

Section II

(previously Section I of Oregon OSHA's Technical Manual)

SAMPLING, MEASUREMENTS METHODS and INSTRUMENTS

CHAPTER 1: PERSONAL SAMPLING FOR AIR CONTAMINANTS

CHAPTER 2: [OCCUPATIONAL SKIN EXPOSURE](#)

CHAPTER 3: TECHNICAL EQUIPMENT: ON-SITE MEASUREMENTS

CHAPTER 4: SAMPLE SHIPPING AND HANDLING

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SECTION II: CHAPTER 2

SURFACE CONTAMINANTS, SKIN EXPOSURE, BIOLOGICAL MONITORING AND OTHER ANALYSES

Chapter Revision Information:

- *This chapter was previously identified as Section 1, Chapter 2 in Oregon OSHA’s circa 1996 **Technical Manual**. The Section number was modified from Section I to Section II in December 2014 to provide uniformity with the Federal OSHA Technical Manual (OTM).*
- *In December 2014, the original “Sampling for Surface Contamination” chapter was replaced by Federal OSHA’s February 11th, 2014 update “Personal Sampling for Air Contaminants”.*
- *In December 2014, Federal OSHA’s February 11th, 2014 Technical Manual update “Occupational Skin Exposure” was customized to make the document’s instructions specific to Oregon OSHA’s sampling equipment, laboratory and state specific regulations.*
- *In December 2014, several references to Federal OSHA CPL’s, Directives, and Field Operations Manual (FOM) were revised when appropriate to reflect Oregon OSHA’s Field Inspection Reference Manual (FIRM).*

SECTION II: CHAPTER 2

SURFACE CONTAMINANTS, SKIN EXPOSURE, BIOLOGICAL MONITORING AND OTHER ANALYSES

TABLE OF CONTENTS

| | | |
|------|---|----|
| I. | <u>INTRODUCTION</u> | 5 |
| II. | <u>BASICS OF SKIN EXPOSURE</u> | 6 |
| | A. Effects on the Skin | 6 |
| | B. Skin Absorption | 7 |
| | C. Risk Assessment | 8 |
| | D. Estimating the Extent of Absorption of Chemicals through Skin . . . | 10 |
| | E. Glove Permeability | 12 |
| III. | <u>WIPE SAMPLING, FIELD PORTABLE X-RAY FLUORESCENCE SAMPLING, DERMAL SAMPLING AND BIOLOGICAL MONITORING</u> | 13 |
| | A. Surface Wipe Sampling | 13 |
| | B. Field Portable X-Ray Fluorescence | 14 |
| | C. Dermal Sampling | 15 |
| | D. Biological Sampling | 15 |
| IV. | <u>SAMPLING METHODOLOGY</u> | 16 |
| | A. Surface Wipe Sampling | 16 |
| | B. Skin Sampling Methods | 18 |
| | C. Biological Monitoring Methodology | 19 |
| V. | <u>ENFORCEMENT RECOMMENDATIONS</u> | 22 |
| VI. | <u>CUSTOM SERVICES</u> | 24 |
| | A. Mass Spectrometry | 24 |
| | B. Materials Analysis | 25 |
| | C. Sampling for Biological Pathogens | 25 |
| | D. Explosibility Analysis | 25 |
| VII. | <u>REFERENCES</u> | 27 |

LIST OF APPDENENDICES

| | | |
|--------------------------------------|---|----|
| APPENDIX: A | Chemicals Noted for Skin Absorption | 29 |
| APPENDIX: B-1 | Biological Exposure Guidelines (BEI & OES) | 40 |
| APPENDIX: B-2 | Biological Exposure Guidelines (General Industry) . | 46 |
| APPENDIX: C | Procedures for Collecting Wipe Samples | 53 |
| APPENDIX: D | Combustible Dust Bulk Sampling | 55 |

I. Introduction

The purpose of this chapter is to provide guidance to OSHA Compliance Safety and Health Officers (CSHOs) and to the industrial hygiene community on the potential for skin exposure to chemicals in the workplace and the available means of assessing the extent of skin exposure. This chapter provides guidance for the use and interpretation of surface wipe sampling for assessing potential contamination which may lead to biological uptake through inhalation, ingestion, or dermal exposure. This chapter discusses methods for assessing skin contamination, such as dermal dosimeters (e.g., sorbent pads) and dermal wipe sampling, and provides guidance for monitoring of biological uptake. Finally, this chapter provides guidance for certain specialized analyses unrelated to dermal exposure, such as soil analysis, materials failure analysis, explosibility determinations, and identification of unknowns.

Skin exposure to chemicals in the workplace is a significant problem in the United States. Both the number of cases and the rate of skin disorders exceed recordable respiratory conditions. In 2010, 34,400 recordable skin diseases or disorders were reported by the Bureau of Labor Statistics (BLS) at a rate of 3.4 illnesses per 10,000 full-time employees, compared to 19,300 respiratory conditions with a rate of 1.9 illnesses per 10,000 full-time employees (BLS, 2011).

In addition to causing skin diseases, many chemicals that are readily absorbed through the skin can cause other health effects and contribute to the dose absorbed by inhalation of the chemical from the air. Skin absorption can occur without being noticed by the worker. This is particularly true for non-volatile chemicals that are hazardous and which remain on work surfaces for long periods of time. The number of occupational illnesses caused by skin absorption of chemicals is not known. However, of the estimated 60,000 deaths and 860,000 occupational illnesses per year in the United States attributed to occupational exposures, even a relatively small percentage caused by skin absorption would represent a significant health risk (Boeniger, 2003).

Biological monitoring refers to testing which is conducted to determine whether uptake of a chemical into the body has occurred. Biological monitoring tests assess a sample of a worker's urine, blood, exhaled breath, or other biological media to evaluate the presence of a chemical or its metabolite, or a biochemical change characteristic of exposure to a particular chemical. Biological exposure guidelines such as the American Conference of Governmental Industrial Hygienists (ACGIH) Biological Exposure Indices (BEIs) are numerical values below which it is believed nearly all workers will not experience adverse health effects. The BEI values correspond to the biological uptake that would occur in workers exposed to airborne concentrations at the ACGIH Threshold Limit Value (TLV). When biological monitoring indicates that workers have been exposed to a chemical, but the airborne concentrations are below any exposure limits, it suggests that exposures are occurring by another route, such as dermal absorption and/or ingestion.

Where other exposure routes are suspected, surface wipe sampling may be useful. Surface wipe sampling in areas where food and beverages are consumed and stored (including water bubblers, coolers, and drinking fountains) can be used to assess the potential for ingestion or dermal exposure. Such wipe sampling results can be used to support citations for violations of the Sanitation standard, 1910.141, or the applicable housekeeping provisions of the expanded health standards, such as Chromium (VI), 1910.1026. To assess the potential for skin absorption,

surface wipe sampling in work areas may be used to show the potential for contact with contaminated surfaces. Such results could be used to support violations of the Personal Protective Equipment (PPE) standard, OAR 437-002-0134, or applicable provisions of the expanded health standards, such as the Methylenedianiline standard, 1910.1050. For direct assessment of skin contamination, skin wipe sampling or dermal dosimetry may be used.

In addition, [Section VI](#) of this chapter, Custom Services, provides guidance for submitting samples to the Oregon OSHA Lab for specialized analyses including:

- Materials failure analysis.
- Explosibility determinations including:
 - Combustible dust analysis
 - Flash points
 - Energetic reactivity of chemicals
 - Autoignition temperatures
- Biological sampling for organisms (or chemicals associated with their presence) such as:
 - Fungi
 - Bacteria (such as Legionella)
 - Endotoxin (component of the outer membrane of certain gram-negative bacteria)
- Mass spectrometry analysis for identification of unknown materials in:
 - Industrial processes
 - Indoor air samples
 - Contaminated water samples

Many of these tests are labor intensive and custom in nature. Always discuss the need for specialized analysis with the Oregon OSHA Lab prior to collecting or sending samples.

[Appendix D](#) discusses techniques for combustible dust sampling. Such sampling is conducted where the potential for rapid combustion/burning (deflagration) or violent burning with rapid release of pressure (explosion) is suspected due to the presence of accumulations of settled dust. Bulk samples of settled dust may be collected and submitted to the Oregon OSHA Lab to send to the federal OSHA Salt Lake Technical Center (SLTC). Contact the Oregon OSHA Laboratory prior to collecting samples. Lab analysis is used to determine whether the composition of the dust poses an explosion hazard.

II. Basics of Skin Exposure

A. Effects on the Skin

Skin contact with chemicals can result in irritation, allergic response, chemical burns, and allergic contact dermatitis. Irritant dermatitis may be caused by a variety of substances such as strong acids and bases (primary irritants). Some examples of chemicals which are potent irritants include: ammonia, hydrogen chloride, and sodium hydroxide. Generally, primary irritants produce redness of the skin shortly after exposure with the extent of damage to the tissue related to the relative irritant properties of the chemical. In most instances, the symptoms of primary

irritation are observed shortly after exposure; however, some chemicals produce a delayed irritant effect because the chemicals are absorbed through the skin and then undergo decomposition within aqueous portions of the skin to produce primary irritants. Ethylene oxide, epichlorohydrin, hydroxylamines, and the chemical mustard agents, such as bis (2-chloroethyl) sulfide, are classic examples of chemicals which must first decompose in the aqueous layers of the skin to produce irritation.

Allergic contact dermatitis, unlike primary irritation, is caused by chemicals which sensitize the skin. This condition is usually caused by repeated exposure to a relatively low concentration chemical which ultimately results in an irritant response. Frequently, the sensitized area of skin is well defined, providing an indication of the area of the skin which has been in contact with the sensitizing material.

A wide variety of both organic and inorganic chemicals can produce contact dermatitis. Some examples of these chemicals include: aromatic nitro compounds (e.g., 2,4-dinitrochlorobenzene), diphenols (e.g., hydroquinone, resorcinol), hydrazines and phenylhydrazines, piperazines, acrylates, aldehydes, aliphatic and aromatic amines, epoxy resins, isocyanates, many other organic chemicals, and metals (e.g., hexavalent chromium). These substances can also produce contact sensitization. Allergic contact dermatitis is present in virtually every industry, including agriculture, chemical manufacturing, rubber industry, wood, painting, bakeries, pulp and paper mills, healthcare and many others. Also associated with both irritant and allergic contact dermatitis are metalworking fluids (see federal OSHA's Safety and Health Topics page on [Metalworking Fluids](#)).

Lastly, there is a class of chemicals which can produce allergic reactions on the skin after exposure to sunlight or ultraviolet (UV) light. These chemicals are called photosensitizers. Polynuclear aromatic compounds from coke ovens and the petroleum-based tars are examples of chemicals which can be photoactivated on the skin to cause an irritant response.

B. Skin Absorption

In addition to the effects that chemicals can directly have on the skin, the skin also acts as a pathway for chemicals to be absorbed into the body. The skin primarily consists of two layers—the epidermis and the dermis. The outer layer of the epidermis is composed of a compacted layer of dead epidermal cells called the stratum corneum which is approximately 10 – 40 micrometers thick. The stratum corneum is the primary barrier for protection against chemical penetration into the body. Its chemical composition is approximately 40 percent protein, 40 percent water, and 20 percent lipid or fat. Because skin cells are constantly being produced by the body, the stratum corneum is replaced by the body approximately every two weeks.

Chemical absorption through the stratum corneum occurs by a passive process in which the chemical diffuses through this dead skin barrier. Estimates of the amount of chemicals absorbed through the skin as discussed below assume that the chemicals passively diffuse through this dead skin barrier and are then carried into the body by the blood flow supplied to the dermis.

A number of conditions can affect the rate at which chemicals penetrate the skin. Physically damaged skin or skin damaged from chemical irritation or sensitization or sunburn will generally

absorb chemicals at a much greater rate than intact skin. Organic solvents which defat the skin and damage the stratum corneum may also result in an enhanced rate of chemical absorption. If a chemical breakthrough occurs while wearing gloves or other protective clothing, the substance becomes trapped against the skin, leading to a much higher rate of permeability than with uncovered skin. A worker who wears a glove for an extended period of time experiences enhanced hydration to the skin simply because of the normal moisture which becomes trapped underneath the glove. Under these conditions, chemical breakthrough or a pinhole leak in a glove can result in greater chemical absorption due to increased friction, contact time with the substance and increased temperature resulting in a higher overall absorption through the skin. In another example, a worker may remove a glove to perform a task which requires increased dexterity, exposing the skin to additional chemical exposure even after redonning the glove.

C. Risk Assessment (Establishing a Significant Risk of Skin Exposure)

Risk is determined from the degree of hazard associated with a material, together with the degree of exposure. Note that dermal exposures may vary widely between workers based on individual hygiene practices. The dermal hazard can be ranked based upon the degree of skin damage or systemic toxicity associated with the chemical of interest. Those settings with both a high degree of potential exposure and a high degree of dermal hazard would warrant the closest attention, and justify collecting sampling data to document the potential exposure, such as wipe sampling, skin sampling, or biological monitoring.

