Nuisance Odors: Is there a Concern - 12340

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ABSTRACT

Nuisance odors are generally thought of as just being annoying or unpleasant and not causing any physiological harm to our internal organs or other biologic systems. Yet during an excavation of buried animal remains, field workers experienced a multitude of symptoms that are associated with exposures to toxic materials. An examination of the decomposition process revealed that there is a potential off-gassing of a number of common, yet harmful chemicals including ammonia, mercaptans, hydrogen sulfide, butyric acid and phenol. In addition, other compounds, that have limited information such as established health data and occupational exposure limits, were also potential contaminants-of-concern. While a variety of monitoring and sampling techniques were used to assess worker exposures, all results indicated non-detectable airborne concentrations. Nevertheless, workers were experiencing such symptoms as nausea and headaches. As such, protective measures were necessary for field personnel to continue work while having confidence that the project was instituting sincere steps to ensure their health and safety. Researching the possible reasons for the causes of workers exhibiting adverse health effects from nuisance odors revealed that such exposures initiate electrochemical pathways, starting from the olfactory bulb to the brain, followed by a transfer of information to such biologic systems as the hypothalamus and pituitary gland. These systems, in turn, secrete hormones that cause a number of involuntary reactions; many of which are observed as typical adverse health effects, when in fact, they are merely reactions caused by the brain's memory; most likely created from previous experiences to unpleasant odors. The concern then focuses of how the Occupational Safety and Health community shall respond to such workplace exposures. Future work in this area may need to focus on the viability of current occupational exposure limits and the possibility of revising these standards. Another area of consideration would be whether nuisance odors will need separate and distinct criteria with regards to hazard identification and control.

INTRODUCTION

When one thinks of health concerns at Hazardous Waste Operations and Emergency Response (HAZWOPER) sites, airborne contamination is arguably the main issue. Respiratory protection, medical surveillance, monitoring methods as well as training are mandatory requirements specified by the Occupational Safety and Health Administration (OSHA) per 29 CFR 1910.120 [1], commonly known as the HAZWOPER Standard, and are designed to protect workers from such health hazards. While many of the hazardous materials associated with HAZWOPER sites have distinctive odors, it is not uncommon to find the airborne concentrations of on-site contaminants to be well within their respective occupational exposure limits (OELs): the most common being OSHAs permissible exposure limits (PELs) [1] and the Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists

(ACGIH) [2]. As such, the potential for these materials to cause physiological dysfunction to the various human biological systems is considered low while protective measures are relaxed, if not removed. Nevertheless, workers may still detect their presence through the sense of smell and often cause workers to be bothered at the unpleasant odor in which they must work. These airborne assaults are then referred to nuisance odors [3]. According to United States law, nuisance is defined as:

"…the unreasonable, unwarranted and/or unlawful use of property, which causes inconvenience or damage to others, either to individuals and/or to the general public. Nuisances can include noxious smells, noise, burning, misdirection of water onto other property, illegal gambling, unauthorized collections of rusting autos, indecent signs and pictures on businesses and a host of bothersome activities. Where illegal they can be abated (changed, repaired or improved) by criminal or quasi-criminal charges. If a nuisance interferes with another person's quiet or peaceful or pleasant use of his/her property, it may be the basis for a lawsuit for damages and/or an injunction ordering the person or entity causing the nuisance to desist (stop) or limit the activity (such as closing down an activity in the evening)." [4]

During the 1950's through the 1970's, studies were conducted at the Hanford Department of Energy (DOE) Site in Richland, Washington to understand the biological effects due to intake and uptake of fissile material, such as strontium-90. Experimentation involved animal test subjects where routes of exposure of ingestion (Figure 1), and intraperitoneal injection were studied. Animal excreta were collected and analyzed, tracking the amount of radioactivity associated with animals' biologic absorption process. Upon death, a final assay was conducted, followed by discarding the carcass remains (including excreta products collected throughout the process) in trenches located within close proximity to the laboratory facilities [5].

