June 2022

Outcomes of a Periodic Exposure Assessment of Workers at a University Campus

Logan M. Armagast
University of South Florida

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by

Logan M. Armagast

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Public Health
with a concentration in Occupational Exposure Science
College of Public Health
University of South Florida

Major Professor: Rene' Salazar, Ph.D.
Steven Mlynarek, Ph.D.
Thomas Bernard, Ph.D.

Date of Approval:
June 21, 2022

Keywords: Exposure Monitoring, Data Collection, Data Interpretation, Methodologies

Acknowledgements

This manuscript was supported by grant number T42OH008438, funded by the National Institute for Occupational Safety and Health (NIOSH) under the Centers for Disease Control and Prevention (CDC). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIOSH or CDC or the Department of Health and Human Services.

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Abstract

Standards promulgated by the Occupational Safety and Health Administration (OSHA) are applicable to most businesses in the private sector, however, state and local government entities are not under OSHA's jurisdiction. Universities that receive public funding fall under the category of state and local government entities and, unless an OSHA-approved State plan explicitly states otherwise, they are not required to demonstrate compliance with OSHA standards and are not subject to OSHA inspections. Without being constrained by federal regulation, those responsible for ensuring the health and safety of employees at publicly funded universities have some leeway in their methods for evaluating the conditions of work environments. The purpose of this study is to compare the methods used for assessing worker exposures in a university setting with OSHA requirements by describing typical exposure assessment processes. Exposures to three exposure agents were assessed: formaldehyde, volatile organic compounds, and noise. The results of this study indicate that the methods used to assess workplace exposures in this setting are not always consistent with OSHA methodologies. It is recommended that future, similar assessments utilize standardized sampling and analytical methods to protect employees from workplace exposures.

Chapter 1: Introduction

In 1970, the United States Congress adopted the Occupational Safety and Health Act (OSH Act) which gave federal government the authority to promulgate and enforce standards aimed at promoting occupational safety and health (United States Department of Labor [DOL], 1981). Soon after, the Occupational Safety and Health Administration (OSHA) was established in 1971 to serve as the federal agency responsible for carrying out the OSH Act (DOL, 2002). The standards that OSHA establishes are applicable to most businesses in the private sector, however, state and local government entities are not under OSHA's jurisdiction (Occupational Safety and Health Administration [OSHA], 2010). Universities that receive public funding fall under this category of state and local government entities. These universities are not required to demonstrate compliance with OSHA standards and are not subject to OSHA inspection unless an OSHA-approved State plan explicitly states otherwise (Congressional Research Services, 2020). Without being constrained by federal regulation, those responsible for ensuring the health and safety of employees at publicly funded universities have some leeway in conducting assessments for workplace health and safety.

1.1 Statement of Purpose and Research Questions

The purpose of this study is to compare the methods used for assessing worker exposures in a university setting with OSHA requirements by describing typical exposure assessment processes. Exposures to three exposure agents were assessed: formaldehyde, volatile organic compounds, and noise. The following are the research questions of this study:

1. Are the methods employed for selection of workers for exposure monitoring consistent with OSHA methodologies?
2. Are the methods employed for data collection consistent with OSHA exposure assessment methodologies?
3. Are the methods employed for data interpretation consistent with OSHA data interpretation methodologies?

Chapter 2: Literature Review

2.1 Workplace Exposure Agents

In the occupational environment, workers can be exposed to chemical, physical, and biological agents. The category of chemical agents includes any chemical compound whether it be in the form of solid, liquid, or gas (OSHA, 2001). The effects of exposure to chemical agents vary greatly and are largely dependent on the toxicity of the substance, magnitude of exposure, and duration of exposure. The category of physical agents includes sources of energy such as noise, radiation, and extreme temperatures (Canada Centre for Occupational Health and Safety [CCOHS], 2022). Exposure to physical agents can result in disease and or injury. The category of biological agents includes microorganisms and their associated toxins, plant sourced toxins, and plant and animal sourced allergens (Plog & Quinlan, 2012). Exposure to biological agents can result in infection, allergic reactions, toxic reactions, and carcinogenic reactions.

2.1.1 Formaldehyde

At room temperature, formaldehyde exists as a colorless, flammable gas with a distinct odor (Agency for Toxic Substances and Disease Registry [ATSDR], 2015). Formaldehyde can be used in industry for the manufacture of certain products such as paper, plywood, resins, and fertilizer (National Institute for Occupational Safety and Health [NIOSH], 2019). Formaldehyde can also be found in consumer products, building materials, and tobacco smoke (ATSDR, 2015). Some examples of products and materials containing formaldehyde are cleaners, antiseptics, cosmetics, carpets, paints, and varnishes. Those involved in manufacturing processes that use formaldehyde or produce formaldehyde-containing products are likely to be exposed. In addition, workers using formaldehyde-containing products, such as pathologists, embalmers, healthcare professionals, and laboratory workers, are also at risk of exposure.

Exposure to formaldehyde can result in a variety of adverse health effects, be they acute or chronic (ATSDR, 2015; NIOSH, 2019). Formaldehyde is considered a highly reactive gas and has the potential to cause direct tissue irritation (ATSDR, 2015). The health effects of formaldehyde exposure depend largely on the route of exposure. Inhalation exposure can result in upper respiratory tract irritation. Exposure through dermal contact and ingestion may result in skin irritation and gastrointestinal tract irritation, respectively. The chronic health effects of formaldehyde exposure include upper respiratory, gastrointestinal tract, and skin cancers. Some studies have shown a higher prevalence of nose and throat cancers in workers that suffer repeated exposures to formaldehyde when compared to the general population (ATSDR, 2015).

2.1.2 Volatile Organic Compounds

Volatile organic compounds (VOCs) are organic chemical compounds that readily evaporate under normal temperature and pressure conditions (United States Environmental Protection Agency [EPA], 2022). VOCs are a broad category that includes a wide variety of chemicals that can be emitted from either liquids or solids (EPA, 2021). The manufacture and use of different household products and materials can release VOCs into the surrounding environment (EPA, 2022). Some examples of household products that contain VOCs are glues and adhesives, cleaners and disinfectants, paints, and various solvents such as paint strippers (EPA, 2021). Additionally, building materials and furnishings can serve as household sources of VOC exposure.

Exposure to VOCs can result in a variety of adverse health effects. The health effects of VOC exposure vary greatly depending on the compound in question (EPA, 2021). Some VOCs can be highly toxic while others have not been found to be associated with any known health effects. Exposure to VOCs can result in either short-term or long-term health effects. Irritation of the eyes, nose, throat, and respiratory tract are common short-term health effects of VOC exposure. In addition, headaches, nausea, and loss of coordination can also result. The long-term health effects of VOC exposure involve kidney, liver, and central nervous system damage. Some VOCs have also been found to have the potential to induce carcinogenic effects.

2.1.3 Noise

Recent estimates suggest that approximately 22 million workers in the United States are exposed to excessive levels of noise (Themann & Masterson, 2019). Workers can be exposed to noise in every major sector of industry with manufacturing, mining, and construction being the most common. There are countless different sources of noise exposure. In the industrial environment, different types of machinery, equipment, and power tools are common sources. Exposure to noise can also occur during non-work activities such as lawn mowing, recreational shooting, and hunting.

Exposure to excessive levels of noise can result in both auditory and non-auditory health effects. The most common auditory effects of noise exposure are noise-induced hearing loss (NIHL), tinnitus, and hyperacusis. NIHL can occur when either long-term exposure to continuous noise or short-term exposure to impact noise causes damage to the hair cells of the cochlea which is located in the inner ear (Themann & Masterson, 2019). Initially, NIHL is characterized by a temporary shift in the threshold of human hearing, commonly referred to as a temporary threshold shift (TTS). A TTS can resolve within 16 to 48 hours, however, repeated exposures can cause this shift to become permanent. When the shift becomes permanent it is referred to as a permanent threshold shift (PTS). In addition to NIHL, noise exposure can result in tinnitus and hyperacusis. Tinnitus is characterized by a sensation of sound when in the absence of any exposure. Hyperacusis is characterized by an increased sensitivity or reduced tolerance to noise (Themann & Masterson, 2019). The auditory effects of noise exposure can be particularly debilitating, leading to negative impacts on workplace safety and the overall quality of life of those afflicted.

