sensory stimulation in the vast majority of workers (e.g., about 80–95%).

Keywords Odor · Risk perception · Chemosensory effects · Occupational exposure limits · Industrial hygiene

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Introduction

Chemicals from municipal, agricultural, and industrial sources produce odors that affect everyday life. Pleasant smells are often associated with good food, favorite places, or loved ones. Foul odors may bring thoughts of unhappiness, bad memories, and polluted or dirty air. These chemicals are detected by both olfactory and trigeminal stimulation. Olfactory stimulation relays messages to the brain using the first cranial nerve for odor perception. Trigeminal stimulation is responsible for sensing the irritation or pungency of a chemical using the fifth cranial nerve (Shusterman 1992). Although anatomically distinct, both pathways help people to distinguish and characterize the inspired air.

Sensory irritants are important when characterizing the quality of the workplace. Interestingly, nearly 33% of the nearly 1,000 chemicals for which an OEL has been established have odor or irritation as their most sensitive adverse effect (Paustenbach 2000). For this reason, as well as others, it is important to understand the characteristics of a chemical, the work environment, and the worker. These factors influence whether a particular airborne concentration of a chemical is considered acceptable, barely tolerable or intolerable.

In an occupational setting, exposure to a chemical odor is considered adverse when an unwanted response occurs as a result of the exposure. An unwanted response may range from an unpleasant smell to a more serious, irritating effect. The person experiencing this unwanted response is more inclined to perceive himself/herself to be at a higher risk for further adverse health effects. He/she may begin to associate the chemical with danger. In the past, OELs attempted to prevent these unwanted responses, especially irritation. In many cases, however, highly sensitive persons may have left workplaces that they found unacceptable, while the less sensitive workers remained. This may have influenced the body of data from which most of the current OELs were derived. It has long been recognized that, in some cases, a chemical may be odorous but not cause any adverse health effects, thereby creating a perception of risk in those exposed. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) committee and the German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission) have, over the years, handled this challenge in slightly different manners. The purpose of this paper is to examine the role chemical odors play in risk perception and whether these can be accommodated in the setting of OELs.

Chemosensory models

Figure 1 depicts three chemosensory models described in detail by Dennis Shusterman in 2001 (Shusterman 2001). Model I represents chemicals that are potent irritants, such as methyl isothiocyanate (MITC), that do not have a detectable odor at the lowest concentration they may cause irritation in humans (irritation threshold). In other words, the irritating effect of the chemical will be recognized at concentration levels below which an odor is detected. This is a rare situation with respect to most chemicals encountered in the workplace.

A much more common scenario is presented by Model II. In this case, on an ascending concentration scale, the chemical's odor is detected before irritation occurs. For example, phosphine (PH_3) gas is not an irritant at the odor threshold, or at concentrations that its odor is first detected. Therefore, as long as the airborne concentration remains below the irritation threshold, PH_3 gas does not cause adverse health effects and may be tolerated by those exposed. However, if exposure occurs above the irritation threshold, an unconditioned adverse response may follow. This experience may then lead to conditioned adverse responses occurring anytime the chemical odor is detected in the future, even at concentrations below the irritation threshold (Shusterman (2001). Hence, exposure to the chemical at concentrations below which they cause any adverse effects may no longer be tolerated.

The final chemosensory model, Model III, represents situations where the concentration at which one can smell the chemical (odor threshold) is much lower (more than one order of magnitude) below that at which irritation occurs (irritation threshold). Examples of chemicals that follow this model are hydrogen sulfide (H_2S) and various mercaptans. Exposures to these chemicals often promote a perception of increased risk and increased symptom reporting even though the concentrations are well below those that may cause an adverse effect.

Influence of odor on risk perception

Occupational and environmental odors play important roles in how workplaces and neighborhoods are