In estimating the potential exposure, consider the following:

- The risk of chemical splash.
- Significant differences in work practices between individuals.
- Use of gloves versus hand tools when in direct contact with chemicals.
- Use of shared tools.
- Cleaning frequencies for tools and equipment, including doorknobs, telephones, light switches, keyboards and actuators on control panels.

The dermal exposure potential can be ranked based upon the:

- Frequency and duration of skin contact.
- The amount of skin in contact with the chemical.
- The concentration of the chemical.
- The likely retention time of the material on the skin (e.g., highly volatile or dry powdery materials are not likely to remain in contact with the skin, whereas materials with a higher molecular weight and sticky materials will remain in contact with the skin and thus be available for dermal exposure).
- The potential for dermal absorption, as described below.

The absorption of chemicals through the skin can have a systemic toxic effect on the body. In certain instances dermal exposure is the principal route of exposure, especially for chemicals which are relatively non-volatile. For example, biological monitoring results of coke oven workers coupled with air monitoring of the workers' exposure demonstrated that 51 percent of the average total dose of benzo[a]pyrene absorbed by coke oven workers occurred via skin

contact (VanRooij et al., 1993). Studies of workers in the rubber industry suggest that exposure to genotoxic chemicals present in the workplace is greater via the skin than via the lung (Vermeulen et al., 2003).

Dermal exposures will contribute significantly to overall exposure for those chemicals with low volatility and high dermal penetration, such as many pesticides. One indicator of the volatility of a chemical is the Vapor Hazard Ratio (VHR). The VHR is the ratio between the vapor pressure (at a given temperature and pressure) and the airborne exposure limit for a chemical; the lower the VHR, the less significant the airborne exposure to vapor and the greater the potential for dermal penetration.

A common indicator of dermal absorption potential is the relative solubility of a material in octanol and water, often called the octanol-water partition coefficient (K_{ow}). This partition coefficient is often expressed in the logarithmic form as $\text{Log } K_{ow}$. Chemicals with a $\text{log } K_{ow}$ between -0.5 and + 3.0 are the most likely to penetrate the skin (Ignacio and Bullock, 2006). Chemicals must have some degree of lipid (fat) solubility to absorb into the stratum corneum. To penetrate into the layer of skin, they must have some degree of solubility in water.

Note also that skin penetration may be increased under conditions of high humidity. When temperatures are elevated, sweating may contribute to increased skin absorption. Wearing ineffective or compromised gloves, for example, may actually increase dermal penetration. Proper selection and maintenance of chemical protective gloves, as required by the PPE standard (OAR 437-002-0134), are essential to ensure effective protection. [Section II.E](#) provides additional information regarding glove permeability.

Chemicals for which dermal exposures are recognized as making a significant contribution to overall worker exposure include pesticides, formaldehyde, phenolics, coal tar, creosote, and [acrylamide in grouting operations](#).

[Appendix A](#) lists chemicals with systemic toxicity for which skin absorption is recognized as making a significant contribution to occupational exposure. This list includes only chemicals that have OSHA PELs or ACGIH TLVs and a “skin designation” or “skin notation,” and is not intended to be a comprehensive list. This exposure may occur by contact with vapor, aerosols, liquid, or solid materials, and includes contact with the skin, mucous membranes and the eyes. Where high airborne concentrations of vapor or aerosol occur involving a chemical noted for dermal absorption, the issue of exposed skin should be considered carefully. Note also that certain chemicals, such as dimethyl sulfoxide (DMSO) are known to facilitate dermal absorption of other chemicals.

For chemicals which are absorbed through the skin and which are hazardous, the levels of exposure on the skin must be maintained below a level at which no adverse effects would be observed. One of the simplest ways of determining this amount is to estimate the amount of a chemical which can be absorbed into the body based upon an air exposure limit. For example, the ACGIH Threshold Limit Value (TLV) for methylenedianiline (MDA) is 0.1 parts per million (ppm), or 0.81 milligrams per cubic meter of air (mg/m^3). If we assume that the average worker breathes 10 m^3 of air in an eight-hour workday, and further assume that all of the MDA is

absorbed from the air at the PEL, then the maximum allowable dose to the body per workday becomes:

$$(0.81 \text{ mg/m}^3) \times (10 \text{ m}^3) = 8.1 \text{ mg maximum allowable dose to the body for MDA}$$

In addition to using OSHA PELs, ACGIH TLVs or other occupational exposure limit (OEL) can also be used to establish the maximum allowable dose in the same manner. This method assumes that the toxic effects of the chemical are systemic and that the toxicity of the chemical is independent of the route of exposure. Note that the concept of a maximum allowable dose cannot be used to enforce compliance with the Oregon OSHA PELs for air contaminants (OAR 437-002-0382) through back-calculation of a measured dermal exposure.

The lethal dose to the skin which results in death to 50 percent of exposed animals (LD₅₀ dermal) is also a useful comparative means of assessing dermal exposure hazards. The OSHA acute toxicity definition (defined in 1910.1200 Appendix A, Section A.1.1) as it relates to skin exposure refers to those adverse effects that occur following dermal administration of a single dose of a substance, or multiple doses given within 24 hours. Substances can be allocated to one of four acute dermal toxicity categories according to the numeric cut-off criteria specified in Table 1 below. Acute toxicity values are expressed as approximate LD₅₀ dermal values or as acute toxicity estimates or ATE (see Appendix A of 1910.1200 for further explanation on the application of ATE. Refer to Table A.1.2 in Appendix A for Conversions to ATEs).

| TABLE 1. CLASSIFICATION CRITERIA FOR ACUTE DERMAL TOXICITY* | | | | |
|--|------------|----------------|-------------------|---------------------|
| Exposure Route | Category 1 | Category 2 | Category 3 | Category 4 |
| Dermal LD ₅₀ (mg/kg bodyweight; rat or rabbit preferred animal species) | ≤ 50 | > 50 and ≤ 200 | > 200 and ≤ 1,000 | > 1,000 and ≤ 2,000 |
| * Dermal administration of a single dose of a substance, or multiple doses given within 24 hours. See 1910.1200 Appendix A for classification criteria for mixtures. Source: Adapted from 29 CFR 1910.1200 Appendix A | | | | |

If available, the no observable effect level (NOEL) can also be useful in establishing a safe exposure level. Skin notations or skin designations for chemicals listed with ACGIH TLVs or the OSHA PELs are also useful guides; however, many chemicals (e.g., hexone, xylene and perchloroethylene) which can pose a dermal hazard are not designated.

D. Estimating the Extent of Absorption of Chemicals through Skin

For exposure to chemicals which are recognized as systemic toxins, that is, chemicals which are toxic once absorbed into the bloodstream, the route of exposure to the chemical may not be important. Hence, the maximum allowable dose can be used as a basis for determining if a chemical poses a skin exposure hazard. The extent of absorption of a chemical through the skin is a function of the area of the exposed skin, the amount of the chemical, the concentration of the chemical on the skin, the rate of absorption (flux rate) into the skin, and the length of time exposed (Kanerva et al., 2000). Assume, for example, that a worker has contact on the interior portion of both hands to a solution of phenol (10 percent solution by weight) for two hours.

Approximately how much phenol would be absorbed? The flux rate, J, is determined by:

$$J = (K_p)(\text{Concentration of Chemical on Skin})$$

Where K_p is skin permeability coefficient of compound in water (cm/hr)

K_p for phenol = 0.0043 cm/hr (K_p values are available in the [EPA Dermal Risk Assessment Guide](#); EPA/540/R/99/005, 2004)

Thus, at a concentration of 10 percent by weight (10 g/100 cm³; 10,000 mg/100 cm³; or 100 mg/cm³ where 1 cm³ of water weighs 1 g and 1 g equals 1,000 mg):

$$J = (0.0043 \text{ cm/hr}) \times (100 \text{ mg/cm}^3) = 0.43 \text{ mg}/(\text{cm}^2 \cdot \text{hr})(\text{flux rate})$$

Hence, under these conditions, 0.43 mg of phenol will be absorbed through the skin per cm² of exposed skin per hour.

Therefore, the absorbed dose of phenol through the skin of a worker's two hands (both hands exposed with an approximate area of 840 cm²) would be determined as follows:

$$\text{Absorbed Dose} = (840 \text{ cm}^2) \times (0.43 \text{ mg}/(\text{cm}^2 \cdot \text{hr})) (2 \text{ hr}) = 722 \text{ mg absorbed over a two-hour period.}$$

This compares to an allowable dose (PEL = 19 mg/m³) via the lung for an eight-hour exposure of 190 mg [(19 mg/m³) x (10 m³)]. Hence, this two-hour exposure via the skin would represent absorption of phenol which is 3.8 times the allowable dose via the lung.

The following hypothetical example illustrates the relative importance of skin absorption as a factor in exposure. Let us assume that a worker is wearing gloves and the gloves are exposed to a phenol solution. Let us further assume that the penetration through the gloves is detected by a hand wipe sample, and that 75 mg of phenol is reported present from a water hand rinse of the worker's hands taken before lunch. Let us further assume that the amount of phenol detected inside the glove at the lunch break represents a uniform constant exposure which occurred shortly after the beginning of the work shift. Finally, let us further assume that the 75 mg of phenol is present in approximately 10 milliliter (mL) of water (perspiration) present on the surface of the skin. How much phenol was absorbed in the eight-hour period?

First, we determine the flux rate: $J = (0.0043 \text{ cm/hr}) \times (75 \text{ mg}/10 \text{ cm}^3) = 0.0322 \text{ mg}/(\text{cm}^2 \cdot \text{hr})$
(flux rate)

$$\text{Absorbed Dose} = (840 \text{ cm}^2) \times (0.0322 \text{ mg}/(\text{cm}^2 \cdot \text{hr}))(8 \text{ hr}) = 216 \text{ mg of phenol absorbed}$$

Hence, the estimated amount of phenol absorbed into the body is greater than the maximum dose of phenol permitted to be absorbed via the lung, which is 190 mg.

E. Glove Permeability

Permeation is the process by which a chemical moves through a protective clothing material on a molecular basis. This process includes the: 1) Sorption of molecules of the chemical into the contacted (challenge side) surface of the test material; 2) Diffusion of the sorbed molecules in the material; and 3) Desorption of the molecules from the opposite (collection side) surface of the material. Glove manufacturers publish breakthrough data which reflect the length of time which occurs before a chemical permeates through a particular type of glove material. These tests are performed using American Society for Testing and Materials (ASTM) Method F739 (Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact) in which a pure or neat chemical is placed on one side of a section of the glove material and the time it takes to penetrate through the glove material is measured by analyzing the air on the other side of the glove material to detect chemical breakthrough. ASTM F739 measures the initial breakthrough of the chemical through the glove material (normalized or standardized as a rate of $0.1\mu\text{g}/\text{cm}^2/\text{minute}$) and the rate of permeation. The cumulative amount of chemical that permeates can also be measured or calculated.

Unfortunately, these breakthrough times can be misleading because actual breakthrough times will typically be less than reported by the manufacturer. This is the case because permeation rates are affected by temperature (as temperature increases, permeation rates increase) and the temperature of skin is greater than the test temperature, resulting in an increased permeability rate. Secondly, glove thinning occurs along pressure points where a worker may grip a tool or otherwise exert pressure on an object while wearing a glove. Glove degradation and reuse of gloves can also dramatically reduce a glove's impermeability to chemicals. Additionally, only limited breakthrough data for solvent mixtures is available and in many cases the breakthrough time for a solvent mixture is considerably less than would be predicted from the individual breakthrough times for each of the individual solvent components. Finally, batch variability can also result in wide variations in breakthrough times from one glove to the next (Klingner and Boeniger, 2002). Further, it is difficult to generalize glove breakthrough data from one manufacturer to the next, or even between one model of glove and another from the same manufacturer. This is particularly true for disposable gloves, since different fillers may be used in the formulation of different gloves, resulting in different breakthrough performance.

As a result of these limitations, it is necessary that the employer evaluate glove selection and use to prevent worker exposure as specified in OAR 437-002-0134(12). Guidance on conducting in-use testing methods for glove selection is available (Boeniger and Klingner, 2002).

III. Wipe Sampling, Field Portable X-Ray Fluorescence Sampling, Dermal Sampling and Biological Monitoring

A. Surface Wipe Sampling

Surface wipe sampling is conducted to assess the presence of a contaminant on surfaces in the workplace that may lead to worker exposure. Surfaces contaminated with hazardous liquid, particles, or dried residue may be contacted by workers, leading either to dermal exposure or transfer to foodstuffs and accidental ingestion. Settled dusts containing toxic material may be disturbed and re-suspended, resulting in inhalation exposure.

In instances where surface contamination is suspected and the employer has not required the use of effective PPE for workers in these areas, wipe sampling may be an effective means of documenting that a skin hazard exists. Wipe sampling can help establish that a significant amount of surface contamination is present in areas in which workers are not effectively protected by PPE. Wipe samples taken inside the sealing surface of "cleaned" respirators can establish the absence of an effective respiratory protection program.

In areas where exposures to toxic metals such as lead (Pb) occur, wipe sampling of settled dust can demonstrate that a reservoir for potential exposure exists; resuspension of such settled dusts can lead to inhalation exposure. This is particularly true if improper housekeeping techniques are used, such as: dry sweeping; blowing off surfaces with compressed air; or using a shop vac instead of a HEPA-rated vacuum cleaner.