Some research has shown associations between noise exposure and impacts on workplace safety, general health, and well-being. Those afflicted with NIHL may experience problems with speech and communication which can impact workplace safety by increasing the likelihood of accidents (Mirza et al., 2018; Themann & Masterson, 2019). These problems with speech and communication can also impact well-being by leading to feelings of social isolation and depression. Noise exposure has also been associated with sleep disturbances which can further effect well-being (Themann & Masterson, 2019). In terms of general health, research has shown associations between noise exposure and non-auditory health effects. Most notably, exposure to excessive levels of noise has been associated with an increased prevalence of cardiovascular disease, cognitive decline, and dementia (Mirza et al., 2018; Themann & Masterson, 2019).

2.2 Assessing Workplace Exposures

When employees are anticipated to be exposed to chemical agents, an evaluator may collect either personal air samples or ‘general’, also known as ‘area’, air samples to assess the conditions of the work environment (NIOSH, 1977). Personal air samples are collected from the breathing zone of the worker and result in a value that represents the workers actual level of exposure. Personal air samples can be used to assess compliance with both time-weightedaverage (TWA) and short-term exposure limits. To assess for compliance with TWA and short-term exposure limits, full period and partial period air samples are collected, respectively. In addition to personal air samples, an evaluator may choose to collect area air samples which can provide an estimation of the concentration of contaminants present in the work environment. Area air samples cannot be used to determine levels of exposure or to assess compliance with health and safety standards.

OSHA standards require that the sampling and analytical methods used to assess exposures to chemical agents have a particular degree of accuracy which can vary depending on the chemical agent to which the worker is exposed (Plog & Quinlan, 2012). Standardized sampling and analytical methods specify a degree of accuracy and can be used by evaluators to assess exposures to chemical agents. These methods can be found in either the NIOSH Manual of Analytical Methods or in OSHA's Sampling and Analytical Methods publication.

When assessing exposures to physical agents, assessment methodology varies depending on the physical agent that a worker is anticipated to be exposed to. For example, when assessing exposures to noise, an evaluator may use noise dosimeters to obtain records of daily exposure or sound level meters to take area noise measurements (Plog & Quinlan, 2012). When assessing exposures to ionizing radiation, an evaluator may use film badges, thermo-luminescent dosimeter badges, or optically stimulated luminescence dosimeter badges to conduct either personal or area sampling. When assessing exposure to physical agents, personal samples can be used to gauge compliance with relevant health and safety standards while area samples or measurements can be used to gain an understanding of the conditions present in the work environment.

2.2.1 Formaldehyde

There are four standardized sampling and analytical methods that can be used for determining the concentration of formaldehyde in air: NIOSH Method 2016, NIOSH Method 2541, NIOSH Method 3500, and OSHA Method 52.

NIOSH Method 2016 can be used to assess both STEL and TWA formaldehyde exposures by using a cartage containing silica gel that is coated with 2,4- dinitrophenylhydrazine (NIOSH, 2016). This method requires a minimum sampling flow rate of 0.03 liters per minute and a maximum sampling flow rate of 1.5 liters per minute. This method also requires a minimum sample volume of 1 liter and a maximum sample volume of 15 liters. With a sample volume of 15 liters, this method can be used to accurately quantify formaldehyde concentrations ranging from 0.012 ppm to 2.0 ppm.

NIOSH Method 2541 can be used to simultaneously determine both formaldehyde and acrolein concentrations in air by using a solid sorbent tube 10% (2-hydroxymethyl) piperidine on XAD-2, 120 mg/60 mg (NIOSH, 1994a). This method requires a minimum sampling flow rate of 0.01 liters per minute and a maximum sampling flow rate of 0.10 liters per minute. This method also requires a minimum sample volume of 1 liter and a maximum sample volume of 36 liters. With a sample volume of 10 liters, this method can be used to accurately quantify formaldehyde concentrations ranging from 0.24 to 16 ppm.

NIOSH Method 3500 can be used to determine formaldehyde concentrations in air by using a 1-um membrane filter and 2 impingers containing 20 mL 1% sodium bisulfide solution (NIOSH, 1994b). This method requires a minimum sampling flow rate of 0.2 liters per minute and a maximum sampling flow rate of 1 liter per minute. This method also requires a minimum sample volume of 1 liter and a maximum sample volume of 100 liters. With a sample volume of

80 liters, this method can be used to accurately quantify formaldehyde concentrations ranging from 0.02 to 4 ppm.

OSHA Method 52 can be used to assess STEL formaldehyde exposures, TWA formaldehyde exposures, and TWA acrolein exposures by using sampling tubes containing XAD-2 adsorbent that is coated with 10% 2-(hydroxymethyl) piperidine (OSHA, 1989). When assessing for TWA formaldehyde exposures, the method requires a 0.1 liter per minute flow rate and a 24 liter sample volume. When assessing for STEL formaldehyde exposures, this method requires a 0.2 liters per minute flow rate and a 3 liter sample volume.

Passive badges, also known as diffusive samplers, are air sampling devices that are sometimes used to sample for airborne chemical constituents (OSHA, 2014). Sampling methods that use these devices are referred to as passive sampling methods because they do not require the use of air sampling pumps. There are some standardized sampling and analytical methods that permit the use of passive sampling for assessing exposures to chemical agents; however, there are no accepted, standardized methods that permit the use of passive sampling for assessing exposures to formaldehyde (NIOSH, 2016; NIOSH, 1994a; NIOSH, 1994b; OSHA, 1989).

2.2.2 Volatile Organic Compounds

The methods that can be used to determine the concentration of volatile organic compounds in air very depending on the compound in question, however, there are two standardized NIOSH methods that can be used to detect and quantify different volatile organic compounds in a mixture: NIOSH Method 2549 and NIOSH Method 3900.

NIOSH Method 2549 can be used to characterize complex mixtures of volatile organic compounds by using multi-bed sorbent tubes containing graphitized carbons and carbon molecular sieve sorbents (NIOSH, 1996). This method requires a minimum sampling flow rate of 0.01 liters per minute and a maximum sampling flow rate of 0.05 liters per minute. This method also requires a minimum sample volume of 1 liter and a maximum sample volume of 6 liters. Sampling media is analyzed using thermal desorption, gas chromatography, and mass spectrometry. Using this method, any volatile organic compound with mass spectral data can be identified.

NIOSH Method 3900 can be used to determine the concentration of different volatile organic compounds present in a mixture by sampling air using either a 6 liter, 0.45 liter, or 0.4 liter fused-silica lined stainless steel canisters (NIOSH, 2018). This method requires a minimum sampling flow rate of 0.06 milliliters per minute and a maximum sampling flow rate of 50 milliliters per minute. The minimum and maximum sample volumes required for this method vary depending on the volume of the cannister used. This method was developed to accurately measure the concentration of 17 different volatile organic compounds.

2.2.3 Noise

Noise dosimetry is a form a personal sampling that can be used to ensure compliance with noise exposure standards (OSHA, 2013). Noise dosimetry can report results as either TWA exposures or percentages of the PEL. Depending on the standard in question, noise dosimeter recording criteria varies. When conducting an evaluation for assessing compliance with the OSHA PEL, noise dosimeters are set to record data based on an exchange rate of 5 dB, a criterion level of 90 dBA, a threshold level of 90 dBA, an A-frequency weighting, and slow response. Similarly, when conducting an evaluation for assessing compliance with the OSHA Hearing Conservation Amendment, noise dosimeters are set to record data with the same criteria, however the threshold level must be set to 80 dBA. Evaluations aimed at ensuring compliance with the NIOSH REL and ACGIH TLV for noise exposure use noise dosimeters set to record data based on an exchange rate of 3 dB, a criterion level of 85 dBA, a threshold level of 80 dBA, an A-frequency weighting, and slow response (NIOSH, 1998).

Chapter 3: Methods

3.1 Exposure Assessments

The exposure assessments described were conducted between May and July of 2021. The author of this manuscript played the role of an observer and was not involved in the selection of assessment methods or data collection.

3.1.1 Formaldehyde

Laboratory managers and teaching assistants working in the university's gross anatomy lab were anticipated to be at greatest risk of exposure to formaldehyde. Shift durations for employees vary, but they typically spend less than six hours per day, twice per week working in the laboratory. Certain work activities such as preparing specimens for dissection and instructing students while cutting into preserved tissue were anticipated to elevate levels of formaldehyde exposure. General exhaust ventilation was relied upon to limit inhalation exposures without the use of respiratory protection. Protective clothing was relied upon to limit exposure through dermal contact.