Fig 1. Test Animals Being Introduced to Fissile Materials via Ingestion

METHOD

Hazard Assessment

Information pertaining to animal remains was reviewed. Because the material was buried 30 to 50 years ago, it was expected that biological decomposition should have resulted in negligible remains (bones, skin, etc). Therefore, it was concluded that health effects due to decomposition products would not be present to any substantial degree that would cause adverse health effects [6]. Nevertheless assessment methods were conducted. Direct-reading instrumentation, including photoionization detectors (for volatile organic compounds – VOCs) and multigas instruments (for explosive gases and hydrogen sulfide) were used for possible airborne contaminant determination.

The specific instrumentation used was the RAE Systems PGM-54 Multi-Rae Plus with Oxygen, lower explosive limit (LEL), hydrogen sulfide and carbon monoxide gas sensors with a photoionization detector containing an 11.7 eV lamp. The detection limit for the PID was 0.1 ppm. Daily pre and post response checks were conducted.

Stop Work

Within the first hour of excavation, animal carcasses and bagged excrement were unearthed. Immediately, strong odors saturating the air resulted in a number of workers experiencing the classic symptoms of nausea and headaches. While the odors were prevalent throughout the remediation site, all direct-reading instrumentation indicated non-detect concentrations. At this point work stopped while hazard identification, assessment and controls were reevaluated. This required an in-depth look at the decomposition process to understand what health hazards should be considered.

The Decomposition Process

The decomposition process for mammals is categorized into six stages: each having unique factors that relate to specific chemical off-gassing which can then be related to specific odors and subsequent health hazards.

Stage 1: Still Living – While living, organisms are not outwardly decomposing. However the intestines contain a diversity of bacteria, protozoans and nematodes. Some of these micro-organisms are ready for a new life, should the host die.

Stage 2: Initial Decay - Although shortly after death the body appears fresh from the outside, the microorganisms described in Stage 1 begin to digest the intestine itself. They eventually break out of the intestine and start digesting the surrounding internal organs. The body's own digestive enzymes (normally in the intestine) also spread through the body, contributing to its decomposition. Simultaneously, enzymes inside individual cells are released when the cell dies. These enzymes break down the cell and its connective tissues.

From the moment of death, flies are attracted to the corpse and begin to lay eggs around wounds and natural body openings (mouth, nose, eyes, anus, genitalia). These eggs hatch and move into the body, often within 24 hours. The life cycle of a fly from egg to maggot to fly takes from two to three weeks. However, this process may take considerably longer at low temperatures.

Stage 3: Putrefaction - Bacteria break down tissues and cells, releasing fluids into body cavities. Through anaerobic respiration various gases including hydrogen sulfide and methane, are produced. In addition, two uncommon organic materials, putrescine ($NH_2(CH_2)_4NH_2$) and cadaverine ($NH_2(CH_2)_5NH_2$)are also produced. These materials are four and five aliphatic hydrocarbons (respectively) diamines and have been described as most foul-smelling (putrid); however, they are very attractive to a variety of insects.

As anaerobic respiration continues, there is a build up of gases; thus creating pressure within the corpse. This pressure inflates the body and forces fluids out of cells and blood vessels and into the body cavity.

The young maggots move throughout the body, spreading bacteria, secreting digestive enzymes and tearing tissues with their mouth hooks. They move as a maggot mass benefiting from communal heat and shared digestive secretions.

The rate of decay increases, and the smells and body fluids that begin to emanate from the body attract more blowflies, flesh flies, beetles and mites. The later arriving flies and

A large volume of body fluids drain from the body at this stage and seep into the surroundings. Other insects and mites feed on this material.

The insects consume the bulk of the flesh and the body temperature increases with their activity. Bacterial decay is still very important, and bacteria will eventually consume the body if insects are excluded.

By this stage, several generations of maggots are present on the body and some have become fully grown. They migrate from the body and bury themselves in the soil where they become pupae. Predatory maggots are much more abundant at this stage, and the pioneer flies cease to be attracted to the corpse. Predatory beetles lay their eggs in the corpse and their larvae then hatch out and feed on the decaying flesh. Parasitoid wasps are much more common, laying their eggs inside maggots and pupae.

Stage 5: Butyric Fermentation - All the remaining flesh is removed over this period and the body dries out. It has a cheesy smell, caused by butyric acid which attracts a new suite of corpse organisms.