In break areas, the presence of surface contamination can lead to contamination of foodstuffs and hence, accidental ingestion of toxic material. The same is true for contamination on drinking fountains. Contamination found on the clean side of a shower or locker area could suggest the potential for take-home contamination, resulting in additional toxic exposures occurring while away from work. All of these types of wipe sampling results can be used to support violations of the housekeeping requirements found in the expanded health standards in Subdivision Z of Oregon Administrative Rules, Chapter 437, Division 2.

In many instances, several wipe samples taken in an area suspected of being contaminated may be useful. For example, some surfaces which would be expected to be contaminated with chemicals because of airborne deposition of a non-volatile chemical may actually be relatively free of surface contamination because of frequent contact of the surface by workers (i.e., frequently contacted surfaces may be expected to be "clean" because of contaminant removal by frequent worker contact). Wipe samples of frequently contacted surfaces in conjunction with less frequently contacted surfaces in the same vicinity can be useful to establish the likelihood that skin exposure is occurring in "clean" areas in which PPE is not being used, or is being improperly used.

Housekeeping deficiencies may also be demonstrated by wipe samples which show major differences in surface contamination between work areas that have been routinely cleaned and areas which have not been recently cleaned. This sampling would allow the CSHO to demonstrate the employer's failure to maintain a clean work area. A reference control wipe

sample or samples taken from areas in which exposure is not anticipated will also help to establish the relative amount of surface contamination.

Surface wipe sampling can be conducted qualitatively, for example, wiping irregular surfaces such as a doorknob, tool handle or faucet handle, or quantitatively, in which an area of specified size is wiped. Wiping an area of a specified size is necessary to determine the concentration of a contaminant on a surface. This is needed for estimating the amount of contamination to which workers are potentially exposed. The customary size of the surface area to be wiped is a 10 cm x 10 cm square, i.e., 100 cm². The 100 cm² value approximates the surface area of a worker's palm. Thus, the amount of contaminant in a 100 cm² sample could all be transferred to a worker's hand upon contact.

In industries such as the pharmaceutical industry, a common rule of thumb is to use the maximum allowable dose (based on the chemical's airborne exposure limit in units of µg/m³) and the approximate area of a worker's hand (100 cm²) to arrive at an acceptable value for surface contamination in work areas (i.e., a housekeeping standard). For example, if the eight-hour TWA exposure limit for a chemical is 1 µg/m³, the maximum allowable dose for that chemical is 10 µg. As noted in [Section II.C.](#), the chemical's eight-hour time-weighted average (TWA) airborne exposure limit is multiplied by 10 m³, the volume of air inhaled by an average worker in an eight-hour workday, to determine the maximum acceptable dose (i.e., 1 µg/m³ x 10 m³ = 10 µg). The maximum acceptable dose is then divided by the area of a worker's hand to determine the acceptable surface limit of 10 µg/100 cm² or 0.1 µg/cm². By this rule of thumb, the amount of contaminant picked up by one hand contacting the contaminated surface is equivalent to the toxic dose allowed by the eight-hour TWA airborne exposure limit (determined by multiplying by the 10 m³ of air breathed by an average worker in an eight-hour workday).

For highly toxic materials, hazardous levels of surface contamination will often be invisible to the unaided eye, while limits of detection for wipe sampling will be considerably more sensitive. For example, the limit of visible residue for active pharmaceutical ingredients is typically 1–5 µg/cm², whereas good surface wipe sampling techniques can have limits of detection in the low nanogram range. This underscores the essential value of surface wipe sampling in areas where highly toxic materials such as lead or chromium (VI) are present.

B. Field Portable X-Ray Fluorescence Sampling

NOTE: At this time, the Oregon OSHA Lab does not have a XRF available for use. The following italicized content within Section III, subsection B is provided for informational purposes only:

X-ray fluorescence (XRF) provides real-time measurements of elemental metal on surfaces. This may be useful to measure metal in settled dust on contaminated surfaces, or in surface coatings such as on painted metal or wood. XRF uses the interaction of x-rays with a target material to determine the elements present and their relative concentrations. When the target material has been excited by being bombarded with high-energy x-rays (or gamma rays), the material emits secondary or fluorescent x-rays that are characteristic of each element present. The rate of generation of the emitted

fluorescent x-rays is proportional to the elemental concentration and is used to quantify the results.

Because x-rays will penetrate an object, the XRF will detect metals both on the surface and within the substrate of the material. To determine the quantity of removable metal contamination on a work surface, a reading is first taken on the uncleaned surface. The surface is then cleaned with a metal removal wipe until all visible dust, dirt, and debris is removed. After cleaning, a second reading is taken at the same spot and its value is subtracted from the initial reading to determine the surface concentration of metals.

The same sampling and citation strategies used for wipe sampling apply to XRF sampling. The advantage of XRF over wipe sampling is its rapid (approximately one minute per reading) sampling rate and the real-time results. For laboratory confirmation of XRF results, the area sampled with the XRF can be wipe-sampled using the traditional methods described in this chapter and submitted to the Oregon OSHA Lab for analysis.

C. Dermal Sampling

Skin sampling is used to estimate the amount of material which contacts the skin and is relevant both for materials that affect the skin, such as corrosive materials, and for materials which absorb through the skin and have systemic effects.

Dermal exposure may be assessed through either direct or indirect methods. Direct methods measure the amount of material which contacts the skin, for example, through wipe tests which remove and recover the material from exposed skin, or use of sorbent patches (dosimeters) which are placed over the skin and capture material which would have contaminated the skin. Indirect methods measure the amount of contaminant that enters the body. Indirect methods are also known as biological monitoring.

D. Biological Monitoring

Biological monitoring is used to assess uptake into the body of a contaminant of concern. Biological monitoring is defined by the American Industrial Hygiene Association Committee on Biological Monitoring as "the assessment of human exposure through the measurement of internal chemical markers of exposure, such as the chemical agent itself and/or one of its metabolites or an exposure related biochemical change unrelated or related to disease, in human biological samples" such as urine, blood, or exhaled breath (AIHA, 2004). Biological monitoring by itself does not indicate the route of exposure to the material. Airborne sampling, skin sampling, and/or surface sampling would be needed to pinpoint the source of exposure.

Biological monitoring can be a useful technique for determining if dermal exposure is a significant contributor to the worker's overall exposure. For example, in a work environment in which the air exposure to a specific chemical is well controlled, an abnormally elevated biological monitoring result will likely indicate that skin or ingestion is a major mode of exposure. Coupled with evidence of surface contamination, and documentation of poor or non-existent personal protection against chemical skin exposure, biological monitoring can be a valuable means of documenting dermal exposure to a chemical. Biological monitoring could also

be used to assess the effectiveness of PPE, such as chemical protective clothing or gloves, or the effectiveness of cartridge change schedules for air-purifying respirators. Prior to conducting biological monitoring, determine the variables that may affect the results including the potential for interferences (e.g., diet, over-the-counter drugs, personal care products, existing medical conditions, other).

Biological monitoring data can hypothetically be used to back-calculate an estimate of the corresponding airborne exposure that would have resulted in observed biological exposure. This requires the availability of adequate exposure modeling for the toxic material of interest. For example, this is done in cases of overt carbon monoxide poisoning, as described below in [Section IV.C.1](#).

Biological monitoring by itself does not indicate that a toxic or adverse health effect has occurred, only that the material has entered the body. Biological exposure guidelines, such as the ACGIH BEIs, are numerical values below which it is believed nearly all workers will not experience adverse health effects. Where measured levels exceed a BEI, this finding provides evidence that exposures have occurred which can result in an adverse health effect. Further, a number of the OSHA expanded health standards in Subdivision Z contain biological monitoring provisions. [Appendix B1](#) summarizes the 2012 ACGIH BEIs and the biological monitoring guidelines contained in the OSHA expanded health standards.

In addition, NIOSH offers guidance for biological monitoring, which may be found at the following link: [NIOSH Biological Monitoring Summaries](#). The NIOSH Biomonitoring Summaries provide a brief overview of the usage, environmental pathways, sources of exposure, toxicology, health effects, and human exposure information for most of the chemicals or chemical groups evaluated in the [National Report on Human Exposure to Environmental Chemicals](#).

Finally, there are many studies in the peer-reviewed literature that report exposure levels for numerous chemicals measured as biological matrices for workers in a variety of occupations and industries. These studies can be useful, in a comparative fashion, for assessing the extent of exposure between exposed and unexposed workers when the workplace in the study involves the same conditions (e.g., chemical exposure, type of work) as the workplace being inspected.

IV. Sampling Methodology

A. Surface Wipe Sampling

The most common surface testing technique is surface wipe sampling. The [OR-OSHA Lab Sampling Procedures](#) contain wipe sampling information for the chemicals commonly sampled with wipes, including the type of wipe to use.

Sometimes, the wipe is moistened with distilled water or other suitable solvent prior to wiping the surface of interest. This technique facilitates transfer of the contaminant from the surface to the wipe. It is best to use a minimum of water/solvent on the wipe so that all of the water/solvent

will be picked up by the wipe and not left behind on the sampled surface. Ghost wipes are pre-wetted and ready for use.

The percent recovery of the contaminant of interest from the sampled surface may vary with the characteristics of the surface sampled (e.g., rough or smooth), the solvent used, and the technique of the person collecting the sample. Consequently, surface wipe sampling may be only semi-quantitative. No OSHA standards currently specify acceptable surface limits. Results of surface wipe sampling are used qualitatively to support alleged violations of housekeeping standards and requirements for cleanliness of PPE. Enforcement guidance is described in more detail in [Section VI](#).

Templates may be used to define a relatively constant surface area for obtaining a wipe sample, but are not always helpful. Templates can only be used on flat surfaces, and they can cause cross-contamination if the template is not thoroughly cleaned between each use. Constructing single-use 10cm x 10cm templates is recommended (e.g., using cardstock or file folders). Cardboard templates may also be obtained from the Oregon OSHA Lab, either 10cm x 10cm or 1ft x 1ft. The CSHO may want to sample a much larger surface area than the area covered by a template (e.g., the CSHO may want to determine the cleanliness of a lunch table or other large surface area). In all cases, the CSHO should measure the dimensions of the area being sampled and record this value on the OSHA Information System (OTIS) sampling worksheet because the mass amount of chemical measured by the laboratory will be used to determine the mass per unit area for the wipe sample.

The [Oregon OSHA Lab wipe sampling](#) document provides general procedures for collecting surface wipe samples, including wipe sampling procedures for skin contamination, diisocyanates, and asbestos.

Other surface testing techniques include direct-reading swab and wipe tests and vacuum dust collection to collect bulk samples of dust for analysis. Swab and wipe test kits with colorimetric indicators are available for contaminants, including lead, chromate, cadmium, amines, aliphatic and aromatic isocyanates, and others. These nonquantitative assessments can be used to provide an immediate indication in the field of the presence of a contaminant on a surface or the general level of surface contamination. The presence of contamination can be used to provide evidence for housekeeping deficiencies.

Lead, chromate and other test swabs are self-contained units with a fiber tip at one end and glass ampoules with reactive materials inside the swab barrel. The swabs are activated by squeezing at the crush points marked on the barrel of the swab, shaking well to mix the reagents, and then squeezing until the reactive liquid comes to the tip of the swab. While squeezing gently, the tip of the swab is rubbed on the surface to be tested for 30 to 60 seconds. The tip of the swab turns color in the presence of the chemical (for example pink to red for lead and pink to purple for chromates). Color development depends on the concentration of chemical present. Potential limitations associated with swabs include:

Interferences in color development from chemicals or other materials that may be present (e.g., dark colored dust or dirty surfaces obscuring color development on the lead swab tip; rubbing too long or too hard causing a metallic film to collect on the lead swab tip which obscures the color change; bleeding occurring on the lead swab tip when the test surface is painted red; and high concentrations of mercuric chloride or molybdate interfering with the color development of chromate swabs).

- Delayed results (e.g., up to 18 hours for the detection of lead chromate in marine and industrial paints).
- Destruction or damage to the testing surface to assess multiple layers on metal parts or painted surfaces.

NOTE: Contact the [Oregon OSHA Lab](#) to discuss wipe sampling before considering use of these methods.

B. Skin Sampling Methods

Skin sampling methods are classified as “interception” and “removal” methods. Interception methods use a “dosimeter” such as a sorbent pad placed on the skin or clothing, which “intercepts” the contaminant before it reaches the skin. After the exposure period ends, the dosimeter is removed, and either extracted in the field to recover and stabilize the analyte of interest, or sealed and sent for laboratory analysis to determine the mass of contaminant collected on the pad. In some cases, direct reading pads are available which undergo a colorimetric change when exposed to the contaminant of interest. Skin wipes are available for aromatic and aliphatic amines, aromatic and aliphatic isocyanates, hydrazine, acid and base contaminants, and phenols.

