

Responses to odors in occupational environments

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Purpose of review

There is mounting evidence that the presence of airborne chemicals that produce odor and irritation can be a significant impediment to a productive and healthy workforce, even among individuals without chemical sensitivity.

Recent findings

Studies investigating odor and irritant-induced symptoms in occupational environments suggest that poor indoor air quality, coupled with psychosocial factors such as the work environment, personality and stress, can lead to the development of building-related complaints and exacerbate chemical intolerance and symptoms. The practice of introducing pleasant odors in the workplace to improve productivity and mood is not well supported by current research.

Summary

Managing the response to odors and irritants in the workplace is critical to maintaining the health and well being of workers. There is a critical need for regulatory organizations in the United States and elsewhere to harmonize guidelines for occupational exposure limits. In addition, management must engage in risk communication and education of workers in order to ensure that misperception of risk from odors does not lead to illness and loss of well being.

Keywords

chemical sensitivity, irritants, occupational exposure limits, odors, risk perception

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Introduction

Understanding the potential for odors and irritants to elicit adverse reactions in the workplace is a critical feature in maintaining the health, well being and comfort of workers. This paper will review the current state of our knowledge regarding the types of sensory, psychological and behavioral effects and symptom reports produced by the perception of odors and irritants in occupational environments. In addition, however, the recent practice of scenting work environments to elevate mood, increase concentration and promote relaxation will also be discussed.

Although there are documented adverse effects on olfactory function from exposure to airborne occupational chemicals, these effects are beyond the scope of this review. For a recent review of olfactory toxicity in humans and experimental animals, see [1].

In the following sections, we briefly review the physiological systems that are responsible for the perception of odors and irritants and the factors contributing to individual variation in the perception of odors and irritants, including genetics, health, age and experience. This is followed by a section describing the current research on

adverse responses to odors and irritants in the workplace, ranging from sick building syndrome (SBS) to mass psychogenic illness (MPI). We follow this by describing some recent uses of odors in the workplace that are thought to improve the occupational environment. We also provide some background on the regulation of odors/irritants in the workplace in the United States and worldwide, and discuss the difficulty inherent in setting occupational limits for odors and irritants that are protective of the health and comfort of the majority of workers.

Odor and irritant perception: physiology and individual variation

The initial stages of odor and irritant perception are localized within the nose. The nasal cavity is innervated by the olfactory nerve (CN I) whose primary function is odorant detection. Odor information is transmitted via the bundles of axons that form the olfactory nerve (CN I), which extend from the olfactory receptor cells in the olfactory epithelium through the cribriform plate to synapse, unbranched, within the olfactory bulb, a small structure in the base of the forebrain where receptor input is integrated prior to being transmitted to primary and secondary olfactory areas in the brain.

In addition to the olfactory receptors, the nasal cavity is innervated by unmyelinated, free nerve endings of the maxillary and ethmoid branches of the trigeminal nerve, which are capable of detecting chemically and mechanically stimulated sensations of pungency, irritation, warmth and coolness. Chemical stimulation of the trigeminal nerve (known as chemesthesis) often combines with stimulation of the olfactory nerve to produce sensations that form an overall perception of a chemical. For example, low concentrations of ammonia produce a distinct odor; however, higher concentrations may also elicit a mucosal burning or tingling, which is the chemesthetic or irritant component of perception. Most chemicals at sufficiently high concentrations are capable of eliciting upper respiratory tract irritation in addition to odor sensations. Because these two sensory pathways (olfaction and chemesthesis) can be activated by a single chemical stimulus and localized to the nose, workers often experience and report odor and irritation as a unitary perception.

Individual variation in olfactory and trigeminal sensitivity arises from many factors, including genetics, health, age and experience. For example, an individual's genetic profile determines what receptors are expressed and thus, what can be detected via smell [2]. Conditions such as allergies or chronic rhinosinusitis can render an individual either more or less sensitive to the perception of odors and irritants [3–5]. Age-related declines have been documented for both the perception of odor and intranasal irritation [6,7], whereas repetitive exposure typically leads to sensory adaptation that also greatly decreases the ability to detect volatile chemicals [8]. Thus, what might constitute an annoying odor or irritant sensation to one worker might barely be noticed by another and leads to controversy over what segment of the worker population should be targeted when attempting to minimize discomfort.

Responses to odors/irritants in the workplace

In the section that follows, we describe the current perspective on the types of adverse responses that can occur from exposure to odors and irritants in the workplace. We also discuss the limited evidence for the use of odors to improve productivity in occupational environments.