The surface of the body that is in contact with the ground becomes covered with mould as the body ferments.

The reduction in soft food makes the body less palatable to the mouth-hooks of maggots, and more suitable for the chewing mouthparts of beetles. Beetles feed on the skin and ligaments. Many of these beetles are larvae. They hatch from eggs, laid by adults, which fed on the body in earlier stages of decay.

The cheese fly consumes any remaining moist flesh at this stage, even though it is uncommon earlier in decay.

Predators and parasitoids are still present at this stage including numerous wasps and beetle larvae.

Stage 6: Dry Decay - The body is now dry and decays very slowly. Eventually all the hair disappears leaving the bones only.

Animals which can feed on hair include tineid moths, and micro-organisms like bacteria. Mites, in turn, feed on these micro-organisms.

They remain on the body as long as traces of hair remain, which depends on the amount of hair that covers the particular species. Humans and pigs have relatively little hair and this stage is short for these species [7].

of direct-reading instrumentation would still continue, while establishing action levels to stop work. These action levels included PID readings of 10 ppm for a continuous 2-minute period, as well as 1 ppm for the hydrogen sulfide sensor (also based on a continuous 2-minute period). Goggles to protect eyes were also available for those employees who desired protection from potential eye irritation; however, this was not mandatory, as many employees voiced a concern due to possible limited visibility while working within close proximity to heavy equipment.

Once the decomposition process was reviewed, as well as the feasibility to identify and quantify such contaminants, on-site assessment protocol was established. When a decomposition product was identified but a sampling and analytical process was not available, it was decided not to conduct an exposure assessment. Such was the case for the chemicals cadervene and putrescine, for while they are known decomposition products, they do not have an established analytical protocol. Substances that were targeted included:

- Ammonia
- Butyric acid
- Ethylamine
- Hydrogen Sulfide
- Mercaptans (methyl, ethyl and butyl)
- Dimethyl Disulfide (methyl disulfide)
- Phenol

Below is a summary of the sampling and analytical methods used.

Sampling and Analytical Methodology

<u>Ammonia</u>

Ammonia was collected and analyzed using NIOSH method S347. This requires connecting sulfuric acid-treated silica gel tubes to a sampling pump operating at approximately 0.1 – 0.2 liters per minute (LPM). Airborne ammonia vapors were collected around the trench perimeters. In addition, a personal sample was collected for the excavator operator. Analysis was conducted by ion meter readings [8].

<u>Butyric acid</u>

Because butyric acid does not have an established OEL or sampling protocol, an carboxylic acids, they could be collected and analyzed using the same technique. Nevertheless the laboratory needed to obtain a proper standard for propionic acid to ensure propionic acid could be isolated for proper analysis. Area samples were collected near the trench perimeters [8].

Ethylamine

Samples are collected by drawing air at a flow rate of 0.1 – 0.2 LPM through sampling tubes containing XAD-7 resin coated with 10% NBD chloride by weight as described in the OSHA 36 method. The samples are desorbed with 5% (w/v) NBD chloride in tetrahydrofuran (with a small amount of sodium bicarbonate present), heated in a hot water bath, and analyzed by high-performance liquid chromatography using a fluorescence or visible detector (NIOSH, 2005). Area samples were collected at the trench perimeters [8].

Hydrogen Sulfide

Hydrogen sulfide was collected per the NIOSH 6013 method. This technique requires activated charcoal tubes connected to sampling pumps operating at a flow rate of 0.1 – 1.5 LPM. Samples were located at the trench perimeters. Analysis was conducted through ion chromatography/conductivity [8].

Mercaptans (methyl, ethyl and butyl)

Three specific mercaptans were analyzed through this sampling event: methyl mercaptan, ethyl mercaptan and butyl mercaptan. Sample and analysis was conducted per NIOSH method 2542. Air samples were collected through 37-mm diameter filter cassettes that were impregnated with mercuric acetate. The recommended flow rates are 0.1 – 0.2 LPM. Both personal and area samples for mercaptans were conducted. Samples were collected about the trench perimeters as well as the excavator operator. Analysis was conducted gas chromatography; flame photometric detector [8].