“Removal” methods remove the contaminant of interest after it has deposited on the skin. Either the skin is rinsed with distilled water or mild washing solution and the rinsate is collected and analyzed for the contaminant of interest, or the skin is wiped with a dry or wetted wipe, and the analyte of interest is then extracted from the wipe. One approach is to place the hands inside a bag that is partially filled with the washing solution, such as distilled water, distilled water with surfactant, or isopropanol diluted with distilled water. The hand is then dipped in the solution and shaken a specified number of times to recover the contaminant from the hand.

Both of these types of methods are qualitative in nature. The percent recovery may be variable or not quantitatively established. Further, no OSHA standards currently specify quantitative limits for dermal exposure. Qualitative documentation of the presence of a contaminant on the skin is sufficient to determine whether PPE is inadequate, whether due to inappropriate selection, maintenance, or cleaning.

When considering dermal sampling, federal OSHA’s webpages at the following link: [Dermal Dosimetry](#) may be considered.

1. Direct Reading Patches/Charcoal Felt Pads

In some instances, direct reading patches and/or bandage-type patches can be worn inside a glove to demonstrate directly through a color change that an exposure has occurred because of breakthrough. Sensor pads are available for aromatic and aliphatic amines, aromatic and aliphatic isocyanates, hydrazine, acid and base contaminants, and phenols. In other instances, charcoal felt patches or bandages can be worn which can be analyzed by a laboratory to establish the presence of glove permeation by volatile organic chemicals. These charcoal pads may also be used for detection of less volatile organic chemicals. However, poor sample recoveries from a charcoal surface for higher molecular weight substances may result in underestimating the extent of skin exposure for these types of chemicals.

When sampling inside a glove, OSHA recommends that workers being sampled wear disposable gloves inside their normal PPE, with the indicator/charcoal felt pads being placed on the disposable glove surface. Placing the pad on the disposable glove between the skin surface and the regular PPE eliminates any potential skin exposure from the chemicals used in the colorimetric pads, and also reduces any effects that perspiration might have on the sampling pads.

For inside-the-glove sampling, it also is advisable to use a control pad to measure the concentration of airborne volatile chemicals. This control pad should be attached to the worker's clothing while the worker performs his/her normal tasks. The glove sample result would then be corrected for the amount of the organic chemical in the airborne sample to determine the amount of organic chemical actually permeating the protective glove relative to the amount of organic chemical entering the glove opening. This procedure, therefore, would allow the sampler to identify the possible route of glove contamination.

2. Wipe Sampling of Skin

Skin wipe samples taken on potentially exposed areas of a worker's body are a useful technique for demonstrating exposure to a recognized hazard. For water-soluble chemicals, a wipe pad moistened with distilled water can be used to wipe the skin. Generally, the best procedure is to allow workers to use the wipe pad to clean their skin surfaces, and then have them insert the wipe pad into a clean container, which is labeled and sealed. Hands, forearms, faces, and possibly feet may be exposed to contaminants that a wipe sample of the skin can be used to establish exposure. Include a blank water sample and use only distilled water, or another source of water approved by the laboratory, for analysis purposes.

C. Biological Monitoring Methodology

NOTE: At this time, the Oregon OSHA Lab does not offer Biological monitoring. The following italicized content within Section IV, subsection C is provided for informational purposes only:

In the event that a CSHO believes biological monitoring would be valuable to assess and evaluate worker exposure to a substance or mixture of substances, he or she should first contact their Health of Safety manager and the Oregon OSHA Laboratory to determine

appropriate arrangements to pursue biological monitoring. Biological sampling requires special consideration and will be addressed on a case-by-case basis.

Biological monitoring results can be used to demonstrate significant skin absorption, ingestion or airborne exposures. For instance, when wipe/skin sampling has indicated exposure, a voluntarily obtained worker biological sample may prove useful in documenting that skin exposure to the chemical of concern has occurred. Ideally, it is desirable to have samples from a number of workers who are suspected of being exposed. Also, control samples from individuals who do not have skin exposure, or are suspected of much less exposure, are valuable. Note that skin sampling conducted just prior to biological monitoring may result in decreased biological uptake.

1. Carboxyhemoglobin Evaluation

Biological monitoring can also be used to estimate the degree of exposure after an emergency. Table 2 shows the relationship between airborne carbon monoxide (CO) concentrations and steady state carboxyhemoglobin (COHb) levels.

| TABLE 2. CARBON MONOXIDE (CO) CONCENTRATION VERSUS BLOOD CARBOXYHEMOGLOBIN (COHb) LEVELS* | |
|--|---|
| CO Concentration (ppm) | Steady-State Blood COHb Levels (percent) |
| 0.1 | 0.25 |
| 0.5 | 0.32 |
| 1 | 0.39 |
| 2 | 0.50 |
| 5 | 1.0 |
| 10 | 1.8 |
| 15 | 2.5 |
| 20 | 3.2 |
| 40 | 6.1 |
| 60 | 8.7 |
| 80 | 11 |
| 100 | 14 |
| 200 | 24 |
| 400 | 38 |
| 600 | 48 |
| 800 | 56 |
| 1,000 | 61 |

*Predicted using the Coburn-Forster-Kane (CFK) model.
Source: ATSDR, 2009

Post-exposure COHb measurements can be used to back-calculate airborne CO concentrations in order to determine whether a citation is warranted. COHb values provided by a non-OSHA medical professional may be evaluated using a special algorithm on the Federal OSHA Intranet from the SLTC. COHb values may be determined either from a blood sample, a breath analyzer, or a Pulse CO-Oximeter™ finger measurement.

The SLTC employs a modified, more accurate version of the Coburn-Forster-Kane equation than the closed-form version used in the 1972 NIOSH Criteria Document. The SLTC equation calculates the eight-hour TWA. Poisoning cases generally involve levels above five percent COHb. The calculation also provides an incident-specific sampling and analytical error designed to deal with the uncertainties in the data. The calculation is performed at the SLTC and the results are critically assessed for accuracy by the SLTC staff prior to reporting. The SLTC carbon monoxide experts are available to assist CSHOs in acquiring data and in interpreting results.

The following are suggestions to help ensure that the most accurate calculations will be performed.

- *Before going on site, download, print and read the Carbon Monoxide Worksheet ("Submitting Data for the Carbon Monoxide Calculation at the OSHA Salt Lake Technical Center (SLTC)"). Take the worksheet to the site.*
- *If possible, call one of the SLTC carbon monoxide experts before going to the site, especially if methylene chloride is used. The Carbon Monoxide Worksheet lists the SLTC contact persons on the worksheet.*
- *Collect vital statistics for the victim(s) (age, weight, sex, living or deceased).*
- *Detail smoking activity (first-hand, second-hand tobacco smoke).*
- *Document oxygen saturation-affecting conditions such as pre- and post-exposure activity levels and oxygen therapy.*
- *Provide accurate timelines (how long the worker was exposed, when the worker was removed, how long resuscitation was performed, the time between removal and when the COHb was taken, etc.).*
- *List signs and symptoms of suspected exposure.*
- *Review the document for accuracy and completeness before submitting it to the SLTC.*

2. Hydrogen Sulfide

For evaluation of suspected hydrogen sulfide (H₂S) overexposures, blood thiosulfate monitoring is recommended (Ballerino-Regan and Longmire, 2010). Blood sulfide levels are useful only if obtained within two hours of exposure, and sulfhemoglobin levels are not useful for documenting H₂S exposure. Urinary thiosulfate levels are frequently used as a biomarker, however, a quantitative relationship between hydrogen sulfide exposure levels and urinary thiosulfate levels has not been established (ATSDR, 2006). Urine thiosulfate elevation does not occur in the case of rapid fatalities but may be elevated in nonfatally exposed workers. Analysis of COHb may also be useful, since this is a reported metabolite of H₂S (NIOSH 2005-110, 2004).

For biological monitoring, proper sampling containers and a protocol for handling and shipping samples need to be followed. In general, a qualified laboratory which is experienced in the analysis of biological samples will provide sample vials, shipping containers, and the technical expertise to properly collect, store and ship specimens.

3. Review of Employer Biological Monitoring Results

In instances in which an employer has been conducting biological monitoring, the CSHO shall evaluate the results of such testing. The results may assist in determining whether a significant quantity of the toxic material is being ingested or absorbed through the skin. However, the total body burden is composed of all modes of exposure (e.g., inhalation, ingestion, absorption and injection). For the CSHO to assess the results of the biological monitoring, all the data (including any air monitoring results) must be evaluated to determine the source(s) of the exposure and the most likely mode(s) of entry.

*Results of biological monitoring which have been voluntarily conducted by an employer shall **not** be used as a basis for citations. In fact, OSHA promotes the use of biological monitoring by employers as a useful means for minimizing exposures and for evaluating the effectiveness of control measures.*

Citations, in consultation with the Health and Safety Enforcement manager, would be appropriate when biological monitoring results indicate an unacceptable level of exposure, and the employer is unable to demonstrate that meaningful efforts to reduce or control the exposure(s) were taken.

V. Enforcement Recommendations

There are currently no surface contamination criteria or quantifications for skin absorption included in OSHA standards. CSHOs should consult Oregon OSHA's Field Inspection Reference Manual ([FIRM](#)) for guidance (e.g., see Chapter 2, Section XIII – Common Health Violations) on citing improper personal hygiene practices based on the absorption hazard. The expanded health standards in Subdivision Z generally contain housekeeping provisions that address the issue of surface contamination. Exposures to various chemicals are addressed in specific standards for general industry, construction, and shipyard employment. For example:

- Formaldehyde, see 1910.1048 (paragraph (j) contains the housekeeping requirements).
- Methylenedianiline, see 1910.1050 (paragraph (f) provides that regulated areas must be established for areas with dermal exposure potential and paragraph (l) contains housekeeping requirements).
- Acrylonitrile, see 1910.1045 (paragraph (k) provides that surfaces must be kept free of visible liquid acrylonitrile).

The housekeeping provisions are generally the most stringent for the metals, which in solid form may contaminate surfaces and become available for ingestion or inhalation if housekeeping practices are poor. OSHA standards for the following metals contain provisions stating that “surfaces be maintained as free as practicable of accumulations of” the toxic metal and housekeeping requirements such as a prohibition on use of compressed air for cleaning surfaces:

- Arsenic, see 1910.1018 (standard includes strict housekeeping requirements in paragraphs (k) and (m)).
- Lead, see 29 CFR 1910.1025 (standard contains strict housekeeping requirements in paragraphs (h) and (i)).
- Chromium (VI), see 1910.1026 (standard contains strict housekeeping requirements in paragraphs (i) and (j)).
- Cadmium, see 1910.1027 (standard includes strict housekeeping requirements in paragraphs (j) and (k)).

Useful information on dermal exposure standards can be found at [Dermal Exposure - OSHA Standards Safety and Health Topics Page](#).

Despite the lack of specific criteria or quantitative data for use in the enforcement of elevated exposures to surface and skin chemical hazards in the workplace, it is well established that skin exposure and ingestion of chemicals is a significant mode of occupational exposure. In instances in which a hazard can be established which is not addressed in a specific OSHA standard, the compliance officer may consider a General Duty Clause citation (ORS 654.010) to address this concern. Use of the General Duty Clause is discussed in Chapter 2, Section IV of the Field Inspection Reference Manual ([FIRM](#)).

In lieu of issuing an ORS 654.010 citation, it is suggested that alternative citations be issued under one or more of the following OSHA standards:

- Sanitation, see Division 2, Subdivision J, 1910.141. In instances where a high degree of surface contamination is evident, or clear evidence exists to establish skin exposure of workers to a recognized hazard, then 1910.141(a)(3) can be cited. That is, the CSHO can establish that the employer has failed to keep the workplace "clean to the extent that the nature of the work allows."
- Hazard Communication, see Division 2, Subdivision Z, 1910.1200. 1910.1200(h) can be cited based upon the evidence collected by the CSHO to demonstrate that the employer failed to adequately inform and train workers on the hazards present in the workplace.
- Personal Protective Equipment, see Division 2, Subdivision I, OAR 437-002-0134. A specific citation may be issued for deficiencies in PPE under OAR 437-002-0134, which requires that the employer evaluate the hazards, select proper PPE, and train workers on proper use of the PPE.

- Respiratory Protection, see Division 2, Subdivision I, 1910.134. The respiratory protection standard contains specific cleaning provisions in paragraph (h).
- Occupational Exposure to Hazardous Chemicals in Laboratories, see Division 2, Subdivision Z, 1910.1450.
 - Paragraph (f) contains the hazard communication requirements to adequately inform and train workers on the hazards present in the laboratory.
 - Paragraph (e)(3) specifies occupational safety and health requirements that must be included in the Chemical Hygiene Plan. It also requires the employer to include the measures that will be taken to ensure the protection of laboratory workers.
 - Paragraph (a)(2)(ii) requires that any prohibition of eye or skin contact specified in an expanded health standard be observed.
- Pertinent standards dealing with construction (Oregon Administrative Rule, Chapter 437, Division 3.).

VI. Custom Services

The following services are available on a case-by-case basis at the Oregon OSHA Lab. Concurrence from the Enforcement Manager in an email (or via other means) sent to the Oregon OSHA Lab Manager must be received before the Oregon OSHA Lab can commit to providing explosibility analysis.