During this assessment, a total of two area samples and four personal samples were collected. Area samples were collected to provide information regarding ambient formaldehyde concentrations within the workspace. Personal samples were collected in full period and partial period to assess TWA and short-term exposures, respectively. Area samples were collected using sorbent tubes and AP Buck personal sampling pumps. Personal samples were collected using passive badges.

Before employees arrived at the job site, industrial hygiene personnel prepared for area sampling. To prepare for area sampling, two sampling pumps were calibrated to a nominal 0.30 liters per minute flow rate using an AP Buck soap film calibrator. After the sampling pumps were calibrated, the equipment was transported to the lab. Upon arriving at the lab, area sampling stations were positioned at the east and northwest sections of the lab. The sampling pumps were then powered on, and the sample start time was recorded. Area sampling ceased after 8 hours had elapsed. At this time, the sampling pumps were powered off and the sorbent tubes were prepared for shipment to the environmental laboratory for further analysis.

While area samples were being collected, industrial hygiene personnel waited for the laboratory manager and teaching assistants to arrive so that they could proceed with personal sampling. To begin personal sampling, a passive badge was clipped to the laboratory managers lapel and sample start time was recorded. Shortly after, a second badge that was used to evaluate short-term exposure was donned by the laboratory manager in the same fashion. This second badge was then removed and stored after 15 minutes had elapsed. Teaching assistants arrived a few hours after the laboratory manager had begun their work shift. Once they had arrived, passive badges were clipped to their lapels and sample start times were recorded. Personal sampling ceased at the end of the work shift. At this time, the remaining passive badges were doffed and prepared for shipment to the environmental laboratory for further analysis.

3.1.2 Volatile Organic Compounds

Hazardous waste disposal workers typically spend 2 to 3 hours per week working at the on-site hazardous waste disposal facility. While working at this facility, employees are tasked with bulking compatible laboratory wastes into common storage containers for further transport and disposal. Employees were anticipated to be at greatest risk of exposure to VOCs while working at this facility. To limit potential exposures, workers wear full-face OV/PM 100 respirators while on-site and all bulking is performed under a laboratory fume hood.

For this portion of the study, exposures to volatile organic compounds were assessed by using 0.4-liter evacuated cannisters to collect personal air samples. Just before the start of the work shift, industrial hygiene personnel prepared the summa canisters for personal sampling and assisted hazardous waste disposal workers with donning the equipment. To prepare for personal sampling, Teflon tubing was attached to the sample inlet of the cannister so that air could be drawn in from the breathing zone of the worker. The cannister was then placed in a specialized harness used for summa canister personal sampling applications. After each worker had donned the equipment, the flow valves were opened so that air could begin flowing into the cannister. Sample start times were then recorded and employees were allowed to start their work shifts. Sampling ceased at the end of the work shift. The air flow valves were then closed, and sample stop times were recorded. The summa canisters were then prepared for shipment to the environmental laboratory for further analysis.

3.1.3 Noise

During the summer months, typical work shifts for groundskeeping crew members average around 8 hours per day. These employees are responsible for performing a variety of job functions, most of which involve the use of mechanical equipment with high-powered motors. Tasks such as lawn mowing, weed whacking, and leaf blowing were anticipated to elevate levels of noise exposure. Due to this anticipation, workers use hearing protection when using such equipment.

For this portion of the study, a total of three grounds crew workers were monitored for noise exposure using TSI Quest Edge 5 personal noise dosimeters. The dosimeters were set to simultaneously record data using OSHA PEL, OSHA Hearing Conservation, and ACGIH / NIOSH noise exposure monitoring criteria. Industrial hygiene personnel arrived on site just before the start of the work shift to perform pre-calibrations and to assist workers with donning the equipment. Pre-calibrations were performed using an AC-300 Acoustical Calibrator which emitted a 114 dB pure tone into each dosimeter. After performing pre-calibrations, the noise dosimeters were clipped to the shirt of each worker and adjusted so that the microphone was positioned within the worker's hearing zone. The dosimeters were then set to begin recording data. At this time, sample start times were recorded and employees were allowed to begin their work shifts. Sampling ceased at the end of the work shift. At this time, industrial hygiene personnel assisted workers with doffing the equipment and performed post-calibrations using the same acoustical calibrator.

Chapter 4: Results

4.1 Exposure Assessment Outcomes

4.1.1 Formaldehyde

This assessment consisted of full period, partial period, and area sampling. Full period samples were collected to assess TWA exposures. Partial period samples were collected to assess short term exposures. Area samples were collected to obtain information regarding ambient formaldehyde concentrations within the workspace.

4.1.1.1 Full Period Sampling

Table 1 provides the results for the full period sampling portion of this assessment. Sample durations for the Laboratory Manager, Teaching Assistant-1, and Teaching Assistant-2 were 365, 122, and 121 minutes, respectively.

Table 1. Full Period Sampling Results

Employee	Sample Mass (µg)	Sample Duration (min)	Sampling Rate (mL/min)	Sample Volume (L)	Sample Concentration (PPM)	8-HR TWA (PPM)
Laboratory Manager	1.3	365	16.2	5.913	0.18	0.14
Teaching Assistant-1	0.43	122		1.976	0.18	0.05
Teaching Assistant-2	1.2	121		1.960	0.51	0.13

The results for the full-shift sampling portion of this assessment varied among employees. Resulting sample concentrations for the Laboratory Manager, Teaching Assistant-1, and Teaching Assistant-2 were 0.18, 0.18, and 0.51 ppm, respectively. Assuming zero exposure for the remainder of the work shift, TWA exposures were calculated. Resulting TWA exposures for the Laboratory Manager, Teaching Assistant-1, and Teaching Assistant-2 were 0.14, 0.05, and 0.13 ppm, respectively. Using the sample mass reported for the Laboratory Manager, an example of the calculation used to determine sample concentrations is provided in Table 2.

Table 2. Example Calculation for Sample Concentrations

Given
Sample Mass = 1.3 μg Sampling Rate = 16.2 mL/min Sample Duration = 365 min Molar Volume at STP = 24.45 L / mol Formaldehyde Molecular Weight = 30.031 g/mol
Solve for Sample Volume
Sample Volume = Sample Duration (min) * Sampling Rate (mL/min) * 1L / 1000mL Sample Volume = 365 min * 16.2 mL/min * 1L / 1000mL Sample Volume = 5913 mL * 1L / 1000 mL Sample Volume = 5.913 L
Solve for Sample Concentration in μg/L
Sample Concentration = [Sample Mass (μg) / Sample Volume (L)] Sample Concentration = [1.3 μg / 5.913 L] Sample Concentration = 0.2199 μg/L
Solve for Sample Concentration in PPM
Sample Concentration = Sample Concentration (μg/L) * [Molar Volume / Molecular Weight] Sample Concentration = 0.2199 μg/L * [24.45 L/mol / 30.031 g/mol] Sample Concentration = 0.18 ppm

Using the sample concentration calculated above, an example of the calculation used to determine 8-hr TWA exposures is provided in Table 3.

Table 3. Example Calculation for TWA Exposures

Given
Sample Concentration = 0.18 ppm Exposure Duration = 365 min Zero Exposure Duration = 115 min
Solve for TWA Exposure Assuming Zero Exposure for Remainder of Shift
TWA Exposure = [365 min * 0.18 ppm + 115 min * 0 ppm] / 480 min TWA Exposure = 0.14 ppm

The results for the full period sampling portion of this assessment in comparison to relevant occupational health and safety standards are provided in Table 4.

Table 4. Full Period Sampling Results and Comparison to Standards

Employee	**8-HR TWA (PPM)**	**OSHA PEL (PPM)**	**OSHA Action Limit (PPM)**	**ACGIH TLV-TWA (PPM)**	**NIOSH REL (PPM)**
Laboratory Manager	0.14	0.75	0.5	0.1	0.016
Teaching Assistant-1	0.05				
Teaching Assistant-2	0.13				

4.1.1.2 Partial Period Sampling

The results for the partial period sampling portion of this assessment in comparison to relevant occupational health and safety standards are provided in Table 5. The sample duration for the partial period sampling portion of this assessment was 15 minutes for the Laboratory Manager. One field blank sample was also sent to the environmental laboratory for analysis however, it was left unopen and thus no sample duration was recorded.