Multiple chemical sensitivity

Multiple chemical sensitivity (MCS), also known as idiopathic environmental intolerance (IEI), is an acquired chronic disorder characterized by multiple recurrent symptoms, which affect different organs. Its sufferers consider it to be caused by exposure to low levels of environmental chemicals, which are at a well tolerated concentration for the majority of the population [9]. Among the medical establishment, there is no consensus on whether MCS–IEI symptoms are due to a

psychological response to perceived chemical toxicity or to a physiological–pathological interaction between the chemical agents and organ systems [10].

Odors are considered to be one of the key triggers that may induce MCS symptoms, and in the few studies controlling for odor, blinding MCS patients to the perception of odor has been shown to reduce or eliminate all symptom reports [11]. Moreover, several studies [12–14] have shown no differences in either odor threshold sensitivity or identification ability among MCS patients and controls, leading many researchers to conclude that the adverse responses to odors among MCS patients arises from higher level processing of the odor stimuli. In support of this position, recent studies using brain imaging techniques suggest that people suffering from MCS process olfactory information differently as compared with controls [15,16^{••}]. Hillert *et al.*'s [15] study using PET showed that MCS patients in response to odors have reduced activation of cerebral regions involved in olfactory processing, and at the same time had an odorant-related increase activation of other cerebral areas such as anterior cingulate cortex (involved in anticipation, attention, conditioning and perceptual selection) and cuneus–precuneus (retrieval of episodic memories including odor memory). They suggested that this pattern of activation in MCS indicated a top-down regulation of odor response via cingulate cortex. Interestingly, they did not find signs of neuronal sensitization in MCS odor processing. On the contrary, Orriols *et al.* [16^{••}], using single-photon emission computed tomography, also found that odor stimulation produced a significant decrease in the activation of olfactory processing areas in MCS patients as compared with controls, but odor stimulation significantly increased activation of other brain areas in controls as compared with MCS patients.

Another approach was used by Andersson *et al.* [17^{••}] to detect cognitive differences in odor processing with people suffering from MCS. In this case, they looked at reaction time using event-related potentials in response to chemical stimuli. They found that people with chemical sensitivity showed increased attentional bias toward chemical stimuli, such that these patients had difficulties in ignoring chemical stimuli when asked to pay attention to another task. In addition, MCS patients showed signs of sensitizations instead of the expected habituation after repeated chemical exposure [17^{••}].

Taken together, these results suggest that the symptom reports related to odor perception among MCS patients result from differences in cognitive processing rather than differences in sensitivity or susceptibility to chemicals. Nevertheless, given the extreme intolerance individuals with this condition will exhibit toward odorous

environments, it remains an exceedingly difficult problem to manage in the workplace.

Building-related illness

SBS or nonspecific building-related illness is a condition that primarily affects workers in nonindustrial environments such as office buildings, schools or even hospitals. The symptoms are characterized by skin irritation, headache and respiratory problems often attributed to indoor air pollution coupled with work-related stress and individual differences in susceptibility. An excellent review [18] of SBS was recently published in this journal.

Volatile compounds, which give rise to the perception of odor, are one of the primary triggers thought to elicit SBS complaints. To evaluate this, a study of 176 office buildings in Finland measured the ambient concentrations of 50 common nonreactive volatile organic compounds (VOCs) and formaldehyde to determine the association between these levels and SBS complaints. Although the levels of formaldehyde in more than 50% of the buildings were above the concentration thought to elicit sensory irritation, no relationship was found between the reported symptoms and the levels of VOCs or formaldehyde [19].

Inadequate ventilation, leading to the buildup of odors and irritants, has also been suggested as causal in eliciting SBS. Because of increased energy concerns in the 1970s, the design of new office buildings focused on energy efficiency, leading to 'tight' or 'sealed' buildings with little natural ventilation and a concomitant increase in building-related complaints. To evaluate this relationship, studies have investigated the association between ventilation, air quality and SBS complaints, with conflicting results. A recent study [20] compared the prevalence of SBS symptoms among workers from a sealed versus a nonsealed (naturally ventilated) building, using a standardized SBS questionnaire to characterize the symptoms. In addition, measurements of indoor air quality, including relative humidity, total particulate matter (TPM) and total VOCs (TVOCs) were taken. Although indoor air quality was found to be worse in the naturally ventilated building with higher levels of TPM, TVOCs and benzene, the prevalence of SBS symptoms was greater in the sealed building [20]. These results suggest that perceptual or psychosocial factors other than actual levels of indoor air pollution are driving the workers' response.