A. Mass Spectrometry

The mass spectrometry laboratory at the Oregon OSHA Lab has a number of unique tools to help CSHOs resolve difficult field sampling and analytical issues. For example, mass spectrometry can be used to identify unknown or suspected organic substances found in industrial processes, indoor air quality complaints, and contaminated water. It can also be used to identify secondary substances that are given off from a heated material (i.e., thermal decomposition products).

One of the major functions of the mass spectrometry laboratory is identification and confirmation of analytes measured in gas chromatography (GC) analysis performed at the Oregon OSHA Lab. The same separation and identification techniques used to confirm the identity of known analytes are also useful to identify an unknown material, investigate possible contamination or batch uniformity in a material from an industrial process, or to check for conformity with a Safety Data Sheet.

Using a technique called pyrolysis, some thermally labile compounds can be introduced directly into the mass spectrometer source before heat is applied. Materials can be heated to temperatures as high as 900°C (1650°F), with subsequent introduction of decomposition products into the GC column. Products released from materials involved in a fire, heated by a welder or blowtorch, or

from any process involving heating can be studied in this way.

B. Materials Analysis

The Oregon OSHA Lab provides a variety of services to determine the cause of materials failure. Materials failure analysis examines the extent to which the properties of materials or their use contribute to significant investigations, including fatalities. This procedure often involves collaboration of experts in multiple disciplines including metallurgical engineering, materials science, explosibility, and both organic and inorganic chemistry.

The Oregon OSHA Lab services include assistance in searching for industry standards that help support citations, and assistance with finding an accredited laboratory to perform any analysis that is not done at the Oregon OSHA Lab. The Oregon OSHA Lab tailors the assistance to the particular investigation. The Oregon OSHA Lab can either arrange to assist the investigation of the accident on site, or to review results from an independent laboratory.

C. Sampling for Biological Pathogens

NOTE: At this time, the Oregon OSHA Lab does not offer Biological sampling. The Oregon OSHA Laboratory may be able to make arrangements with an approved contracting service on a case-by-case basis and management approval.

D. Explosibility Analysis

NOTE: At this time, the Oregon OSHA Lab does not offer Explosibility analysis. Arrangements with federal OSHA's Salt Lake Technical Center (SLTC) may be arranged through the Oregon OSHA Lab. The following italicized content within Section VI, Subsection D is provided for informational purposes only:

Explosibility analysis is a complex field and requires specific sampling procedures. Contact the Oregon OSHA Lab for sampling supplies and instruction. Management approval is required for explosibility analysis by the SLTC. Samples are submitted to the Oregon OSHA Lab in the same manner as other samples but must be accompanied by a Federal OSHA air sampling Form OSHA-91S. Request analysis for Class II combustible dust on the form. Procedures for combustible dust sampling are discussed in detail in [Appendix D. Program Directive 268](#) may be referenced for more detailed information.

The Oregon OSHA Lab offers Combustible Dust analysis which provides the amount of combustible material within a sample. Calculations may then be done to interpret the severity of the hazard based on the Grain Dust Combustibility Test:

Protocol to be used for evaluation of grain dust samples for combustibility.

1. Measure the thickness of the accumulated grain dust deposits. If the dust is thicker than one-eighth inch, a potential violation is present and a bulk sample should be taken. Procedures for taking grain dust samples are outlined in [Program Directive A-189](#).

2. The Occupational Health Laboratory will sieve a known mass of the bulk sample to determine what percent passes the 425 um (40 mesh) size limit.
3. A known mass of the sieved dust will be subjected to a combustibility test by ashing at 600°C. The percentage mass lost will be recorded.
4. A hazard may be present if a value greater than one is given by the following formula:

$$\frac{D \times M \times A}{1250}$$

Where: D is the depth of the dust in inches

M is the mass % of the dust passing through the 40 mesh sieve

A is the mass % of dust lost during the combustibility test

Reference: Correspondence with Steve Edwards, OSHA Laboratory, Salt Lake City, Utah.

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APPENDIX A - Chemicals Noted for Skin Absorption (OSHA and ACGIH Designated Only)

| TABLE A-1. OSHA PELs AND ACGIH TLVs WITH SKIN DESIGNATIONS/NOTATIONS | | | | | |
|---|-------------------------|---------------------------------|-----------|-----------------------------|-----------------------|
| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| Acetone cyanohydrin, as CN | 75-86-5 | | | | C 5 mg/m ³ |
| Acetonitrile | 75-05-8 | | | 20 ppm | |
| Acrolein | 107-02-8 | | | | C 0.1 ppm |
| Acrylamide | 79-06-1 | 0.3 mg/m ³ | SAME | 0.03 mg/m ³ | |
| Acrylic acid | 79-10-7 | | | 2 ppm | |
| Acrylonitrile; see 1910.1045 | 107-13-1 | | | 2 ppm | |
| Adiponitrile | 111-69-3 | | | 2 ppm | |
| Aldrin | 309-00-2 | 0.25 mg/m ³ | SAME | 0.05 mg/m ³ | |
| Allyl alcohol | 107-18-6 | 2 ppm; 5 mg/m ³ | SAME | 0.5 ppm | |
| Allyl bromide | 106-95-6 | | | 0.1 ppm | 0.2 ppm |
| Allyl chloride | 107-05-1 | | | 1 ppm | 2 ppm |
| 4-Aminodiphenyl; see 1910.1003 | 92-67-1 | | | (L) | |
| Ammonium perfluorooctanoate | 3825-26-1 | | | 0.01 mg/m ³ | |
| Aniline and homologs | 62-53-3 | 5 ppm; 19 mg/m ³ | SAME | 2 ppm | |
| Anisidine (o-, p-isomers) | 29191-52-4 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| ANTU (alpha Naphthylthiourea) | 86-88-4 | | | 0.3 mg/m ³ | |
| Azinphos-methyl | 86-50-0 | 0.2 mg/m ³ | SAME | 0.2 mg/m ³ (IFV) | |
| Benzene; see 1910.1028. See Table Z-2 for the limits applicable in the operations or sectors excluded in 1910.1028(d) | 71-43-2 | | | 0.5 ppm | 2.5 ppm |
| Benzidine; See 1910.10003 | 92-87-5 | | | (L) | |
| Benzotrichloride | 98-07-7 | | | | C 0.1 ppm |
| Beryllium and beryllium compounds (as Be) | 7440-41-7 | | | 0.00005 mg/m ³ I | |
| Bromoform | 75-25-2 | 0.5 ppm; 5 mg/m ³ | SAME | 0.5ppm | |

| TABLE A-1. OSHA PELS AND ACGIH TLVS WITH SKIN DESIGNATIONS/NOTATIONS | | | | | |
|--|-------------------------|--------------------------------------|---------------------------------|-------------------------------|-------------------------|
| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| 2-Butoxyethanol | 111-76-2 | 50 ppm; 240 mg/m ³ | SAME | 20ppm | |
| n-Butylamine | 109-73-9 | (C)5 ppm; (C)15 mg/m ³ | SAME | | C 5ppm |
| tert-Butyl chromate (as CrO ₃); see 1910.1026 | 1189-85-1 | | | | C 0.1 mg/m ³ |
| n-Butyl glycidyl ether (BGE) | 2426-08-6 | | | 3 ppm | |
| o-sec-Butylphenol | 89-72-5 | | | 5 ppm | |
| Captafol | 2425-06-1 | | | 0.1 mg/m ³ | |
| Carbaryl (Sevin) | 63-25-2 | | | 0.5 mg/m ³ (IFV) | |
| Carbon disulfide | 75-15-0 | | 20 ppm; 60 mg/m ³ | 1 ppm | |
| Carbon tetrachloride | 56-23-5 | | 10 ppm; 65 mg/m ³ | 5 ppm 31 mg/m ³ | 10 ppm |
| Catechol | 120-80-9 | | | 5 ppm | |
| Chlordane | 57-74-9 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| Chlorinated camphene | 8001-35-2 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | 1 mg/m ³ |
| Chloroacetone | 78-95-5 | | | | C 1 ppm |
| Chloroacetyl chloride | 79-04-9 | | | 0.05 ppm | 0.15 ppm |
| o-Chlorobenzylidene malonitrile | 2698-41-1 | | | | C 0.05 ppm |
| Chlorodiphenyl (42% Chlorine) (PCB) | 53469-21-9 | 1 mg/m ³ | SAME | 1 mg/m ³ | |
| Chlorodiphenyl (54% Chlorine) (PCB) | 11097-69-1 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| 1-Chloro-2-propanol | 127-00-4 | | | 1 ppm | |
| 2-Chloro-1-propanol | 78-89-7 | | | 1 ppm | |
| beta-Chloroprene | 126-99-8 | 25 ppm; 90 mg/m ³ | SAME | 10 ppm | |
| 2-Chloropropionic acid | 598-78-7 | | | 0.1 ppm | |
| Chlorpyrifos | 2921-88-2 | | | 0.1 mg/m ³ (IFV) | |
| Citral | 5392-40-5 | | | 5 ppm (IFV) | |
| Coumaphos | 56-72-4 | | | 0.05 mg/m ³ (IFV) | |

TABLE A-1. OSHA PELS AND ACGIH TLVS WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|--|----------------------------|---------------------------------------|--|------------------------------|---------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| Cresol, all isomers | 1319-77-3 | 5 ppm; 22 mg/m ³ | SAME | 20 mg/m ³ (IFV) | |
| Crotonaldehyde | 4170-30-3 | | | | C 0.3 ppm |
| Cumene | 98-82-8 | 50 ppm; 245 mg/m ³ | SAME | 50ppm | |
| Cyanides (as CN) | (4) | 5 mg/m ³ | SAME (1915 no skin designation) | | |
| Cyclohexanol | 108-93-0 | | | 50 ppm | |
| Cyclohexanone | 108-94-1 | | | 20 ppm | 50 ppm |
| Cyclonite | 121-82-4 | | 1.5 mg/m ³ | 0.5 mg/m ³ | |
| 2,4-D (Dichlorophen- oxyacetic acid) ⁵ | 94-75-7 | 10 mg/m ³ | | | |
| Decaborane | 17702-41-9 | 0.05 ppm; 0.3 mg/m ³ | SAME | 0.05 ppm | 0.15 ppm |
| Demeton (Systox) | 8065-48-3 | 0.1 mg/m ³ | SAME | 0.05 mg/m ³ (IFV) | |
| Demeton-S-methyl | 919-86-8 | | | 0.05 mg/m ³ (IFV) | |
| Diazinon | 333-41-5 | | | 0.01 mg/m ³ (IFV) | |
| 2-N-Dibutylaminoethanol | 102-81-8 | | | 0.5 ppm | |
| Dibutyl phenol phosphate | 2528-36-1 | | | 0.3 ppm | |
| Dibutyl phosphate | 107-66-4 | | | 5 mg/m ³ (IFV) | |
| Dichloroacetic acid | 79-43-6 | | | 0.5 ppm | |
| 3,3'-Dichlorobenzidine; see 1910.1003 | 91-94-1 | | | (L) | |
| 1,4-Dichloro-2-butene | 764-41-0 | | | 0.005 ppm | |
| Dichlorodiphenyltri- chloroethane (DDT) | 50-29-3 | 1 mg/m ³ | SAME | | |
| Dichloroethyl ether | 111-44-4 | (C)15 ppm; (C)90 mg/m ³ | SAME | 5 ppm | 10 ppm |
| 1,3-Dichloropropene | 542-75-6 | | | 1 ppm | |
| Dichlorvos (DDVP) | 62-73-7 | 1 mg/m ³ | SAME | 0.1 mg/m ³ (IFV) | |
| Dicrotophos | 141-66-2 | | | 0.05 mg/m ³ (IFV) | |
| Dieldrin | 60-57-1 | 0.25 mg/m ³ | SAME | 0.1 mg/m ³ (IFV) | |
| Diesel fuel, as total | 68334-30-5; 68476-30-2; | | | 100 mg/m ³ (IFV) | |

TABLE A-1. OSHA PELs AND ACGIH TLVs WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|--|--|---------------------------------|--|-----------------------------|---------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| hydrocarbons | 68476-31-3; 68476-34-6; 77650-28-3 | | | | |
| Diethanolamine | 111-42-2 | | | 1 mg/m ³ (IFV) | |
| Diethylamine | 109-89-7 | | | 5 ppm | 15 ppm |
| 2-Diethylaminoethanol | 100-37-8 | 10 ppm; 50 mg/m ³ | SAME (1915 no skin designation) | 2 ppm | |
| Diethylene triamine | 111-40-0 | | (C)10 ppm; (C)42 mg/m ³ | 1 ppm | |
| Diisopropylamine | 108-18-9 | 5 ppm; 20 mg/m ³ | SAME | 5 ppm | |
| Dimethyl acetamide | 127-19-5 | 10 ppm; 35 mg/m ³ | SAME | 10 ppm | |
| bis(2-Dimethylaminoethyl)ether (DMAEE) | 3033-62-3 | | | 0.05 ppm | 0.15 ppm |
| Dimethylaniline (N,N-Dimethylaniline) | 121-69-7 | 5 ppm; 25 mg/m ³ | SAME | 5 ppm | 10 ppm |
| Dimethyl carbamoyl chloride | 79-44-7 | | | 0.005 ppm | |
| Dimethyl-1,2-dibromo-2,2-dichloroethyl phosphate (Naled) | 300-76-5 | | | 0.1 mg/m ³ (IFV) | |
| Dimethyl disulfide | 624-92-0 | | | 0.5 ppm | |
| Dimethylformamide | 68-12-2 | 10 ppm; 30 mg/m ³ | SAME | 10 ppm | |
| 1,1-Dimethylhydrazine | 57-14-7 | 0.5 ppm; 1 mg/m ³ | SAME | 0.01 ppm | |
| Dimethyl sulfate | 77-78-1; 77-78-3 | 1 ppm; 5 mg/m ³ | SAME | 0.1 ppm | |
| Dinitrobenzene (all isomers) | 528-29-0; 99-65-0; 100-25-4 | 1 mg/m ³ | SAME | 0.15 ppm | |
| Dinitro-o-cresol | 534-52-1 | 0.2 mg/m ³ | SAME | 0.2 mg/m ³ | |
| Dinitrotoluene | 25321-14-6 | 1.5 mg/m ³ | SAME | 0.2 mg/m ³ | |
| Dioxane (Diethylene | 123-91-1 | 100 ppm; | SAME | 20 ppm | |