Table 5. Partial Period Sampling Results and Comparison to Standards

Employee	**Sample Mass (µg)**	**Sample Duration (min)**	**Sample Concentration (PPM)**	**OSHA STEL**	**ACGIH TLV-STEL (PPM)**	**NIOSH STEL (PPM)**
Laboratory Manager	0.21	15	0.69	2.0	0.3	0.1
Field Blank	<0.050	N/A	N/A			

4.1.1.3 Area Sampling

The results for the area sampling portion of this assessment are provided in Table 6. The sample durations for the area sampling portion of this assessment were 481 and 480 minutes.

Table 6. Area Sampling Results

Sample	Sample Mass (μg)	Sample Duration (min)	Average Flow Rate (LPM)	Sample Volume (L)	Sample Concentration (mg/m^3)	Sample Concentration (PPM)
East	0.75	481	0.026	12.5	0.060	0.049
Northwest	1.4	480	0.036	17.3	0.080	0.065

Area samples were not used to quantify exposures, but instead were used to assess the effectiveness of the laboratory's general exhaust ventilation system. The sample collected in the eastern section of the laboratory was used to determine ambient conditions near the center of the room. The sample collected in the northwest section of the laboratory was used to determine ambient conditions near the exhaust of the ventilation system. The resulting sample concentrations for the east and northwest sections of the lab were 0.049 and 0.065 ppm, respectively.

4.1.2 Volatile Organic Compounds

The results of personal air sampling for Hazardous Waste Worker-1 and Hazardous Waste Worker-2 in comparison to relevant occupational health and safety standards are provided in Table 7. Sample durations for these workers were 3 hours and 21 minutes and 3 hours and 22 minutes, respectively.

Table 7. Volatile Organic Compound Sampling Results and Comparison to Standards

Detected Target Compound	Concentration (PPM)		OSHA PEL (PPM)	NIOSH REL (PPM)	ACGIH TLV-TWA (PPM)
	Hazardous Waste Worker-1	Hazardous Waste Worker-2			
n-Butane	0.0061	ND	NE	800	1000
Ethanol	0.750	0.210	1000	1000	1000
Isopropyl alcohol(2-Propanol)	0.120	0.029	400	400	200
Acetone	0.200	0.100	1000	250	250
Acetonitrile	0.220	0.180	40	20	20
Methylene chloride	1.800	1.000	25	LFC	50
Methyl-tert-butyl ether (MTBE)	0.0042	ND	NE	NE	50
n-Hexane	1.600	0.540	500	50	50
Ethyl acetate	0.930	0.510	400	400	400
Chloroform	0.078	0.046	50	2	10
Tetrahydrofuran	0.077	0.043	200	200	50
Cyclohexane	0.010	ND	300	200	100
n-Heptane	0.0055	0.0082	500	85	400
Toluene	0.0068	ND	200	100	20

ND = Not Detected
NE = Not Established
LFC = Lowest Feasible Concentration

Personal air sampling for Hazardous Waste Worker-1 resulted in a total of 14 target compounds being detected. Personal air sampling for Hazardous Waste Worker-2 resulted in a total of 10 target compounds being detected. Concentrations of each target compound ranged from 0.0055 to 1.8 ppm. Comparatively, the occupational exposure limits for each target compound range from 2 to 1000 ppm.

4.1.3 Noise

The calibration results for this assessment are provided in Table 8. The sample durations for Grounds Crew Workers-1 and Grounds Crew Worker-2 were 8 hours and 15 minutes and 8 hours and 19 minutes, respectively. Grounds Crew Worker-3 left their shift early, resulting in a sample duration of only 4 hours and 53 minutes.

Table 8. Noise Dosimeter Calibration Summary

Employee	**Pre-Calibration (dBA)**	**Post-Calibration (dBA)**	**Deviation (dBA)**
Grounds Crew Worker-1	113.9	114.2	0.3
Grounds Crew Worker-2	114.0	112.9	1.1
Grounds Crew Worker-3	114.0	112.2	1.8
Percent Difference = ǀ Pre-Calibration - Post-Calibration ǀ			

The results of pre- and post-calibration showed deviations in recorded noise levels that ranged from 0.3 dBA to 1.8 dBA. The OSHA technical manual states that deviations in recorded noise levels greater than 1 dB may suggest that there is an issue with the equipment used (OSHA, 2013). Given these deviations, it was determined that there may have been issues with the dosimeters used to assess noise exposures for Grounds Crew Worker-2 and Grounds Crew Worker-3.

Noise dosimeters were set to simultaneously record data using OSHA PEL, OSHA Hearing Conservation, and ACGIH / NIOSH exposure monitoring criteria. The results obtained by recording data using each criterion are provided in Table 9. Please note that these results are projected because full-shift monitoring was not performed.

Table 9. Noise Dosimetry Results (Projected)

Employee	**OSHA PEL**		**OSHA Hearing Conservation**		**ACGIH / NIOSH**	
	8-HR TWA (dBA)	**8-HR Percent Dose (%)**	**8-HR TWA (dBA)**	**8-HR Percent Dose (%)**	**8-HR TWA (dBA)**	**8-HR Percent Dose (%)**
Grounds Crew Worker-1	89.6	95.1	90.2	104.1	94.3	863.4
Grounds Crew Worker-2	90.5	107.8	91.0	116.3	93.9	788.6
Grounds Crew Worker-3	91.8	129.5	92.3	137.9	92.7	601.1

The standards that should not be exceeded when using each exposure monitoring criterion are provided in Table 10.

Table 10. Noise Exposure Standards

Monitoring Criteria					
OSHA PEL		**OSHA Hearing Conservation**		**ACGIH / NIOSH**	
8-HR TWA (dBA)	**8-HR Percent Dose (%)**	**8-HR TWA (dBA)**	**8-HR Percent Dose (%)**	**8-HR TWA (dBA)**	**8-HR Percent Dose (%)**
90	100	90	100	85	100

Using OSHA PEL exposure monitoring criteria, the resulting TWA exposures for Grounds Crew Workers-1, -2, and -3 were 89.6, 90.5, and 91.8 dBA, respectively. The resulting 8-hour percent doses for these workers were 95.1, 107.8, and 129.5, respectively.

Using OSHA Hearing Conservation exposure monitoring criteria, the resulting TWA exposures for Grounds Crew Workers-1, -2, and -3 were 90.2, 91.0, and 92.3 dBA, respectively. The resulting 8-hour percent doses for these workers were 104.1, 116.3, and 137.9, respectively.

Using ACGIH / NIOSH exposure monitoring criteria, the resulting TWA exposures for Grounds Crew Workers-1, -2, and -3 were 90.2, 91.0, and 92.3 dBA, respectively. The resulting 8-hour percent doses for these workers were 104.1, 116.3, and 137.9, respectively.

Chapter 5: Discussion

5.1 Exposure Assessment Outcomes

5.1.1 Formaldehyde

Full period sampling resulted in TWA exposures of 0.14 ppm for the Laboratory Manager, 0.05 ppm for Teaching Assistant-1, and 0.13 ppm for Teaching Assistant-2. This indicates that all exposures were below the OSHA PEL and Action Limit for formaldehyde which are 0.75 and 0.5 ppm, respectively. This also indicates that the Laboratory Manager and Teaching Assistant-2 were exposed in excess of the ACGIH TLV-TWA for formaldehyde and that all exposures were in excess of the NIOSH REL for formaldehyde which are 0.1 and 0.016 ppm, respectively.

The resulting sample concentration for the partial period sampling portion of this assessment was 0.69 ppm for the Laboratory Manager. This indicates that they were exposed to formaldehyde at a concentration below the OSHA STEL which is 2.0 ppm. However, this also indicates that they were exposed in excess of both the ACGIH TLV-STEL and NIOSH STEL for formaldehyde which are 0.3 and 0.1 ppm, respectively.

Area samples were not used to quantify exposures, but instead were used to assess the effectiveness of the laboratory’s general exhaust ventilation system. The sample collected in the eastern section of the laboratory was used to determine ambient conditions near the center of the room. The sample collected in the northwest section of the lab was used to determine ambient conditions near the exhaust of the ventilation system. The resulting sample concentrations for the east and northwest sections of the laboratory were 0.049 and 0.065 ppm, respectively. Lower concentrations near the center of the room and higher concentrations near the exhaust indicated that the ventilation system was efficient in reducing ambient formaldehyde concentrations.