Although environmental risk factors for the emergence of SBS complaints have been well documented, much of the research focus has shifted toward understanding the personal risk factors for SBS, including the role of personality traits, chemical intolerance and psychosocial work environment. Numerous epidemiological investigations have found a strong relationship between building-

related complaints, chemical intolerance and personality factors [18]. However, in a recent laboratory study, Fiedler *et al.* [21] investigated the relationship between SBS symptoms, VOC exposure, stress and personality traits and found that people high on the dimension of negative affectivity were more anxious after exposure to VOCs, but negative affectivity was not correlated with increased symptom reports. However, they and others have acknowledged that it is very difficult, if not impossible, to recruit individuals with high levels of negative affectivity or concerns about chemical exposure into controlled exposure studies. Thus, it is likely that these and similar results represent an underestimation of the true impact of personality and susceptibility factors on the production of building-related illnesses subsequent to odor perception.

A recent study [22] suggested that oxidative stress was a potential mechanism underlying the elicitation of SBS. They found that the presence of urinary 8-hydroxydeoxyguanosine (8-OHdG), a biomarker related to oxidative stress on DNA, was significantly elevated in participants reporting SBS symptoms. This compound, 8-OHdG, was also significantly associated with VOCs and carbon dioxide levels in the offices [22]. What remains unclear from this study, however, is whether 8-OHdG is simply a biomarker of exposure to VOCs or a biomarker of effect.

In summary, the available evidence points toward a complex interaction between indoor air conditions, such as discernible odor, and personality factors or chemical intolerance among the workforce.

Mass psychogenic illness

MPI, or mass hysteria, refers to 'the collective occurrence of a set of physical symptoms and related beliefs among two or more individuals in the absence of any identifiable pathogen' [23]. Social psychological processes of contagion, in which complaints and symptoms spread from person to person, and convergence, in which groups of people develop similar symptoms at about the same time, underlie MPI. Environmental events, such as an unpleasant odor, can trigger contagion and convergence processes, and occupants who cannot readily identify what has triggered their symptoms often attribute these to any visible environmental changes, such as installation of a new carpet, or invisible agents, such as a 'mystery bug'. MPI symptoms include headache, nausea, weakness, dizziness, sleepiness, hyperventilation, fainting and vomiting, and occasionally skin disorders and burning sensations in the throat and eyes [24,25]. MPI reactions probably arise from the interaction of preexisting poor physical environment conditions (poor ventilation, poor lighting and excessive noise), stressful work conditions (tedious work, poor organizational climate and poor labor-management relations), disposition differences

among individuals (gender differences and differences in anxiety levels), with the occurrence of a triggering event (bad or unusual odor) followed by inappropriate management response to the perceived threat [26,27].

Controlled laboratory studies have consistently shown that the presence of an odor that is mischaracterized as hazardous can produce symptoms in the absence of any toxic trigger [28–30]. More recently, symptoms typical of MPI were experimentally induced by having patients first observe a female confederate inhale a placebo, which was described as a suspected environmental toxin linked to MPI [31]. In the group assigned to subsequently inhale the placebo, observation of the confederate displaying symptoms increased specific symptoms significantly among the female, but not the male, patients. Given the higher preponderance of women exhibiting symptoms in cases of MPI, these results suggest that social modeling may play a role in the development of psychogenic symptoms to odors in the workplace. To mitigate this occurrence, in situations involving the potential for a novel odor to be introduced into the workplace (i.e. changeover in a product line, extensive renovations or new furnishing/carpeting), advance information on the sensory impact and risk communication should be provided to the workforce [32].

Chemosensory distraction/annoyance

For the regulation of chemicals in the workplace, the avoidance of sensory irritation is among the most critical effects and more than 40% of occupational exposure limits (OELs) in the USA as well as in Sweden [33] are based on this endpoint.

However, secondary effects of annoying odors or irritation that interferes with ongoing occupational activities may also be of concern in the work environment. To date, however, the effects of chemosensory stimulation on behavior, attention and distraction have been poorly investigated and thus the impact of odors and irritants on work-related performance is generally unknown.

In the auditory domain, for example, the addition of low-frequency noise to the work environment has been shown to reduce performance in several cognitive tasks [34]. In the chemosensory domain, Van Thriel *et al.* [35] have shown that individuals describing themselves as ‘chemically sensitive’ performed worse in a divided attention task during exposure to 1-octanal and isopropanol than did nonsensitive individuals. However, this finding was not confirmed in a study [36] investigating the distractive effects of 2-ethylhexanol on a divided attention task, in which there was neither a general effect nor a consistent effect across chemically sensitive individuals. Nevertheless, the potential for annoying or distracting effects of odors or irritants on work-related performance cannot be

ruled out on this basis, as this may differ across specific chemicals as well as interact with personality characteristics and the type of work performed [37]. Indeed, as discussed later, there are three chemicals for which the Occupational Safety and Health Administration (OSHA)-recommended OEL is based on objectionable odors, which are thought to be sufficiently distracting as to cause safety hazards in the workplace [38].