TABLE A-1. OSHA PELS AND ACGIH TLVS WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|--|-------------------------------|---------------------------------------|--|---|---------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| dioxide) | | 360 mg/m ³ | | | |
| Dioxathion | 78-34-2 | | | 0.1 mg/m ³ (IFV) | |
| Dipropylene glycol methyl ether (2-Methoxymethylethoxy)propanol) | 34590-94-8 | 100 ppm; 600 mg/m ³ | SAME | 100 ppm | 150 ppm |
| Diquat | 2764-72-9; 85-00-7; 6385-62-2 | | | 0.5 mg/m ³ (D); 0.1 mg/m ³ (R) | |
| Disulfoton | 298-04-4 | | | 0.05 mg/m ³ (IFV) | |
| Endosulfan | 115-29-7 | | 0.1 mg/m ³ | 0.1 mg/m ³ (IFV) | |
| Endrin | 72-20-8 | 0.1 mg/m ³ | SAME | 0.1 mg/m ³ | |
| Epichlorohydrin | 106-89-8 | 5 ppm; 19 mg/m ³ | SAME | 0.5 ppm | |
| EPN | 2104-64-5 | 0.5 mg/m ³ | SAME | 0.1 mg/m ³ (D) | |
| Ethion | 563-12-2 | | | 0.05 mg/m ³ (IFV) | |
| 2-Ethoxyethanol (Cellosolve) | 110-80-5 | 200 ppm; 740 mg/m ³ | SAME | 5 ppm | |
| 2-Ethoxyethyl acetate (Cellosolve acetate) | 111-15-9 | 100 ppm; 540 mg/m ³ | SAME | 5 ppm | |
| Ethyl acrylate | 140-88-5 | 25 ppm; 100 mg/m ³ | SAME | 5ppm | 15ppm |
| Ethylamine | 75-04-7 | | | 5 ppm | 15 ppm |
| Ethyl bromide | 74-96-4 | | | 5 ppm | |
| Ethyl chloride | 75-00-3 | | | 100 ppm | |
| Ethylene chlorohydrin | 107-07-3 | 5 ppm; 16 mg/m ³ | SAME | | C 1 ppm |
| Ethylenediamine | 107-15-3 | | | 10 ppm | |
| Ethylene dibromide | 106-93-4 | | (C)25 ppm; (C)190 mg/m ³ | — | — |
| Ethylene glycol dinitrate | 628-96-6 | (C)0.2 ppm; (C)1 mg/m ³ | SAME | 0.05 ppm | |
| Ethyleneimine; see 1910.1003 | 151-56-4 | | | 0.05 ppm | 0.1 ppm |
| N-Ethylmorpholine | 100-74-3 | 20 ppm; 94 mg/m ³ | SAME | 5 ppm | |

TABLE A-1. OSHA PELs AND ACGIH TLVs WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|--|--------------------------|---------------------------------|-----------|------------------------------|---------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| Fenamiphos | 22224-92-6 | | | 0.05 mg/m ³ (IFV) | |
| Fensulfothion | 115-90-2 | | | 0.01 mg/m ³ (IFV) | |
| Fenthion | 55-38-9 | | | 0.05 mg/m ³ (IFV) | |
| Fonofos | 944-22-9 | | | 0.1 mg/m ³ (IFV) | |
| Formamide | 75-12-7 | | | 10 ppm | |
| Furfural | 98-01-1 | 5 ppm; 20 mg/m ³ | SAME | 2 ppm | |
| Furfuryl alcohol | 98-00-0 | | | 10 ppm | 15 ppm |
| Heptachlor | 76-44-8 | 0.5 mg/m ³ | SAME | 0.05 mg/m ³ | |
| Heptachlor epoxide | 1024-57-3 | | | 0.05 mg/m ³ | |
| Hexachlorobenzene | 118-74-1 | | | 0.002 mg/m ³ | |
| Hexachlorobutadiene | 87-68-3 | | | 0.02 ppm | |
| Hexachloroethane | 67-72-1 | 1 ppm; 10 mg/m ³ | SAME | 1 ppm | |
| Hexachloronaphthalene | 1335-87-1 | 0.2 mg/m ³ | SAME | 0.2 mg/m ³ | |
| Hexafluoroacetone | 684-16-2 | | | 0.1 ppm | |
| Hexamethyl phosphoramidate | 680-31-9 | | | — | |
| n-Hexane | 110-54-3 | | | 50 ppm | |
| 2-Hexanone (Methyl n-butyl ketone) | 591-78-6 | | | 5 ppm | 10 ppm |
| Hydrazine | 302-01-2 | 1 ppm; 1.3 mg/m ³ | SAME | 0.01 ppm | |
| Hydrogen cyanide ⁶ | 74-90-8 | 10 ppm; 11 mg/m ³ | SAME | | C 4.7 ppm |
| Hydrogen fluoride (as F) | 7664-39-3 | | | 0.5 ppm | C 2 ppm |
| 2-Hydroxypropyl acrylate | 999-61-1 | | | 0.5 ppm | |
| Isooctyl alcohol | 26952-21-6 | | | 50 ppm | |
| 2-Isopropoxyethanol | 109-59-1 | | | 25 ppm | |
| n-Isopropylaniline | 768-52-5 | | | 2 ppm | |
| Kerosene/Jet fuels, as total hydrocarbon vapor | 8008-20-6; 64742-81-0 | | | 200 mg/m ³ P | |
| Lindane | 58-89-9 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| Malathion Total dust | 121-75-5 | 15 mg/m ³ | SAME | 1 mg/m ³ (IFV) | |

TABLE A-1. OSHA PELs AND ACGIH TLVs WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|---|-------------------------|--|------------------------|----------------------------|------------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| Manganese cyclopentadienyl tricarbonyl, as Mn | 12079-65-1 | | | 0.1 mg/m ³ | |
| Mercury (as Hg) | 7439-97-6 | 0.1 mg/m ³ | 0.1 mg/m ³ | 0.1 mg/m ³ | |
| Mercury (elemental and inorganic forms) | 7439-97-6 | 0.1 mg/m ³ | 0.1 mg/m ³ | 0.025 mg/m ³ | |
| Mercury (organo) alkyl compounds (as Hg) | 7439-97-6 | 0.01 mg/m ³ | 0.01 mg/m ³ | 0.01 mg/m ³ | 0.03 mg/m ³ |
| Mercury (vapor) (as Hg) | 7439-97-6 | 0.1 mg/m ³ | 0.1 mg/m ³ | | |
| 2-Methoxyethanol; (Methyl cellosolve) | 109-86-4 | 25 ppm; 80 mg/m ³ | SAME | 0.1 ppm | |
| 2-Methoxyethyl acetate (Methyl cellosolve acetate) | 110-49-6 | 25 ppm; 120 mg/m ³ | SAME | 0.1 ppm | |
| Methyl acrylate | 96-33-3 | 10 ppm; 35 mg/m ³ | SAME | 2 ppm | |
| Methylacrylonitrile | 126-98-7 | | | 1 ppm | |
| Methyl alcohol | 67-56-1 | | | 200 ppm | 250 ppm |
| Methyl bromide | 74-83-9 | (C)20 ppm; (C)80 mg/m ³ | SAME | 1 ppm | |
| Methyl chloride | 74-87-3 | | | 50 ppm | 100 ppm |
| o-Methylcyclohexanone | 583-60-8 | 100 ppm; 460 mg/m ³ | SAME | 50 ppm | 75 ppm |
| 2-Methylcyclopentadienyl manganese tricarbonyl, as Mn | 12108-13-3 | | | 0.2 mg/m ³ | |
| Methyl demeton | 8022-00-2 | | | 0.05 mg/m ³ IFV | |
| 4,4'-Methylene bis(2-chloroaniline) | 101-14-4 | | | 0.01 ppm | |
| 4,4'-Methylene dianiline | 101-77-9 | | | 0.1 ppm | |
| Methyl hydrazine (Monomethyl hydrazine) | 60-34-4 | (C)0.2 ppm; (C)0.35 mg/m ³ | SAME | 0.01 ppm | |
| Methyl iodide | 74-88-4 | 5 ppm; 28 mg/m ³ | SAME | 2 ppm | |
| Methyl isobutyl carbinol | 108-11-2 | 25 ppm; 100 mg/m ³ | SAME | 25 ppm | 40 ppm |
| Methyl isocyanate | 624-83-9 | 0.02 ppm; | SAME | 0.02 ppm | |

TABLE A-1. OSHA PELs AND ACGIH TLVs WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|--|---------------------------------------|--|------------------------------------|----------------------------------|-----------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| | | 0.05 mg/m ³ | | | |
| 1-Methyl naphthalene | 90-12-0 | | | 0.5 ppm | |
| 2-Methyl naphthalene | 91-57-6 | | | 0.5 ppm | |
| Methyl parathion | 298-00-0 | | | 0.02 mg/m ³ (IFV) | |
| Methyl vinyl ketone | 78-94-4 | | | | C 0.2 ppm |
| Monochloroacetic acid | 79-11-8 | | | 0.5 ppm (IFV) | |
| Monocrotophos | 6923-22-4 | | | 0.05 mg/m ³ (IFV) | |
| Monomethyl aniline (N-Methyl aniline) | 100-61-8 | 2 ppm; 9 mg/m ³ | SAME | 0.5 ppm 2.2 mg/m ³ | |
| Morpholine | 110-91-8 | 20 ppm; 70 mg/m ³ | SAME | 20 ppm | |
| Naphthalene ⁷ | 91-20-3 | | | 10 ppm | 15 ppm |
| Natural rubber latex, as inhalable allergenic proteins | 9006-04-6 | | | 0.0001 mg/m ³ I | |
| Nicotine | 54-11-5 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| p-Nitroaniline | 100-01-6 | 1 ppm; 6 mg/m ³ | SAME | 3 mg/m ³ | |
| Nitrobenzene | 98-95-3 | 1 ppm; 5 mg/m ³ | SAME | 1 ppm | |
| p-Nitrochlorobenzene | 100-00-5 | 1 mg/m ³ | SAME | 0.1 ppm | |
| 4-Nitrodiphenyl; see 1910.1003 | 92-93-3 | | | (L) | |
| Nitroglycerin | 55-63-0 | (C)0.2 ppm; (C)2 mg/m ³ | SAME | 0.05 ppm | |
| N-Nitrosodimethylamine; see 1910.1003 | 62-75-9 | | | (L) | |
| Nitrotoluene (all isomers) | 88-72-2; 99-08-1; 99-99-0 | 5 ppm; 30 mg/m ³ | SAME | 2 ppm | |
| Octachloronaphthalene | 2234-13-1 | 0.1 mg/m ³ | SAME | 0.1 mg/m ³ | 0.3 mg/m ³ |
| Paraquat, respirable dust | 4685-14-7; 1910-42-5; 2074-50-2 | 0.5 mg/m ³ 0.1 mg/m ³ (R) | SAME | | |
| Parathion | 56-38-2 | 0.1 mg/m ³ | SAME (1915 no skin designation) | 0.05 mg/m ³ (IFV) | |