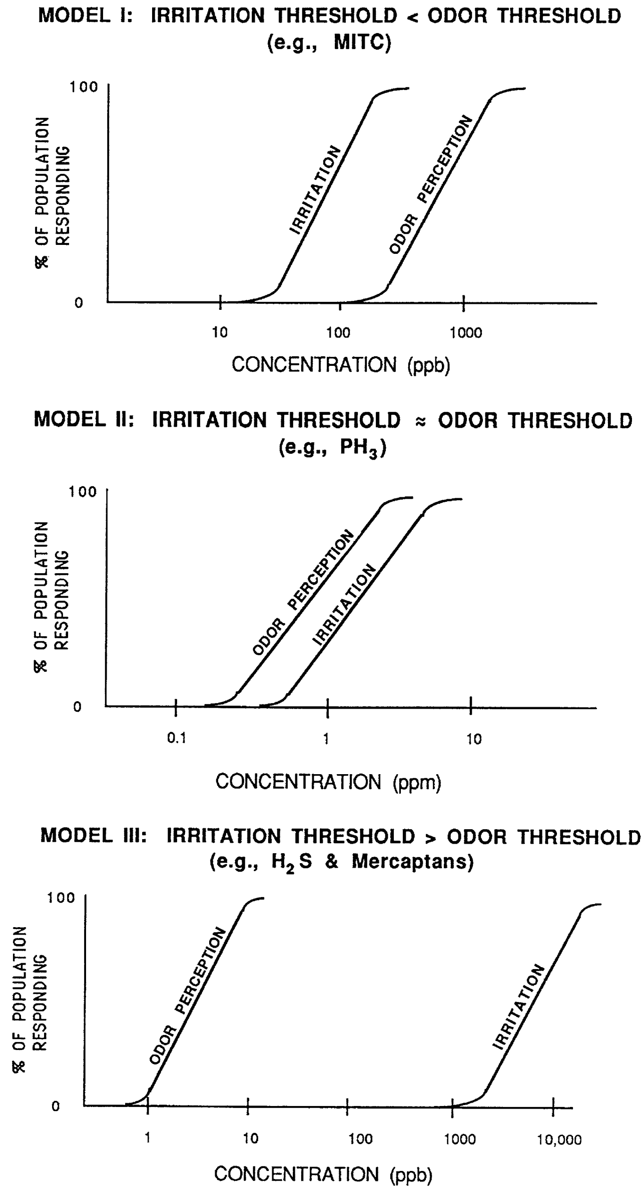

Fig. 1 Chemosensory models taken, with permission, from Shusterman (2001). Model I represents potent chemicals that may cause irritation at levels below which their odor can be detected. Model II represents chemicals that have an odor threshold below the irritation threshold. Model III describes odorous chemicals that have detectable odors at concentration levels several orders of magnitude below the levels at which they are irritants

perceived. Workplace morale and environmental justice issues are often focused around perceptions of increased risk due to unpleasant odors. Factors known to augment risk perception include (Dalton 1996, 1999; Dalton et al. 1997; Shusterman 1992; Shusterman et al. 1991):

- The source or odor is not of perceived benefit to the observer.
- The source or odor is not under the control of the observer.
- The source or odor is considered an exotic or unfamiliar technology.
- The source or odor has perceived risks that are

dreaded (e.g., cancer, birth defects) or are potentially catastrophic.
- The odor reminds the observer of some prior unfortunate event (e.g., such as hydrogen sulfide exposure and nausea).
- The exposure is environmental in nature and may be perceived by the observer to threaten his/her family and neighbors as well as his/herself.

Factors that augment risk perception may also augment symptom reporting when the stimulus is ambiguous (i.e., a potent odorant/weak irritant such as H_2S). Shusterman et al. (1991) found that odor perception and environmental worry exhibited positive interaction when modeled as determinants of symptom prevalence in residents living near hazardous waste sites. In occupational settings, decreased employee morale and increased adverse health symptom reporting may result from a perceived increase in risk due to odorous chemicals.

Furthermore, personal expectations, prior experience and perceived risk of an odor may affect a person's ability to adapt to an odor (Dalton 1996, 1999; Dalton et al. 1997). For example, Dalton et al. (1997) found that subjects were able to adapt to odors more easily if they were under the impression that the odor was good for them or smelled pleasant. The subjects that were told that the odor was bad for them or perceived it as harmful reported higher odor intensities, irritation, and significantly more adverse health effects. It should be noted, however, that adaptation itself could be considered an adverse effect in situations where a chemical is an irritant and the chemical's odor may warn of the chemical's presence before irritating effects occur (chemosensory Models II and III). Odor perception as a warning signal may be lost with adaptation, and therefore, it may be best if adaptation does not occur in some scenarios where irritation is severe.

Developing occupational and environmental standards for odors and irritants

In the United States, OELs have attempted to avoid chronic irritation, rather than simply odor detection, in most workers. In other countries, the percent of workers intended to be protected and the level of protection varies. In some countries, the objective is to minimize worker recognition of odors or irritants. In other countries, it is accepted that a significant fraction of the workforce may recognize the odor or irritant but, lacking adverse effects, it is considered acceptable. For all organizations, the goal of OELs is to keep workers healthy. However, in the case of odorous chemicals, more stringent guidelines may be necessary to keep risk perception and subsequent symptom reporting, low. This is problematic since risk perception is strongly based upon individual biases, and it is technologically infeasible to protect all workers from recognizing unpleasant odors. Therefore, the challenge surrounding this issue is to determine how to set the OELs of odorous chemicals best while balancing engineering feasibility. Furthermore, in some instances, regardless of the magnitude of the specific OEL, additional dialogue with employees with respect to the relationship between odor detection and risk perception may be needed for the OEL to be considered tolerable.