For this assessment, the methods employed for selecting workers for exposure monitoring were not consistent with OSHA methodologies. OSHA states that workers that are anticipated to be frequently exposed to levels at or above the Action Limit should be monitored (OSHA, 2006). Given the typical shift durations for these employees, it can reasonably be anticipated that they would not be exposed to formaldehyde at or above the Action Limit when TWA exposures are calculated by assuming zero exposure for the remainder of the 8-hour period. While the decision to monitor these employees was not consistent with OSHA methodologies, it was beneficial in that the results could be used to gauge compliance with more stringent standards.

The methods employed to collect data for this assessment were not consistent with OSHA methodologies. OSHA states that either standardized NIOSH or OSHA sampling and analytical methods should be used whenever possible to assess workplace exposures (OSHA, 2014). All standardized sampling and analytical methods for formaldehyde require the use of active sampling to assess compliance with health and safety standards (NIOSH, 2016; NIOSH, 1994a; NIOSH, 1994b; OSHA, 1989). During this assessment, passive badges were used to collect personal air samples. Passive badges can be convenient because they do not require the use of air sampling pumps, however, the results obtained from passive sampling are often less accurate when compared to active sampling methods (OSHA, 2014).

The methods employed to interpret data for this assessment were not consistent with OSHA methodologies. The data collected for the personal sampling portion of this assessment was interpreted to represent actual levels of worker exposure. It is suggested that passive sampling should be used for screening purposes and that the data obtained from passive sampling should be interpreted as estimations rather than actual levels of exposure (OSHA, 2014).

5.1.2 Volatile Organic Compounds

Personal air sampling for Hazardous Waste Worker-1 resulted in a total of 14 target compounds being detected. Concentrations of each target compound ranged from 0.0055 to 1.8 ppm. Comparatively, the occupational exposure limits for each target compound range from 2 to 1000 ppm. This indicates that Hazardous Waste Worker-1 had not been exposed to VOCs in excess of any relevant occupational safety and health standards.

Personal air sampling for Hazardous Waste Worker-2 resulted in a total of 10 target compounds being detected. Concentrations of each target compound ranged from 0.0082 to 1 ppm. Comparatively, the occupational exposure limits for each target compound ranged from 2 to 1000 ppm. This indicates that Hazardous Waste Worker-2 had not been exposed to VOCs in excess of any relevant occupational safety and health standards.

While no exposures were found to exceed permissible limits, it is interesting to note that methylene chloride was found to be present in the greatest concentration among all target compounds detected. Hazardous Waste Worker-1 and Hazardous Waste Worker-2 were found to be exposed to methylene chloride at concentrations of 1.8 and 1.0 ppm, respectively. NIOSH recommends reducing exposures to this volatile organic compound to the lowest feasible concentration (OSHA, 2021). The reason for this recommendation is that NIOSH has concluded that methylene chloride has the potential to induce carcinogenic effects.

For this assessment, the methods employed to select workers for exposure monitoring were not consistent with OSHA methodologies. It can reasonably be anticipated that neither of these workers would be frequently exposed to volatile organic compounds at or above respective Action Limits given the brief durations that are spent working at the hazardous waste disposal facility. While the decision to monitor these employees was not consistent with OSHA methodologies, this assessment was still beneficial because it could be used to characterize the mixture of volatile organic compounds present in the workspace.

The methods used to collect data for this assessment were consistent with NIOSH Method 3900, however, the methods used to interpret the data obtained were not consistent with OSHA methodologies. NIOSH Method 3900 is only approved for accurately determining the concentration of 17 different volatile organic compounds (NIOSH, 2018). Most of the compounds that were identified during the assessment did not fall under this approved list. It is likely that the concentrations reported for these compounds were not entirely accurate and that interpreting these results as actual levels of worker exposure exceeded the scope of NIOSH Method 3900. Without determining the concentration of these compounds within a specified degree of accuracy, it is inappropriate to conclude that all exposures were compliant with OSHA standards. These results should have been interpreted as estimations rather than actual levels of exposure.

5.1.3 Noise

The results of this assessment varied based on the exposure monitoring criteria that was used. The results obtained from using OSHA PEL exposure monitoring criteria indicated that Grounds Crew Worker-2 and Grounds Crew Worker-3 were exposed to noise in excess of permissible limits. 8-hour percent doses for these workers were 107.8 and 129.5, respectively. The results also indicated that Grounds Crew Worker-1 had not been exposed to noise in excess of permissible limits. The 8-hour percent dose for this worker was 95.1.

The results obtained by using OSHA Hearing Conservation exposure monitoring criteria indicated that all noise exposures had exceeded permissible limits. Using this criterion, the percent doses for Grounds Crew Workers-1, -2, and -3 were found to be 104.1, 116.3, and 137.9, respectively. Similarly, the results obtained by using ACGIH / NIOSH exposure monitoring criteria indicated that all noise exposures had exceeded acceptable limits. Using this criterion, the percent doses for Grounds Crew Workers -1, -2, and -3 were found to be 863.4, 788.6, and 601.1, respectively.

The methods employed for selecting employees to monitor, data collection, and data interpretation for this assessment were consistent with OSHA methodologies. Selecting to monitor these employees was an appropriate decision because it is fair to anticipate that they would be exposed to noise at or above the Action Limit given their typical shift durations and work assignments. Data was not only collected using OSHA PEL and OSHA Hearing Conservation exposure monitoring criteria, but also using ACGIH and NIOSH criteria. Due to issues with equipment calibration, results for Grounds Crew Worker-2 and Grounds Crew Worker-3 were considered to be inaccurate and recommendations for conducting an additional assessment were made.

Chapter 6: Conclusions

Without being constrained by federal regulation, those responsible for ensuring the health and safety of those working at publicly funded universities have some leeway in selecting methods for conducting health and safety evaluations. The purpose of this study was to compare the methods used for assessing worker exposures in a university setting with OSHA requirements by describing typical exposure assessment processes. Exposures to three exposure agents were assessed: formaldehyde, volatile organic compounds, and noise. The results of these assessments indicated compliance with OSHA health and safety standards, however, the methods employed for selecting employees for monitoring, data collection, and data interpretation were not always consistent with OSHA methodologies. These inconsistencies were most true for the evaluations aimed at assessing exposures to formaldehyde and volatile organic compounds. Given the data collected, responses to the research questions are as follows:

Research Question 1: Are the methods employed for selection of workers for exposure monitoring consistent with OSHA methodologies?

> The methods employed for selecting workers for exposure monitoring were not always consistent with OSHA methodologies. OSHA states that workers that are anticipated to be exposed to levels at or above the Action Limit should be monitored (OSHA, 2014). Given the typical shift durations of laboratory managers, teaching assistants, and hazardous waste disposal workers, it can be anticipated that exposures at or above the Action Limit are unlikely.

Research Question 2: Are the methods employed for data collection consistent with OSHA exposure assessment methodologies?

The methods employed for data collection were not always consistent with OSHA exposure assessment methodologies. When assessing exposures to formaldehyde, passive badges were used to collect personal air samples, however, all standardized sampling and analytical methods for formaldehyde require the use of active sampling. The methods used to evaluate exposure to volatile organic compounds were consistent with NIOSH Method 3900, however, this method is not designed to accurately determine the concentration of all the volatile organic compounds that were detected.

Research Question 3: Are the methods employed for data interpretation consistent with OSHA data interpretation methodologies?

The methods employed for data interpretation were not always consistent with OSHA data interpretation methodologies. The results of personal sampling for formaldehyde were interpreted as actual levels of exposure; however, they should have been interpreted as estimations. The results of the volatile organic compound exposure assessment were also interpreted as actual levels of exposure; however, they should have been interpreted as estimations or as a characterization of the contaminant mixture present in the work environment.

Chapter 7: Limitations and Recommendations

7.1 Exposure Assessments

7.1.1 Formaldehyde

Aside from inconsistencies with OSHA data collection and interpretation requirements, the major limitation to this study was that only one sample was taken to assess compliance with short-term exposure limits. Given the anticipated exposure durations, it would be fair for one to anticipate that most TWA exposures would fall below relevant health and safety standards when assuming zero exposure for the remainder of the 8-hour period. Adjustments in the assessment methodology for this study could have been made to yield more valuable results. Specifically, it would have been beneficial to take partial-period samples for each employee to assess compliance with short-term exposure limits. The results of these samples could have been used to identify activities that have the potential to elevate levels of exposures. After identifying such activities, recommendations for administrative controls could have been made to limit potential exposures.