Dimethyl Disulfide

Dimethyl disulfide was collected at the trench perimeters, using -activated charcoal tubes and analyzed via OSHA method IMIS D-651. This method specifies a flow rate of 0.1 – 0.2 LPM. Analysis was conducted by gas chromatography with a flame photometric detector [8].

RESULTS

As presented in the following tables, laboratory analysis for all samples resulted in non-detect (ND) concentrations with their reported values well within their respective OELs. These occupational health standards are based upon OSHA PELs as well as the ACGIH TLVs. One contaminant –of-concern that did not have an established OEL, butyric acid, was assessed using an alternate strategy. This was accomplished by employing a surrogate, propionic acid and was assessed with a time weighted average of less than 1.35 mg/m^3 or 0.37ppm, indicating laboratory results with exposure concentrations that were within the adapted occupational limit.

Table I Ammonia[a]

Job Title/Location	Concentration (ppm)
Laborer	<0.7
Laborer	<0.7
RCT	<0.7
Haul Truck	<0.6
Loadout Oper.	<0.6
Ex. Operator	<0.15
Blank 3	<20.0 ug
West Side: Trench #1	ND, < 0.52
Excavator Operator	ND, < 0.15
West Side: Trench #1	ND, < 0.57
East Side: Trench # 3	ND, < 0.24
Blank	ND, < 2 µg

[a] TLV 25 ppm

Table II Hydrogen Sulfide[a]

Job Title	Concentration (ppm)
Loadout Oper.	<0.033
Haul Truck	<0.025
Laborer	<0.025
RCT	<0.026
Excavation Oper	<0.023
RCT	<0.025
Blank 3	< 3.0 ug
West End: Trench #2	ND, < 0.050
West End: Trench # 2	ND, < 0.061
East End: Trench #3	ND, < 0.028
	ND,< 3 µg

Table III Phenol[a]

Job Title	Concentration (ppm)
Haul Truck	<0.0028
Loadout Oper.	<0.0029
Laborer	<0.0030
RCT	<0.0029
RCT	<0.0027
Ex Oper	<0.004
Middle: Trench #1	ND, < 0.011
West End: Trench # 2	ND, < 0.018
East End: Trench #3	ND, < 0.0072
Blank	ND,< 0.5 μg

[a] TLV 5 ppm

Table IV Mercatans[a]

Job Title	Butyl Concentration (ppm)	Ethyl Concentration (ppm)	Methyl Concentration (ppm)
RCT	Butyl - <0.035	Ethyl - < 0.021	Methyl - < 0.027
RCT	Butyl - <0.034	Ethyl - < 0.020	Methyl – 0.026
Loadout Oper.	Butyl -<0.032	Ethyl – <0.018	Methyl – <0.024
Ex. Oper.	Butyl –<0.026	Ethyl –<0.015	Methyl –<0.039
Haul Truck	Butyl -<0.019	Ethyl – <0.015	Methyl – <0.026
Laborer	Butyl - <0.029	Ethyl – <0.017	Methyl – <0.022
Laborer	Butyl - <0.033	Ethyl – <0.019	Methyl – <0.025
Blanks 3	Butyl - <10.0 ug	Ethyl - <4.0 ug	Methyl - <4.0 ug
Middle: Trench #1	ND, < .17	ND, < 0.0982	ND, < 0.13
Trackhoe Operator	ND, < 0.026	ND, < 0.015	ND, < 0.039
West End: Trench #2	ND, < 0.12	ND, < 0.072	ND, < 0.092
East End: Trench #3	ND, <0.10	ND, < 0.058	ND, < 0.075
Blank	ND,< 10 μg	ND,< 4 μg	ND,< 4 μg

Table V Butyric Acid[a]

Job Title	Concentration (ppm)
Loader Oper.	<0.46 mg/m3
Laborer	<0.42 mg/m3
Loadout Oper.	<0.37 mg/m3
RCT	<0.46 mg/m3
Haul Truck	<0.52 mg/m3
Blank	<20.0 ug
South End: Trench #1	ND, < 1.7
West End: Trench # 2	ND, < 2.5
East End: Trench #3	ND, < 1.1
Blank	ND,< 20 μg

[a] TLV 10 ppm and is based on Propionic Acid

Table VI Dimethyl Disulfide[a]