Positive effects of workplace odors

In contrast to the foregoing discussion of adverse outcomes that may result from the perception of odors, irritants or both in occupational environments, we now consider the limited evidence for positive effects from introducing fragrance into workplace settings. In many homes and personal spaces, the use of fragrances to affect mood and improve perceived indoor air quality is quite common and has become a multibillion dollar a year business. Although by no means widespread, the coordinated introduction of odors into workplace environments has also been suggested as a method to improve mood and increase productivity. A small but scattered literature suggests that, at low levels, exposure to a pleasant odor can facilitate performance, increase alertness, promote relaxation and elevate mood [39]. In addition, Baron, as reported in Herz [39] found that participants who worked in the presence of a pleasant ambient odor reported higher self-efficacy, set higher goals and were more likely to employ efficient work strategies than participants who worked in a no-odor condition.

Unfortunately, regular exposure to any odor that is present at consistent levels leads to olfactory adaptation, thereby lessening the impact of the perceptual experience. More troublingly, however, is that identifying a scent or aroma that all exposed employees will find pleasant, invigorating or relaxing can be exceedingly difficult, as with only a few exceptions, responses to odors are highly idiosyncratic and based on personal experience. In all studies that measured odor hedonics, personal liking or disliking of an odor was directly related to the directionality of mood or behavioral change. In addition, the potential for one or a few chemically intolerant employees to exhibit symptom responses to a fragranced environment has likely increased employers’ caution for utilizing odors in work environments.

Regulation of odors in the workplace

Exposure to chemicals in the workplace is regulated by different agencies, depending on the country. It is worth noting that there are only three chemicals which the OSHA has regulated based on ‘obnoxious odor’: isopropyl ether, phenyl ether and vinyl toluene [38]. These levels were set based on worker complaints and the assumption that atmospheres containing detectable concentrations of

these substances can endanger workers by distracting them from the task and creating safety hazards. In contrast, of the more than 600 substances for which an OEL has been established, more than 40% are based on the avoidance of sensory irritation [33]. The OELs are set at concentrations considered to be well tolerated and comfortable for the vast majority of the worker population, although the precise percentage of the exposed population is often not specifically identified and may vary widely across limit-setting bodies. An approach for setting OELs based on chemosensory models of perception has recently been described [40] and begins with identifying whether the toxicity of a chemical falls at or below the sensory thresholds for that chemical. If so, then the OEL should be based on that endpoint. However, for many chemicals, the lowest level of adverse effect will be irritation and, for those chemicals, the process should begin with identifying the odor and irritation threshold. If the odor of the chemical is pleasant or does not cause the perception of risk, then setting the OEL should occur at or below a level of sensory irritation that is tolerable by the majority of the workforce. In those cases in which the odor itself may increase the perception of health risk, an effective education program must be employed to adequately disseminate information about the chemicals' properties and expected effects to the workforce.

Perhaps of equal importance, however, is the need to harmonize OELs across the various regulatory bodies in each country, which, to date, has not been systematically addressed. OELs for many chemicals differ significantly depending on whether the limit was set by OSHA or recommended by the American Conference of Government Industrial Hygienists in the USA, the Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission) in Germany or the Scientific Committee on Occupational Exposure Limits (SCOEL) in the European Union. In one recent example, Kleinbeck *et al.* [41[•]] investigated the effects of three concentrations of ethyl acetate on behavior, physiology and psychology and observed no adverse effects at levels that were recommended by the German MAK commission as OELs but which were substantially higher than the proposed SCOEL values for that chemical. Given that studies collecting rigorous human threshold and exposure data are both intensive and costly, there is a critical need for regulatory bodies setting OELs to reach consensus on the percentage of the workforce to be protected, the adverse effects and toxicological endpoints of interest and the methods used to generate those data.

Conclusion

It is very difficult to achieve consensus on the regulation of odors and irritants in the workplace and it is nearly

impossible to achieve an odorless environment. Even if an odor is present at a perithreshold level, recent research indicates that it may be sufficient to generate a conditioned response in individuals who had been previously exposed with adverse consequences [42^{••}]. The potential for enormous individual variation in sensitivity, personality traits and other psychosocial factors is likely to promote great diversity in the tolerance of odors and irritants among any worker population. Therefore, responses to odors and irritants in the workplace will depend greatly on the sensory effects they produce, the beliefs and expectations of the workforce and the degree to which management engages in a comprehensive risk communication program to educate workers as to the safety and hazard profile of the environment. Given the significant potential for odors in the workplace to affect human health and productivity, there is a pressing need for continued research and a coordinated application of those findings in the regulatory process.

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Papers of particular interest, published within the annual period of review, have been highlighted as:

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Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 000–000).

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