It is recommended that future assessments utilizing standardized sampling and analytical methods are conducted to evaluate short-term exposures to formaldehyde. Future assessments can be used to identify activities that have the potential to elevate levels of exposure. Workers can then be encouraged to take extra precautionary measures while performing such activities and to take breaks if symptoms of overexposure are experienced. After implementing administrative controls, additional assessments can be used to assess their effectiveness in reducing exposures to levels below ACGIH and NIOSH standards.

7.1.2 Volatile Organic Compounds

Aside from inconsistencies with OSHA requirements for data interpretation, the major limitation of this study was that it could not be used to assess compliance with short-term exposure limits. Based on the results of this assessment and the typical work shift durations for employees, short-term exposures are anticipated to pose the greatest potential threat to occupational health. It is recommended that any future assessments conducted are agent specific so that the results can be used to evaluate short-term exposures to specific volatile organic compounds.

Future assessments conducted at this facility should use standardized sampling and analytical methods and be used to evaluate short-term exposures to specific VOCs. Sampling methods should be selected based on which contaminants are anticipated to render the greatest exposures. These methods can be used to determine compliance with relevant health and safety standards and to identify work processes that have the potential to elevate levels of exposure. The results assessments can be used to guide the implementation job-specific administrative controls aimed at reducing potential exposures.

7.1.3 Noise

The major limitation to this study was an issue with equipment calibrations. The results of pre- and post-calibration of the dosimeters used to measure noise exposures for Grounds Crew Worker-2 and Grounds Crew Worker-3 deviated by 1.1 and 1.8 dBA respectively. This indicates that there may have been some inaccuracies in the noise exposures measured. To remedy this issue, calibration adjustments should have been made in the field prior to sampling. In addition, industrial hygiene personnel should have considered reaching out to their equipment rental company prior to conducting the assessment to obtain the most recent factory calibration data for the dosimeters used. This information could have been used to help demonstrate the accuracy of the equipment used for the assessment.

Employees that are exposed to noise at these levels should be included in a hearing conservation program (OSHA, 2002). The OSHA requirements for such a program include periodic training, exposure monitoring, and audiometric testing (OSHA, 2002; OSHA, 2013). By utilizing a hearing conservation program, an employer can help to prevent their employees from developing NIHL.

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Appendix A: Sample Durations

Formaldehyde Personal Sampling Durations

Employee	Start Time	Stop Time	Sample Duration (min)
Laboratory Manager	10:05 AM	4:10 PM	365
Laboratory Manager STEL	10:09 AM	10: 24 AM	15
Teaching Assistant-1	2:09 PM	4:11 PM	122
Teaching Assistant-2	2:10 PM	4:11 PM	121
Field Blank	N/A	N/A	N/A

Formaldehyde Area Sampling Durations

Sample	Sample Duration
East	481 min
Northwest	480 min

Volatile Organic Compounds Sampling Durations

Employee	Start Time	Stop Time	Sample Duration
Hazardous Waste Worker-1	7:14 AM	10:35 AM	03:21
Hazardous Waste Worker-2	7:16 AM	10:38 AM	03:22

Noise Dosimetry Sampling Durations

Employee	Start Time	Stop Time	Sample Duration
Grounds Crew Worker-1	7:04:21 AM	3:23:52 PM	08:19:31
Grounds Crew Worker-2	7:03:59 AM	3:19:41 PM	08:15:42
Grounds Crew Worker-3	7:05:38 AM	11:59:09 AM	04:53:31

Appendix B: Calibration Data

Formaldehyde Area Sampling Calibration Data

Area	Average Flow Rate (LPM)
East	0.026
Northwest	0.036

Noise Dosimetry Calibration Data

Employee	Pre-Calibration (dBA)	Post-Calibration (dBA)
Grounds Crew Worker-1	113.9	114.2
Grounds Crew Worker-2	114.0	112.9
Grounds Crew Worker-3	114.0	112.2

Appendix C: Raw Data

Formaldehyde Personal Sampling Raw Data

Employee	Sampling Time (min)	Report Limit (ug)	Report Limit (ppm)	Sample Amt. (ug)	Sample Conc. (ppm)
Lab Manager	365	0.050	0.0068	1.3	0.18
Lab Manager STEL	15	0.050	0.17	0.21	0.69
TA #1	122	0.050	0.020	0.43	0.18
TA #2	121	0.050	0.021	1.2	0.51
Field Blank	n/a	0.050	n/a	<0.050	N/A

Formaldehyde Area Sampling Raw Data

Sample	Volume (L)	Sample Weight (ug)	Sample Concentration (mg/m^3)	Sample Concentration (ppm)	Reporting Limit (mg/m3)
East	12.5	0.75	0.060	0.049	0.0040
Northwest	17.5	1.4	0.080	0.065	0.0029

Hazardous Waste Disposal Worker-1 Raw Data

Target Compound	Result (ppbv)	Reporting Limit (ppbv)	Result (ug/m3)	Reporting Limit (ug/m3)
Propylene	ND	5.4	ND	9.2
Freon 12 (Dichlorodifluoromethane)	ND	2.7	ND	13
Freon 114 (1,2-Dichlorotetrafluoroethan)	ND	2.7	ND	19
Chloromethane	ND	2.7	ND	5.5
n-Butane	6.1	2.7	14	6.4
Vinyl chloride	ND	2.7	ND	6.8
1,3-Butadiene	ND	2.7	ND	5.9
Bromomethane	ND	2.7	ND	10
Chloroethane	ND	2.7	ND	7.1
Ethanol	750	67	1400	130
Bromoethene (Vinyl bromide)	ND	2.7	ND	12
Freon 11 (Trichlorofluoromethane)	ND	2.7	ND	15
Isopropyl alcohol (2-Propanol)	120	2.7	300	6.6
Freon 113 (1,1,2-Trichlorotrifluoroethan	ND	2.7	ND	21
Acetone	200	2.7	480	6.4
1,1-Dichloroethene	ND	2.7	ND	11
Acetonitrile	220	67	360	110
Tertiary butyl alcohol (TBA)	ND	2.7	ND	8.1
Bromoethane (Ethyl bromide)	ND	2.7	ND	12
3-Chloropropene (Allyl chloride)	ND	2.7	ND	8.4
Carbon disulfide	ND	2.7	ND	8.3
Methylene chloride	1800	67	6400	230
Acrylonitrile	ND	2.7	ND	5.8
Methyl-tert-butyl ether (MTBE)	4.2	2.7	15	10
trans-1,2-Dichloroethene	ND	2.7	ND	11
n-Hexane	1600	67	5600	240
1,1-Dichloroethane	ND	2.7	ND	11
Vinyl acetate	ND	2.7	ND	9.4
2-Butanone (MEK)	ND	2.7	ND	7.9
cis-1,2-Dichloroethene	ND	2.7	ND	11
Ethyl acetate	930	67	3400	240
Chloroform	78	2.7	380	13
Tetrahydrofuran	77	2.7	230	7.9
1,1,1-Trichloroethane	ND	2.7	ND	15
Cyclohexane	10	2.7	36	9.2