Job Title	Concentration (ppm)
South End: Trench #1	ND, < 0.030
East End: Trench # 3	ND, < 0.025
Blank	ND, < 1 μg
Loadout Operator	<0.0093
Haul Truck	<0.012
Laborer	<0.0094
Laborer	<0.0093
RCT	<0.0095
Excavation Operator	<0.0083
RCT	<0.0095
Blank 3	<1.0 ug
Loadout Operator	<0.0093

[a] TLV 0.5 ppm

Table VII Ethylamine[a]

Job Title	Concentration (ppm)
Middle: Trench #1	ND, < 0.030
West End: Trench # 2	ND, < 0.054
Blank	ND, < 1 μg
Haul Truck	<0.012
Loadout Operator	<0.013
Laborer	<0.013

DISCUSSION

Decomposition Products and Health Effects

The NIOSH Publication, "Criteria for Controlling Occupational Hazards in Animal Rendering Processes" has identified many potential health risks due to chemicals as well as biologic hazards from carcasses. NIOSH notes that sanitation and personnel hygiene as well as medical pre-placement exams are necessary controls. While inhalation hazards due to work in rendering plants were not recognized as a primary concern, NIOSH does mention that respiratory protection may be considered when specific chemicals are encountered [9]. However, NIOSH does not specifically mention the possibility of respirator use for protection against biologic decomposition.

In the publication by the Centers for Disease Control (CDC), "Health Recommendations for Relief Workers Responding to Disasters" it discusses immunizations for travel overseas, as well as precautions relating to weather conditions and psychological/emotion stressors. The CDC continues to discuss the importance of hand washing (with soap) to remove potentially infectious material from the skin to help prevent the transmission of both respiratory and enteric diseases. The CDC also mentions the use of waterless alcohol-based hand rubs. However respiratory protection is not discussed [10].

During the aftermath of the Indian Ocean Tsunami in December 26, 2004, health recommendations were offered to disaster workers to address gaps in worker and environmental safety. This included the risk for infection due to working with corpses. While respirators were not mentioned, on-site health specialists have addressed protecting the face from liquid splashes by wearing clothes around the mouth; however this was to avoid the transfer of body fluids and not inhalation hazards. Similar to other health reports, personnel hygiene was the most stressed factor for disease prevention [11].

In the Disaster Manual and Guidelines published by the Pan American Health Organization, in conjunction with the World Health Organization, *Management of Dead Bodies on Disaster Situations*:

> "As a final analysis, we can say that dead bodies of animals represent little or no threat to public health. A series of coexisting factors must be present for the animal bodies to constitute a risk to humans. First, the animal should be infected with a disease that can be transmitted to

Thus current literature does not support the assumption that decomposition products necessitate an inhalation hazard. Yet workers involved with the excavation of animal remains exhibited adverse health effects due to an airborne exposure with such materials; even at concentrations that were not just within their respective OEL, but less than laboratory analytical detection limits. While literature has not been able to support a cause and effect relationship regarding the animal decay process and adverse health effects due to inhalation, the question needs to be asked, “how can odors cause the health reactions experienced by the field employees during such work?”

Table VIII presents the OELs and the odor thresholds of the various contaminants of concern discussed. The information shows that the odor threshold; that concentration at which humans can detect an airborne material via sense of smell, is, in most cases, orders of magnitude less than the OEL. Nevertheless, because workers can detect these airborne contaminants, their perception that they are being exposed to an unwanted substance cannot be overlooked, which, in turn, can cause concern.

Table VIII Odor Thresholds -Occupational versus Odor Thresholds [13]

Contaminant	OEL	Odor Threshold
Ammonia	25 ppm (ACGIH TLV)	0.043 ppm (AIHA)
Butyric Acid	10 ppm *	0.010 ppm
Ethylamine	5 ppm	0.95 ppm
Hydrogen Sulfide	10 ppm (ACGIH TLV)	0.00007 ppm
Methyl Mercaptan	0.5 ppm (ACGIH TLV)	0.002 ppm
Ethyl Mercaptan	0.5 ppm (ACGIH TLV)	0.0028 ppm
Butyl Mercaptan	0.5 ppm (ACGIH TLV)	0.0001 ppm
Methyl Disulfide	0.5 ppm	0.00078 ppm
Phenol	5 ppm (ACGIH TLV)	0.0045 ppm (AIHA)

The Physiology of Odors

While odors due to biologic decomposition have not been associated with systemic reactions or dysfunction of specific target organs, through the olfactory system and central nervous system, the pathway of odors can be traced to the point of understanding how such health manifestations can occur.