Although human studies are the most reliable, these data are not often available. In place of human data, there are many models that may be used to help set OELs for irritants. For example, the RD50 method measures the respiratory rate of mice as measured in laboratory studies. The RD50 is the chemical concentration at which a 50% decrease in respiratory frequency is observed. Human irritation thresholds can be estimated as a function of the RD50 value (Nielsen and Alarie 1982; Paustenbach 2001). Furthermore, there are multiple models based on chemical properties that could be used to predict irritation. For example, a model based on disassociation constants can be used for organic acids and bases (Leung and Paustenbach 1988; Paustenbach 2001; Paustenbach 2000).

At this time, there is a need within the occupational health community to identify the percentage of workers that should be protected from any adverse effect when they are exposed to an OEL. To the best of our knowledge, no guideline or standard setting organization has attempted to identify such a value. For example, some of the OELs set by the Occupational Safety and Health Administration (OSHA) in the United States or by the ACGIH are thought to protect virtually 100% of the working population from the possibility of acute toxic effects. Other OELs may protect only 60% of the workforce from reversible adverse effects that do not produce an objective pathologic response, such as irritation. Protecting only 60% of the working population from unpleasant odors may be acceptable, but perhaps a higher percentage should be protected from irritating effects. Once the various groups who set OELs decide the fraction of the worker population they believe needs to be protected, the RD50 and chemical property-based models mentioned above may be useful for helping to identify human irritation thresholds for various compounds.

If the occupational health community gets to the point where elimination of odor perception is the goal, OELs derived from these models may not be ideal. Rather, the OEL would simply be set at the lowest concentration the chemical is detected by the agreed-upon "objective" percentage of the workforce. Currently, setting OELs at concentrations which prevent the detection of odor is frequently not economically feasible, especially for those chemicals that resemble Model III of the chemosensory models. Until society has addressed more serious occupational health hazards, setting OELs for chemicals which are initially detectable due to irritation or odor, but for which self-adaptation quickly occurs and no measurable adverse health effects are expected (even with adaptation), is probably a reason-able compromise for many chemicals. It should be recognized, however, that OELs set at concentrations which do not cause even transient irritation or produce distinct odor recognition in most workers, may still be deemed intolerable by some fraction of the workforce. This is precisely why it is important for the occupational health community to agree upon the percentage of workers (rather than members of the general public) to be protected from sensory irritants at various OELs. After that figure is identified, a standard process for establishing specific concentrations can be agreed upon.

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References

Dalton P (1996) Odor perception and beliefs about risk. Chem Senses 21:447–458

Dalton P (1999) Cognitive influences on health symptoms from acute chemical exposure. Health Psychol 18:579–590

Dalton P, Wysocki CJ, Brody MJ and Lawley HJ (1997) The influence of cognitive bias on the perceived odor, irritation and health symptoms from chemical exposure. Int Arch Occup Environ Health 69:407–417

Leung HW, Paustenbach DJ (1988) Setting occupational exposure limits for irritant organic acids and bases based on their equilibrium disassociation constants. Appl Ind Hyg 3:115–118

Nielsen GD and Alarie Y (1982) Sensory irritation, pulmonary irritation, and respiratory stimulation by airborne benzene and alkylbenzenes: prediction of safe industrial exposure levels and correlation with their thermodynamic properties. Toxicol Appl Pharmacol 65:459–477

Paustenbach DJ (2001) Approaches and considerations for setting occupational exposure limits for sensory irritants: report of recent symposia. AIHAJ 62:697–704

Paustenbach DJ (2000) The history of biological basis of occupational exposure limits for chemical agents. In: Harris R (ed) Patty's industrial hygiene. Wiley, New York, pp 1903–2000

Shusterman D (1992) Critical review: the health significance of environmental odor pollution. Arch Environ Health 47:76–87

Shusterman D (2001) Odor-associated health complaints: competing explanatory models. Chem Senses 26:339–343

Shusterman D, Lipscomb J, Neutra R and Satin K (1991) Symptom prevalence and odor-worry interaction near hazardous waste sites. Environ Health Perspect 94:25–30