2,2,4-Trimethylpentane (Isooctane)	ND	2.7	ND	12
Carbon tetrachloride	ND	2.7	ND	17
n-Heptane	5.5	2.7	22	11
1,2-Dichloroethane	ND	2.7	ND	11
Benzene	ND	2.7	ND	8.5
Trichloroethene	ND	2.7	ND	14
1,2-Dichloropropane	ND	2.7	ND	12
Methyl Methacrylate	ND	2.7	ND	11
Bromodichloromethane	ND	2.7	ND	18
1,4-Dioxane	ND	2.7	ND	10
4-Methyl-2-pentanone (MIBK)	ND	2.7	ND	11
cis-1,3-Dichloropropene	ND	2.7	ND	12
Toluene	6.8	2.7	26	10
trans-1,3-Dichloropropene	ND	2.7	ND	12
1,1,2-Trichloroethane	ND	2.7	ND	15
2-Hexanone (MBK)	ND	2.7	ND	11
Tetrachloroethene	ND	2.7	ND	18
Dibromochloromethane	ND	2.7	ND	23
1,2-Dibromoethane	ND	2.7	ND	21
Chlorobenzene	ND	2.7	ND	12
Ethylbenzene	ND	2.7	ND	12
Xylene (p,m)	ND	5.4	ND	23
Xylene (Ortho)	ND	2.7	ND	12
Styrene	ND	2.7	ND	11
Isopropylbenzene (cumene)	ND	2.7	ND	13
Bromoform	ND	2.7	ND	28
1,1,2,2-Tetrachloroethane	ND	2.7	ND	18
4-Ethyltoluene	ND	2.7	ND	13
1,3,5-Trimethylbenzene	ND	2.7	ND	13
2-Chlorotoluene	ND	2.7	ND	14
1,2,4-Trimethylbenzene	ND	2.7	ND	13
1,3-Dichlorobenzene	ND	2.7	ND	16
1,4-Dichlorobenzene	ND	2.7	ND	16
Benzyl chloride	ND	2.7	ND	14
1,2-Dichlorobenzene	ND	2.7	ND	16
1,2,4-Trichlorobenzene	ND	2.7	ND	20
Hexachloro-1,3-butadiene	ND	2.7	ND	29
Naphthalene	ND	2.7	ND	14
TOTAL	5800		19000	

Hazardous Waste Disposal Worker-2 Raw Data

Target Compound	Result (ppbv)	Reporting Limit (ppbv)	Result (ug/m3)	Reporting Limit (ug/m3)
Propylene	ND	5.4	ND	9.2
Freon 12 (Dichlorodifluoromethane)	ND	2.7	ND	13
Freon 114 (1,2-Dichlorotetrafluoroethan	ND	2.7	ND	19
Chloromethane	ND	2.7	ND	5.5
n-Butane	ND	2.7	ND	6.4
Vinyl chloride	ND	2.7	ND	6.8
1,3-Butadiene	ND	2.7	ND	5.9
Bromomethane	ND	2.7	ND	10
Chloroethane	ND	2.7	ND	7.1
Ethanol	210	67	390	130
Bromoethene (Vinyl bromide)	ND	2.7	ND	12
Freon 11 (Trichlorofluoromethane)	ND	2.7	ND	15
Isopropyl alcohol (2-Propanol)	29	2.7	72	6.6
Freon 113 (1,1,2-Trichlorotrifluoroethan	ND	2.7	ND	21
Acetone	100	2.7	250	6.4
1,1-Dichloroethene	ND	2.7	ND	11
Acetonitrile	180	67	310	110
Tertiary butyl alcohol (TBA)	ND	2.7	ND	8.1
Bromoethane (Ethyl bromide)	ND	2.7	ND	12
3-Chloropropene (Allyl chloride)	ND	2.7	ND	8.4
Carbon disulfide	ND	2.7	ND	8.3
Methylene chloride	1000	67	3600	230
Acrylonitrile	ND	2.7	ND	5.8
Methyl-tert-butyl ether (MTBE)	ND	2.7	ND	10
trans-1,2-Dichloroethene	ND	2.7	ND	11
n-Hexane	540	67	1900	240
1,1-Dichloroethane	ND	2.7	ND	11
Vinyl acetate	ND	2.7	ND	9.4
2-Butanone (MEK)	ND	2.7	ND	7.9
cis-1,2-Dichloroethene	ND	2.7	ND	11
Ethyl acetate	510	67	1800	240
Chloroform	46	2.7	230	13
Tetrahydrofuran	43	2.7	130	7.9
1,1,1-Trichloroethane	ND	2.7	ND	15
Cyclohexane	ND	2.7	ND	9.2

2,2,4-Trimethylpentane (Isooctane)	ND	2.7	ND	12
Carbon tetrachloride	ND	2.7	ND	17
n-Heptane	8.2	2.7	34	11
1,2-Dichloroethane	ND	2.7	ND	11
Benzene	ND	2.7	ND	8.5
Trichloroethene	ND	2.7	ND	14
1,2-Dichloropropane	ND	2.7	ND	12
Methyl Methacrylate	ND	2.7	ND	11
Bromodichloromethane	ND	2.7	ND	18
1,4-Dioxane	ND	2.7	ND	10
4-Methyl-2-pentanone (MIBK)	ND	2.7	ND	11
cis-1,3-Dichloropropene	ND	2.7	ND	12
Toluene	ND	2.7	ND	10
trans-1,3-Dichloropropene	ND	2.7	ND	12
1,1,2-Trichloroethane	ND	2.7	ND	15
2-Hexanone (MBK)	ND	2.7	ND	11
Tetrachloroethene	ND	2.7	ND	18
Dibromochloromethane	ND	2.7	ND	23
1,2-Dibromoethane	ND	2.7	ND	21
Chlorobenzene	ND	2.7	ND	12
Ethylbenzene	ND	2.7	ND	12
Xylene (p,m)	ND	5.4	ND	23
Xylene (Ortho)	ND	2.7	ND	12
Styrene	ND	2.7	ND	11
Isopropylbenzene (cumene)	ND	2.7	ND	13
Bromoform	ND	2.7	ND	28
1,1,2,2-Tetrachloroethane	ND	2.7	ND	18
4-Ethyltoluene	ND	2.7	ND	13
1,3,5-Trimethylbenzene	ND	2.7	ND	13
2-Chlorotoluene	ND	2.7	ND	14
1,2,4-Trimethylbenzene	ND	2.7	ND	13
1,3-Dichlorobenzene	ND	2.7	ND	16
1,4-Dichlorobenzene	ND	2.7	ND	16
Benzyl chloride	ND	2.7	ND	14
1,2-Dichlorobenzene	ND	2.7	ND	16
1,2,4-Trichlorobenzene	ND	2.7	ND	20
Hexachloro-1,3-butadiene	ND	2.7	ND	29
Naphthalene	ND	2.7	ND	14
TOTAL	2700		8700	

Grounds Crew Worker-1 Raw Data

Description	Meter	Value	Description	Meter	Value
Dose	1	108.3 %	Pdose (8:00)	1	104.1 %
Lavg	1	90.2 dB	Leq	1	-
TWA	1	90.5 dB	UL Time	1	00:00:07
STEL	1	164.6 dB	Exp Sec	1	-
Projected TWA (8:00)	1	90.2 dB	Mntime	1	6/28/2021 8:12:24 AM
Mxtime	1	6/28/2021 2:17:34 PM	PKtime	1	6/28/2021 2:17:34 PM
Lasmx	1	123.1 dB	Lafmx	1	-
Lcsmx	1	-	Lcmfx	1	-
Lasmn	1	60.1 dB	Lafmn	1	-
Lcsmn	1	-	Lcfmn	1	-
Lcpk	1	-	Lzpk	1	-
Lapk	1	139.6 dB			
Weighting	1	A	Range Ceiling	1	140 dB
Criterion Level	1	90 dB	ULL	1	115 dB
Dynamic Range	1	80 dB	Exchange Rate	1	5 dB
Response	1	SLOW	Integrating Threshold	1	80 dB
Alarm Level 1	1	-	Alarm Level 2	1	-
Dosimeter Name	1	OSHA HC			
Dose	2	99 %	Pdose (8:00)	2	95.1
Lavg	2	89.6 dB	Leq	2	-
TWA	2	89.9 dB	UL Time	2	00:00:07
STEL	2	164 dB	Exp Sec	2	-
Projected TWA (8:00)	2	89.6 dB	Mntime	2	6/28/2021 8:12:24 AM
Mxtime	2	6/28/2021 2:17:34 PM	PKtime	2	6/28/2021 2:17:34 PM
Lasmx	2	123.1 dB	Lafmx	2	-
Lcsmx	2	-	Lcmfx	2	-
Lasmn	2	60.1 dB	Lafmn	2	-
Lcsmn	2	-	Lcfmn	2	-
Lcpk	2	-	Lzpk	2	-
lapk	2	139.6 dB			
Weighting	2	A	Range Ceiling	2	-