On the top portion of the nasal cavity, near the back, lie the initial detectors of odor molecules; olfactory receptors. These structures are nerve cells or neurons, which transfer chemical stimulus into electrical impulses and number from ten to twenty

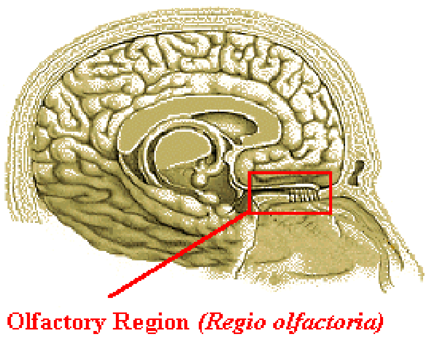
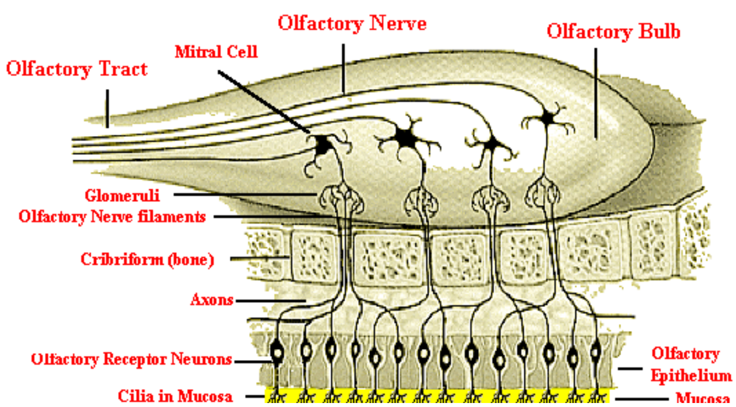


Fig 3. Location of Olfactory Region [15]

Thus, depending on an odorants' chemical structure, it may only be received (or recognized) by a specific olfactory receptor; which in turn, will convert the chemical energy into electrical energy. Depending upon the amount of a specific odorant molecule reaching its corresponding olfactory cell-type, an electrical signal may not be generated (as an energy threshold was not achieved) or may generate an action potential that exceeds a threshold. When the latter happens, the signal propagates along the nerve, through the ethmoidal bone (located between the nasal cavity and the brain compartment; cribiform bone, which is characterized as spongy or sieve-like) where it synapses with the olfactory bulb.



During normal breathing, 10% of the inhaled odorants pass up under the olfactory receptors. However, during a sniffing action, more than 20% of the odorant molecules are carried to the olfactory receptors [14].

Once the signal is transferred to the olfactory bulb, information is distributed to the brain via two distinct pathways: the olfactory nerve and the trigeminal nerve. This entire process, from the nostril to the brain takes approximately ½ second [14].

Information that is transmitted via the olfactory nerve will propagate to the limbic area of the brain. This area of the brain processes emotion and memory and produces signals to the hypothalamus and pituitary glands: both of which initiate numerous involuntary biological functions. Therefore increased breathing or heart rates may occur, as well as causing changes in body temperature, blood pressure, hunger and thirst.

The trigeminal nerve leads to the frontal cortex (front peripheral section) of the brain: This is where conscious sensation occurs as the information is processed with other sensations and is compared with previous life experiences. Thus the odor would be recognized causing an individual to formulate a perception based on previous experiences. This in turn, would trigger a response, resulting in an individual to react favorably, indifferent or negatively.

Realizing the potential for changes in breathing, heart rate, body temperature, blood pressure, etc., physiological disruptions may result from the inhalation of low concentrations of various types of materials; even when such concentrations are well within the accepted OELs.