Criterion Level	2	90 dB	ULL	2	115 dB
Dynamic Range	2	-	Exchange Rate	2	5 dB
Response	2	SLOW	Integrating Threshold	2	90 dB
Alarm Level 1	2	-	Alarm Level 2	2	-
Dosimeter Name	2	OSHA PEL			
Dose	3	898.5 %	Pdose (8:00)	3	863.4 %
Lavg	3	94.3 dB	Leq	3	-
TWA	3	94.5 dB	UL Time	3	00:00:07
STEL	3	139.1 dB	Exp Sec	3	32571.3 Pa^2-Sec
Projected TWA (8:00)	3	94.3 dB	Mntime	3	6/28/2021 8:12:24 AM
Mxtime	3	6/28/2021 2:17:34 PM	PKtime	3	6/28/2021 2:17:34 PM
Lasmx	3	123.1 dB	Lafmx	3	-
Lcsmx	3	-	Lcmfx	3	-
Lasmn	3	60.1 dB	Lafmn	3	-
Lcsmn	3	-	Lcfmn	3	-
Lcpk	3	-	Lzpk	3	-
Lapk		139.6 dB			
Weighting	3	A	Range Ceiling	3	-
Criterion Level	3	85 dB	ULL	3	115 dB
Dynamic Range	3	-	Exchange Rate	3	3 dB
Response	3	SLOW	Integrating Threshold	3	80 dB
Alarm Level 1	3	-	Alarm Level 2	3	-
Dosimeter Name	3	ACGIH			

Grounds Crew Worker-2 Raw Data

Description	Meter	Value	Description	Meter	Value
Dose	1	120.1 %	Pdose (8:00)	1	116.3 %
Lavg	1	91 dB	Leq	1	-
TWA	1	91.3 dB	UL Time	1	00:00:00
STEL	1	165.3 dB	Exp Sec	1	-
Projected TWA (8:00)	1	91 dB	Mntime	1	6/28/2021 8:55:53 AM
Mxtime	1	6/28/2021 1:32:35 PM	PKtime	1	6/28/2021 3:10:15 PM
Lasmx	1	112.7 dB	Lafmx	1	-
Lcsmx	1	-	Lcmfx	1	-
Lasmn	1	63.1 dB	Lafmn	1	-
Lcsmn	1	-	Lcfmn	1	-
Lcpk	1	-	Lzpk	1	-
Lapk		133.2 dB			
Weighting	1	A	Range Ceiling	1	140 dB
Criterion Level	1	90 dB	ULL	1	115 dB
Dynamic Range	1	80 dB	Exchange Rate	1	5 dB
Response	1	SLOW	Integrating Threshold	1	80 dB
Alarm Level 1	1	-	Alarm Level 2	1	-
Dosimeter Name	1	OSHA HC			
Dose	2	111.3 %	Pdose (8:00)	2	107.8 %
Lavg	2	90.5 dB	Leq	2	-
TWA	2	90.7 dB	UL Time	2	00:00:00
STEL	2	164.8 dB	Exp Sec	2	-
Projected TWA (8:00)	2	90.5 dB	Mntime	2	6/28/2021 8:55:53 AM
Mxtime	2	6/28/2021 1:32:35 PM	PKtime	2	6/28/2021 3:10:15 PM
Lasmx	2	112.7 dB	Lafmx	2	-
Lcsmx	2	-	Lcmfx	2	-
Lasmn	2	63.1 dB	Lafmn	2	-
Lcsmn	2	-	Lcfmn	2	-
Lcpk	2	-	Lzpk	2	-
Lapk		133.2 dB			
Weighting	2	A	Range Ceiling	2	-

Criterion Level	2	90 dB	ULL	2	115 dB
Dynamic Range	2	-	Exchange Rate	2	5 dB
Response	2	SLOW	Integrating Threshold	2	90 dB
Alarm Level 1	2	-	Alarm Level 2	2	-
Dosimeter Name	2	OSHA PEL			
Dose	3	814.4 %	Pdose (8:00)	3	788.6%
Lavg	3	93.9 dB	Leq	3	-
TWA	3	94.1 dB	UL Time	3	00:00:00
STEL	3	138.6 dB	Exp Sec	3	29524.7 Pa^2-Sec
Projected TWA (8:00)	3	93.9 dB	Mntime	3	6/28/2021 8:55:53 AM
Mxtime	3	6/28/2021 1:32:35 PM	PKtime	3	6/28/2021 3:10:15 PM
Lasmx	3	112.7 dB	Lafmx	3	-
Lcsmx	3	-	Lcmfx	3	-
Lasmn	3	63.1 dB	Lafmn	3	-
Lcsmn	3	-	Lcfmn	3	-
Lcpk	3	-	Lzpk	3	-
Lapk		133.2 dB			
Weighting	3	A	Range Ceiling	3	-
Criterion Level	3	85 dB	ULL	3	115 dB
Dynamic Range	3	-	Exchange Rate	3	3 dB
Response	3	SLOW	Integrating Threshold	3	80 dB
Alarm Level 1	3	-	Alarm Level 2	3	-
Dosimeter Name	3	ACGIH			

Grounds Crew Worker-3 Raw Data

Description	Meter	Value	Description	Meter	Value
Dose	1	84.3 %	Pdose (8:00)	1	137.9 %
Lavg	1	92.3 dB	Leq	1	-
TWA	1	88.7 dB	UL Time	1	00:00:00
STEL	1	162.8 dB	Exp Sec	1	-
Projected TWA (8:00)	1	92.3 dB	Mntime	1	6/28/2021 7:16:48 AM
Mxtime	1	6/28/2021 7:32:46 AM	PKtime	1	6/28/2021 9:44:02 AM
Lasmx	1	97.3 dB	Lafmx	1	-
Lcsmx	1	-	Lcmfx	1	-
Lasmn	1	63.1 dB	Lafmn	1	-
Lcsmn	1	-	Lcfmn	1	-
Lcpk	1	-	Lzpk	1	-
Lapk		119 dB			
Weighting	1	A	Range Ceiling	1	140 dB
Criterion Level	1	90 dB	ULL	1	115 dB
Dynamic Range	1	80 dB	Exchange Rate	1	5 dB
Response	1	SLOW	Integrating Threshold	1	80 dB
Alarm Level 1	1	-	Alarm Level 2	1	-
Dosimeter Name	1	OSHA HC			
Dose	2	79.2 %	Pdose (8:00)	2	129.5 %
Lavg	2	91.8 dB	Leq	2	-
TWA	2	88.3 dB	UL Time	2	00:00:00
STEL	2	162.3 dB	Exp Sec	2	-
Projected TWA (8:00)	2	91.8 dB	Mntime	2	6/28/2021 7:16:48 AM
Mxtime	2	6/28/2021 7:32:46 AM	PKtime	2	6/28/2021 9:44:02 AM
Lasmx	2	97.3 dB	Lafmx	2	-
Lcsmx	2	-	Lcmfx	2	-
Lasmn	2	63.1 dB	Lafmn	2	-
Lcsmn	2	-	Lcfmn	2	-
Lcpk	2	-	Lzpk	2	-
Lapk		119 dB			
Weighting	2	A	Range Ceiling	2	-

Criterion Level	2	90 dB	ULL	2	115 dB
Dynamic Range	2	-	Exchange Rate	2	5 dB
Response	2	SLOW	Integrating Threshold	2	90 dB
Alarm Level 1	2	-	Alarm Level 2	2	-
Dosimeter Name	2	OSHA PEL			
Dose	3	367.5 %	Pdose (8:00)	3	601.1 %
Lavg	3	92.7 dB	Leq	3	-
TWA	3	90.6 dB	UL Time	3	00:00:00
STEL	3	135.2 dB	Exp Sec	3	13324.3 Pa^2-Sec
Projected TWA (8:00)	3	92.7 dB	Mntime	3	6/28/2021 7:16:48 AM
Mxtime	3	6/28/2021 7:32:46 AM	PKtime	3	6/28/2021 9:44:02 AM
Lasmx	3	97.3 dB	Lafmx	3	-
Lcsmx	3	-	Lcmfx	3	-
Lasmn	3	63.1 dB	Lafmn	3	-
Lcsmn	3	-	Lcfmn	3	-
Lcpk	3	-	Lzpk	3	-
Lapk		119 dB			
Weighting	3	A	Range Ceiling	3	-
Criterion Level	3	85 dB	ULL	3	115 dB
Dynamic Range	3	-	Exchange Rate	3	3 dB
Response	3	SLOW	Integrating Threshold	3	80 dB
Alarm Level 1	3	-	Alarm Level 2	3	-
Dosimeter Name	3	ACGIH			