CONCLUSION

While evidence suggests that odorants do not cause direct toxicological effects to the various biologic systems, they can be influential by initiating symptoms that are associated with known toxins. The difference between the classic toxic systemic reactions and those initiated by nuisance odors can be summarized as one causing a dysfunction of a target organ or system as opposed to triggering a message to the brain which causes a physical reaction.

While strong odors may exist at HAZWOPER work sites, their particular risk of pathogenic disease has yet to be established. This leaves many unanswered questions; the most obvious being, “can an odorous chemical that can result in headaches, nausea, changes in blood pressure, body temperature, etc., be considered negative stimuli, thereby causing symptomatic experiences; will such disciplines as psychology need to be considered as part of the expertise within the field a environmental and occupational health?

In the classic text, “The Fundamentals of Industrial Hygiene” industrial hygiene has been defined as “*that science and art devoted to the anticipation, recognition, evaluation, and control of those environmental factors or stressors arising in or from the workplace that may cause sickness, impaired health and well-being, or significant discomfort among workers or among the citizens of the community”* [3]. Based on this definition, it is indeed the responsibility of the occupational health professional to move forward and to provide an effective program to ‘anticipate, recognize, evaluate, and control’ such airborne contaminants that may not be adequately controlled based on current knowledge and technology. The question is, “Is the industrial hygiene community equipped to carry out this responsibility?” “Are new assessment methods and tools necessary? Are alternate exposure limits needed and can they be adequately implemented?

As more of the non-traditional health hazards become recognized, it appears that it shall be essential for more sophisticated methods to be part of the standard practice used to assess human health. Whether that means more sensitive equipment that has greater detection capabilities, or the development of new technologies designed specifically for these hazards, at present can only be left to speculation.

While the occupational health community may wrestle with these questions, the responsibility of the safety and health community must maintain its diligence. As such, persons within the discipline of environmental and occupational health must continue to communicate the hazards and controls to the work force. Through such efforts, the workforce shall become engaged in the process of hazard identification, assessment and control, which, in turn, will create a greater appreciation and acceptance for field assessment methods as well as the processes by which workplace controls are designed to protect them.

REFERENCES

1. Occupational Safety and Health Administration, Title 29, Code of Federal Regulations, Part 1910. ISBN 978-0-8080-2034-9. 2009, CCH Chicago, ILL.

2. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values for Chemical Substances and Physical Agents, & Biological Indices. 2011, Cincinnati, Oh.

3. Fundamentals of Industrial Hygiene, 5th Edition. Plog, Barbara ed. Itasca, Ill. National Safety Council, 2005

4. “Nuisance” Def. Hill, G. and K., <http://dictionary.law.com/ default2.asp?review=true#hill> 2008, April 4, 2008

5. Dorian, J.J., Richards, V.R., Radiological Characterization of the Retired 100 Areas, United Nuclear Industries, Inc. UNI-946, May, 1978

6. Brounstein, R.A. *Industrial Hygiene Research for Protective Measures for Animal Decomposition Products*. Washington Closure-Hanford, February, 2006.

7. “Decomposition; What Happens to the Body After Death?” Australian Museum. 2003 http://www.deathonline.net/decomposition/decomposition/dry_decay.htm

8. National Institute for Occupational Safety and Health. NIOSH Pocket guide to Chemical Hazards CD-ROM. DHHS (NIOSH) Publication No. 2005-151.

9. National Institute for Occupational Safety and Health NIOSH Criteria Document: Occupational Hazard Assessment: Criteria for Controlling Occupational Hazards in Animal Rendering Processes. NIOSH Publication No. 81-133. NIOSH Cincinnati, Ohio. March 1981

10. Center for Disease Control - Health Recommendations for Relief Workers Responding to Disasters. December 22, 2005. April 1, 2008. http://wwwn.cdc.gov/travel/contentReliefWorkers.aspx

11. Brounstein, R.A. *Industrial Hygiene Report for Potential Airborne Concentrations of Animal Decomposition Products*. Washington Closure-Hanford, March, 2006.

14. Shusterman, D., (1992) Critical review: the health significance of environmental odor pollution. *Arch. Environ.Health,* 47(1): 76-87

16. The Olfactory Bulb. http://flavor.monell.org/~loweg/OlfactoryBulb.htm