TABLE A-1. OSHA PELs AND ACGIH TLVs WITH SKIN DESIGNATIONS/NOTATIONS

| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
|----------------------------------|-------------------------|--------------------------------|--|------------------------------|---------------------|
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| Pentachloronaphthalene | 1321-64-8 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| Pentachlorophenol | 87-86-5 | 0.5 mg/m ³ | SAME | 0.5 mg/m ³ | |
| 2,4-Pentanedione | 123-54-6 | | | 25 ppm | |
| Phenol | 108-95-2 | 5 ppm; 19 mg/m ³ | SAME | 5 ppm | |
| Phenothiazine | 92-84-2 | | | 5 mg/m ³ | |
| p-Phenylene diamine | 106-50-3 | 0.1 mg/m ³ | SAME | 0.1 mg/m ³ | |
| Phenyl glycidyl ether (PGE) | 122-60-1 | | | 0.1 ppm | |
| Phenylhydrazine | 100-63-0 | 5 ppm; 22 mg/m ³ | SAME | 0.1 ppm | |
| Phenyl mercaptan | 108-98-5 | | | 0.1 ppm | |
| Phorate | 298-02-2 | | | 0.05 mg/m ³ (IFV) | |
| Phosdrin (Mevinphos) | 7786-34-7 | 0.1 mg/m ³ | SAME | 0.01 mg/m ³ (IFV) | |
| Picric acid | 88-89-1 | 0.1 mg/m ³ | SAME (1915 no skin designation) | 0.1mg/m ³ | |
| Propargyl alcohol | 107-19-7 | | 1 ppm | 1 ppm | |
| Propylene glycol dinitrate | 6423-43-4 | | | 0.05 ppm | |
| Propylene imine | 75-55-8 | 2 ppm; 5 mg/m ³ | SAME | 0.2 ppm | 0.4 ppm |
| Sodium fluoroacetate | 62-74-8 | 0.05 mg/m ³ | SAME | 0.05 mg/m ³ | |
| Sulprofos | 35400-43-2 | | | 0.1 mg/m ³ (IFV) | |
| TEDP (Sulfotepp) | 3689-24-5 | 0.2 mg/m ³ | SAME | 0.1 mg/m ³ (IFV) | |
| Temephos | 3383-96-8 | | | 1 mg/m ³ (IFV) | |
| TEPP (Tetraethyl pyrophosphaate) | 107-49-3 | 0.05 mg/m ³ | SAME | 0.01 mg/m ³ (IFV) | |
| Terbufos | 13071-79-9 | | | 0.01 mg/m ³ (IFV) | |
| 1,1,2,2-Tetrachloro-ethane | 79-34-5 | 5 ppm; 35 mg/m ³ | SAME | 1 ppm | |
| Tetrachloronaphthalene | 1335-88-2 | 2 mg/m ³ | SAME | 2 mg/m ³ | |
| Tetraethyl lead (as Pb) | 78-00-2 | 0.075 mg/m ³ | 0.1 mg/m ³ | 0.1 mg/m ³ | |
| Tetrahydrofuran | 109-99-9 | | | 50 ppm | 100 ppm |
| Tetramethyl lead (as Pb) | 75-74-1 | 0.075 mg/m ³ | 0.15 mg/m ³ | 0.15 mg/m ³ | |

| TABLE A-1. OSHA PELS AND ACGIH TLVS WITH SKIN DESIGNATIONS/NOTATIONS | | | | | |
|--|-------------------------|---|-----------|---------------------------------|--------------------------------|
| Substance | CAS Number ¹ | OSHA PELs ² | | ACGIH TLVs ³ | |
| | | 1910 | 1926/1915 | TWA | STEL/C ⁴ |
| Tetramethyl succinonitrile | 3333-52-6 | 0.5 ppm; 3 mg/m ³ | SAME | 0.5 ppm | |
| Tetryl (2,4,6-Trinitrophenylmethyl-nitramine) | 479-45-8 | 1.5 mg/m ³ | SAME | 1.5mg/m ³ | |
| Thallium, soluble compounds (as Tl) | 7440-28-0 | 0.1 mg/m ³ | SAME | 0.02 mg/m ³ (1) | |
| Thioglycolic acid | 68-11-1 | | | 1 ppm | |
| Tin, organic compounds (as Sn) | 7440-31-5 | | | 0.1 mg/m ³ | 0.2 mg/m ³ |
| o-Tolidine | 119-93-7 | | | — | |
| Toluene-2,4-diisocyanate (TDI) ⁸ | 584-84-9 | (C)0.02 ppm; (C)0.14 mg/m ³ | | 0.005 ppm | 0.02ppm |
| o-Toluidine | 95-53-4 | 5 ppm; 22 mg/m ³ | SAME | 2 ppm | |
| m-Toluidine | 108-44-1 | | | 2 ppm | |
| p-Toluidine | 106-49-0 | | | 2 ppm | |
| 1,1,2-Trichloroethane | 79-00-5 | 10 ppm; 45 mg/m ³ | SAME | 10 ppm | |
| Trichloronaphthalene | 1321-65-9 | 5 mg/m ³ | SAME | 5 mg/m ³ | |
| 1,2,3-Trichloropropane ⁹ | 96-18-4 | | | 10 ppm | |
| Triethylamine | 121-44-8 | | | 1 ppm | 3 ppm |
| Trimellitic anhydride | 552-30-7 | | | 0.0005 mg/m ³ IFV | 0.002 mg/m ³ IFV |
| 2,4,6-Trinitrotoluene (TNT) | 118-96-7 | 1.5 mg/m ³ | SAME | 0.1 mg/m ³ | |
| Triorthocresyl phosphate | 78-30-8 | | | 0.1 mg/m ³ | |
| Vinyl cyclohexene dioxide | 106-87-6 | | | 0.1 ppm | |
| m-Xylene α,α' -diamine | 1477-55-0 | | | | C 0.1 mg/m ³ |
| Xylidine | 1300-73-8 | 5 ppm; 25 mg/m ³ | SAME | 0.5 ppm (IFV) | |

¹ The chemical abstracts service (CAS) number is for information only. For an entry covering more than one metal compound measured as the metal, the CAS number for the metal is given - not CAS numbers for the individual compounds.

² The OSHA PELs provided under “1910” refer to General Industry, 29 CFR 1910.1000 Table Z-1; “1926” refers to Construction, 29 CFR 1926.55, Appendix A; and “1915” refers to Shipyards, 29 CFR 1915.1000. The PELs are 8-hour time-weighted average (TWA) concentrations unless otherwise noted; a (C) designation denotes a ceiling limit. They are to be determined from breathing-zone air samples. If an entry is only listed in mg/m³, the value is

exact; when listed with a ppm entry, it is approximate. “SAME” indicates the value for 1926 and 1915 is equal to that listed for 1910 unless otherwise noted.

³ The ACGIH TLVs are from the ACGIH publication *2012 TLVs® and BEIs® Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices*. “TWA” refers to 8-hour, TWA concentrations; “STEL” refers to “short-term exposure limit,” a 15-minute TWA concentration; “C” indicates ceiling limit; a concentration that should not be exceeded during any part of the working exposure; “I” indicates inhalable fraction (particle aerodynamic diameter ranging from 0 to 100 micrometers; “IFV” indicates inhalable fraction and vapor; “(L)” indicates exposures by all routes should be carefully controlled to levels as low as possible; “P” indicates application restricted to conditions in which there are negligible aerosol exposures; and “R” indicates respirable fraction (particle aerodynamic diameter ranging from 0 to 10 micrometers).

⁴ Values in this column are STEL values unless noted as ceiling limits with a “C” preceding the value.

⁵ See ACGIH 2012 NIC—proposed change to 10 mg/m³ I (TWA) with skin designation.

⁶ ACGIH separates this listing into “hydrogen cyanide” and “cyanide salts,” while OSHA does not differentiate between the two. Only the hydrogen cyanide TLV is listed here.

⁷ See ACGIH 2012 NIC—proposed change to 5 ppm (TWA) with skin designation, no STEL.

⁸ See ACGIH 2012 NIC—proposed change to 0.001 ppm IFV (TWA), 0.003 ppm IFV (STEL), skin designation.

⁹ See ACGIH 2012 NIC—proposed change to 0.05 ppm (TWA), removal of skin designation.

APPENDIX B1 - Biological Exposure Guidelines (ACGIH BEI and OSHA Expanded Standards Only)

| TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012) | | | | | |
|---|-------------------------|--|-----------------|-------------------------------|-----------|
| Chemical | CAS No. | Determinant | Sampling Time | BEI® | Notation |
| <i>B = Background</i> | <i>Ns = Nonspecific</i> | <i>Nq = Nonquantitative</i> | | <i>Sq = Semi-quantitative</i> | |
| Acetone | 67-64-1 | Acetone in urine | End of shift | 50 mg/L | Ns |
| Acetylcholinesterase inhibiting pesticides | N/A | Cholinesterase activity in red blood cells | Discretionary | 70% of individual's baseline | Ns |
| Aniline | 62-53-3 | Aniline in urine ¹ | End of shift | — | Nq |
| | | Aniline released from hemoglobin in blood | End of shift | — | Nq |
| | | p-Aminophenol in urine ¹ | End of shift | 50 mg/L | B, Ns, Sq |
| Arsenic, elemental and soluble inorganic compounds (excludes gallium arsenide and arsine) | 7440-38-2 | Inorganic arsenic plus methylated metabolites in urine | End of workweek | 35 µg As/L | B |
| Benzene | 71-43-2 | S-Phenylmercapturic acid in urine | End of shift | 25 µg/g creatinine | B |
| | | t,t-Muconic acid in urine | End of shift | 500 µg/g creatinine | B |
| 1,3-Butadiene | 106-99-0 | 1,2 Dihydroxy-4-(N-acetylcyteiny)-butane in urine | End of shift | 2.5 mg/L | B, Sq |
| | | Mixture of N-1- and N-2-(hydroxybutenyl) valine hemoglobin (Hb) adducts in blood | Not critical | 2.5 pmol/g Hb | Sq |
| 2-Butoxyethanol | 111-76-2 | Butoxyacetic acid (BAA) in urine ¹ | End of shift | 200 mg/g creatinine | — |
| Cadmium and inorganic compounds | 7440-43-9 | Cadmium in urine | Not critical | 5 µg/g creatinine | B |
| | | Cadmium in blood | Not critical | 5 µg/L | B |
| Carbon disulfide | 75-15-0 | 2-Thioxothiazolidine-4-carboxylic acid (TTCA) in urine | End of shift | 0.5 mg/g creatinine | B, Ns |

TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012)

| Chemical | CAS No. | Determinant | Sampling Time | BEI® | Notation |
|-----------------------------------|-------------------------|---|---------------------------------|-------------------------------|----------|
| <i>B = Background</i> | <i>Ns = Nonspecific</i> | <i>Nq = Nonquantitative</i> | | <i>Sq = Semi-quantitative</i> | |
| Carbon monoxide | 630-08-0 | Carboxyhemoglobin in blood | End of shift | 3.5% of hemoglobin | B, Ns |
| | | Carbon monoxide in end-exhaled air | End of shift | 20 ppm | B, Ns |
| Chlorobenzene | 108-90-7 | 4-Chlorocatechol in urine ¹ | End of shift at end of workweek | 100 mg/g creatinine | Ns |
| | | p-Chlorophenol in urine ¹ | End of shift at end of workweek | 20 mg/g creatinine | Ns |
| Chromium (VI), water soluble fume | N/A | Total chromium in urine | End of shift at end of workweek | 25 µg/L | — |
| | | Total chromium in urine | Increase during shift | 10 µg/L | — |
| Cobalt | 7440-48-4 | Cobalt in urine | End of shift at end of workweek | 15 µg/L | B |
| | | Cobalt in blood | End of shift at end of workweek | 1 µg/L | B, Sq |
| Cyclohexanol | 108-93-0 | 1,2-Cyclohexanediol in urine ¹ | End of shift at end of workweek | — | Nq, Ns |
| | | Cyclohexanol in urine ¹ | End of shift | — | Nq, Ns |
| Cyclohexanone | 108-94-1 | 1,2-Cyclohexanediol in urine ¹ | End of shift at end of workweek | 80 mg/L | Ns, Sq |
| | | Cyclohexanol in urine ¹ | End of shift | 8 mg/L | Ns, Sq |
| Dichloromethane | 75-09-2 | Dichloromethane in urine | End of shift | 0.3 mg/L | Sq |
| N,N-Dimethylacetamide | 127-19-5 | N-Methylacetamide in urine | End of shift at end of workweek | 30 mg/g creatinine | — |

TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012)

| Chemical | CAS No. | Determinant | Sampling Time | BEI® | Notation |
|--|-------------------------|--|-----------------------------------|-------------------------------|-----------|
| <i>B = Background</i> | <i>Ns = Nonspecific</i> | <i>Nq = Nonquantitative</i> | | <i>Sq = Semi-quantitative</i> | |
| N,N-Dimethylformamide (DMF) | 68-12-2 | N-Methylformamide in urine | End of shift | 15 mg/L | — |
| | | N-Acetyl-S-(N-methylcarbamoyl) cysteine in urine | Prior to last shift of workweek | 40 mg/L | Sq |
| 2-Ethoxyethanol (EGEE) and 2-Ethoxyethyl acetate (EGEEA) | 110-80-5; 111-15-9 | 2-Ethoxyacetic acid in urine ¹ | End of shift at end of workweek | 100 mg/g creatinine | — |
| Ethyl benzene ³ | 100-41-4 | Sum of mandelic acid and phenylglyoxylic acid in urine | End of shift at end of workweek | (0.7 g/g creatinine) | Ns (Sq) |
| | | (Ethyl benzene in end-exhaled air) | (Not critical) | (—) | (Sq) |
| Fluorides | 109-86-4 | Fluoride in urine | Prior to shift | 2 mg/L | B, Ns |
| | | Fluoride in urine | End of shift | 3 mg/L | B, Ns |
| Furfural | 98-01-1 | Furoic acid in urine ¹ | End of shift | 200 mg/L | Ns |
| n-Hexane | 110-54-3 | 2,5-Hexanedion in urine ² | End of shift at end of workweek | 0.4 mg/L | — |
| Lead ⁴ | 7439-92-1 | Lead in blood | Not critical | 30 µg/100 ml | — |
| Mercury ⁵ | N/A | (Total inorganic mercury in urine) | Prior to shift | (35 µg/g creatinine) | (B) |
| | | (Total inorganic mercury in blood) | (End of shift at end of workweek) | (15 µg/L) | (B) |
| Methanol | 67-56-1 | Methanol in urine | End of shift | 15 mg/L | B, Ns |
| Methemoglobin inducers | N/A | Methemoglobin in blood | During or end of shift | 1.5% of hemoglobin | B, Ns, Sq |
| 2-Methoxyethanol (EGME) and 2-Methoxyethyl acetate (EGMEA) | 109-86-4 and 110-49-6 | 2-Methoxyacetic acid in urine | End of shift at end of workweek | 1 mg/g creatinine | — |
| Methyl n-butyl ketone | 591-78-6 | 2,5-Hexanedione in urine ² | End of shift at end of workweek | 0.4 mg/L | — |

TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012)

| Chemical | CAS No. | Determinant | Sampling Time | BEI® | Notation |
|---|-------------------------|---|-----------------------------------|-------------------------------|-----------|
| <i>B = Background</i> | <i>Ns = Nonspecific</i> | <i>Nq = Nonquantitative</i> | | <i>Sq = Semi-quantitative</i> | |
| Methyl chloroform | 71-55-6 | Methyl chloroform in end-exhaled air | Prior to last shift of workweek | 40 ppm | — |
| | | Trichloroacetic acid in urine | End of workweek | 10 mg/L | Ns, Sq |
| | | Total trichloroethanol in urine | End of shift at end of workweek | 30 mg/L | Ns, Sq |
| | | Total trichloroethanol in blood | End of shift at end of workweek | 1 mg/L | Ns |
| 4,4'-Methylene bis(2-chloroaniline) (MBOCA) | 101-14-4 | Total MBOCA in urine | End of shift | — | Nq |
| Methyl ethyl ketone (MEK) ⁶ | 78-93-3 | MEK in urine | End of shift | 2 mg/L | (—) |
| Methyl isobutyl ketone (MIBK) | 108-10-1 | MIBK in urine | End of shift | 1 mg/L | (—) |
| N-Methyl-2-pyrrolidone | 872-50-4 | 5-Hydroxy-N-methyl-2-pyrrolidone in urine | End of shift | 100 mg/L | (—) |
| Naphthalene ⁷ | 91-20-3 | 1-Naphthol ¹ + 2-Naphthol ¹ | End of shift | — | Nq, Ns |
| Nitrobenzene | 98-95-3 | Total p-nitrophenol in urine | End of shift at end of workweek | 5 mg/g creatinine | Ns |
| | | Methemoglobin in blood | End of shift | 1.5% of hemoglobin | B, Ns, Sq |
| Parathion | 56-38-2 | Total p-nitrophenol in urine | End of shift | 0.5 mg/g creatinine | Ns |
| | | Cholinesterase activity in red cells | Discretionary | 70% of individual's baseline | B, Ns, Sq |
| Pentachlorophenol (PCP) ⁸ | 87-86-5 | (Total PCP in urine) | (Prior to last shift of workweek) | (2 mg/g creatinine) | (B) |
| | | (Free PCP in plasma) | (End of shift) | (5 mg/L) | (B) |

TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012)

| Chemical | CAS No. | Determinant | Sampling Time | BEI® | Notation |
|---|-------------------------------------|--|---------------------------------|-------------------------------|----------|
| <i>B = Background</i> | <i>Ns = Nonspecific</i> | <i>Nq = Nonquantitative</i> | | <i>Sq = Semi-quantitative</i> | |
| Phenol | 108-95-2 | Phenol in urine ¹ | End of shift | 250 mg/g creatinine | B, Ns |
| Polycyclic aromatic hydrocarbons (PAHs) | varies with the compound or mixture | 1-Hydroxypyrene (1-HP) in urine ¹ | End of shift at end of workweek | — | Nq |
| 2-Propanol | 67-63-0 | Acetone in urine | End of shift at end of workweek | 40 mg/L | B, Ns |
| Styrene | 100-42-5 | Mandelic acid plus phenylglyoxylic acid in urine | End of shift | 400 mg/g creatinine | Ns |
| | | Styrene in venous blood | End of shift | 0.2 mg/L | Sq |
| Tetrachloroethylene | 127-18-4 | Tetrachloroethylene in end-exhaled air | Prior to shift | 3 ppm | — |
| | | Tetrachloroethylene in blood | Prior to shift | 0.5 mg/L | — |
| Tetrahydrofuran | 109-99-9 | Tetrahydrofuran in urine | End of shift | 2 mg/L | — |
| Toluene | 108-88-3 | Toluene in blood | Prior to last shift of workweek | 0.02 mg/L | — |
| | | Toluene in urine | End of shift | 0.03 mg/L | — |
| | | o-Cresol in urine ¹ | End of shift | 0.3 mg/g creatinine | B |
| Toluene diisocyanate ⁹ | 584-84-9; 91-08-7 | Toluene diamine in urine ¹ | End of shift | 5 µg/g creatinine | Ns |
| Trichloroethylene | 79-01-6 | Trichloroacetic acid in urine | End of shift at end of workweek | 15 mg/L | Ns |
| | | Trichloroethanol in blood ² | End of shift at end of workweek | 0.5 mg/L | Ns |
| | | Trichloroethylene in blood | End of shift at end of workweek | — | Sq |
| | | Trichloroethylene in end-exhaled air | End of shift at end of workweek | — | Sq |

| TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012) | | | | | |
|--|---|-------------------------------|-----------------------------|--------------------|-------------------------------|
| Chemical | CAS No. | Determinant | Sampling Time | BEI® | Notation |
| <i>B = Background</i> | <i>Ns = Nonspecific</i> | | <i>Nq = Nonquantitative</i> | | <i>Sq = Semi-quantitative</i> |
| Uranium | 7440-61-1 | Uranium in urine | End of shift | 200 µg/L | — |
| Xylenes (technical or commercial grade) | 95-47-6; 108-38-3; 106-42-3; 1330-20-7 | Methylhippuric acids in urine | End of shift | 1.5 g/g creatinine | — |

¹ Denotes with hydrolysis.

² Denotes without hydrolysis; n-hexane, methyl n-butyl ketone and trichloroethylene.

³ 2012 Notice of Intended Changes (NIC) revises ethyl benzene entry as follows: Sum of mandelic and phenylglyoxylic acids in urine; end of shift at end of workweek; 0.15 g/g creatinine; Ns.

⁴ Note: Women of childbearing potential, whose blood Pb exceeds 10 µg/dl, are at risk of delivering a child with a blood Pb over the current Centers for Disease Control guideline of 10 µg/dl. If the blood Pb of such children remains elevated, they may be at increased risk of cognitive deficits. The blood Pb of these children should be closely monitored and appropriate steps should be taken to minimize the child's exposure to environmental lead. (CDC: Preventing Lead Poisoning in Young Children, October 1991; See BEI® and TLV® *Documentation for Lead*).

⁵ 2012 NIC revises mercury entry as follows: Mercury in urine; prior to shift; 20 µg Hg/g creatinine.

⁶ 2012 NIC revises methyl ethyl ketone entry as follows: Methyl ethyl ketone in urine; end of shift; 2 mg/L; Ns.

⁷ 2012 NIC revises naphthalene entry as follows: 1-Naphthol (with hydrolysis) + 2-Naphthol (with hydrolysis); end of shift; no BEI®; Nq, Ns.

⁸ 2012 NIC revises pentachlorophenol entry as follows: Pentachlorophenol (with hydrolysis) in urine; discretionary; no BEI®; Nq.

⁹ 2012 NIC revises toluene diisocyanate entry as follows: Toluene diamine in urine (with hydrolysis) (sum of 2,4- and 2,6- isomers); end of shift; 5 µg/g creatinine; Ns.

APPENDIX B2 – OSHA General Industry Standard – Specific Biological Monitoring Requirements

| TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910) | | | |
|---|------------------|---|---|
| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
| <i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i> | | | |
| 1910.1017 | Vinyl chloride | Serum specimen testing for: <ul style="list-style-type: none"> • Total bilirubin • Alkaline phosphatase • Serum glutamic oxalacetic transaminase (SGOT) • Serum glutamic pyruvic transaminase (SGPT) • Gamma glutamyl transpeptidase | For workers exposed above the action level: <ul style="list-style-type: none"> • Initial medical examination • Every 6 months for each employee who has been employed in vinyl chloride or polyvinyl chloride manufacturing for 10 years or longer. • Annually for all other employees. • After exposure during emergency situations. |
| 1910.1025 | Lead | Blood sample testing for: <ul style="list-style-type: none"> • Blood lead • Zinc protoporphyrin (ZPP) Blood sample testing for: <ul style="list-style-type: none"> • Blood lead • Hemoglobin and hematocrit determinations, red cell indices, and examination of smear morphology. • ZPP • Blood urea nitrogen • Serum creatinine • Regular urinalysis with microscopic examination. | For workers who are or may be exposed at or above the action level for more than 30 days per year: <ul style="list-style-type: none"> • At least every six months • At least every two months for each worker whose last blood sampling and analysis indicated a blood lead level at or above 40 µg/100 g of whole blood (continuing until two consecutive blood samples and analyses indicate a blood lead level below 40 µg/100 g of whole blood). • Within two weeks after receipt of results indicating a blood lead level exceeding the numerical criterion for medical removal (60 µg/100 g of whole blood). • At least monthly during the removal period of each worker removed from exposure to lead due to an elevated blood lead level. For workers who are or may be exposed at or above action level for more than 30 days per year: <ul style="list-style-type: none"> • Initial exam • Annually, if blood lead level is at or above 40 µg/100 g of whole blood at any time in the preceding 12 months. |

TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910)

| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
|--|-----------|--|---|
| <p><i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i></p> | | | |
| | | <p>Pregnancy testing or laboratory evaluation of male fertility, if requested by worker.</p> | <ul style="list-style-type: none"> • As soon as possible upon notification by worker of development of signs/symptoms of lead intoxication, worker desires medical advice on effects of current/past exposure on ability to procreate a healthy child, or worker has demonstrated difficulty in breathing during a respirator fitting test or during use. • As medically appropriate for worker removed from exposure due to risk of material impairment of health or otherwise limited pursuant to final medical determination. |
| 1910.1027 | Cadmium | <p>Urine testing for:</p> <ul style="list-style-type: none"> • Cadmium in urine (CdU), standardized to grams of creatinine (g/Cr) • Beta-2 microglobulin in urine (B(2)-M), standardized to grams of creatinine (g/Cr), with pH specified <p>Blood sample testing for:</p> <ul style="list-style-type: none"> • Cadmium in blood (CdB), standardized to liters of whole blood (lwb) <p>During required periodic medical examinations workers should be additionally tested for:</p> <ul style="list-style-type: none"> • Blood urea nitrogen • Complete blood count • Serum creatinine • Urinalysis – additional testing for albumin, glucose, and total and low molecular weight proteins. | <p>For currently and/or previously exposed workers, as specified in the standard:</p> <ul style="list-style-type: none"> • Initial exam • At least annually <ul style="list-style-type: none"> • Within one year after initial exam, and at least biennially thereafter. • At varying follow-up frequencies depending on whether currently or previously exposed and biological monitoring findings, as specified in the standard. • After acute exposure during emergency situations. • Upon termination, as specified in the standard. |

TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910)

| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
|---|------------------------------------|--|---|
| <i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i> | | | |
| 1910.1028 | Benzene | Complete blood count testing for: <ul style="list-style-type: none"> • Leukocyte count with differential • Quantitative thrombocyte count • Hematocrit • Hemoglobin • Erythrocyte count and erythrocyte indices After exposure during emergency situations: <ul style="list-style-type: none"> • Urinary phenol test (to be performed on end-of-shift urine sample within 72 hours of the emergency exposure). | For workers exposed under the exposure scenarios specified in the standard: <ul style="list-style-type: none"> • Initial exam • Annually • Complete blood count repeated within two weeks of initial or periodic examination results indicating abnormal blood conditions specified in the standard. After exposure during emergency situations: <ul style="list-style-type: none"> • Complete blood count tests monthly for three months following exposure if phenol test is ≥ 75 mg phenol/Liter of urine. |
| 1910.1029 | Coke oven emissions | Urinalysis testing for: <ul style="list-style-type: none"> • Sugar • Albumin • Hematuria Urinary cytology examination | For workers working in regulated areas at least 30 days per year: <ul style="list-style-type: none"> • Initial exam • Annual urinalysis testing • Annual urinalysis testing plus urinary cytology examination for workers ≥ 45 years old or with \geq five years employment in regulated areas. • Upon termination if worker has not had examination within preceding six months. |
| 1910.1030 | Bloodborne pathogens | Blood sample testing for: <ul style="list-style-type: none"> • Hepatitis B virus (HBV) and human immunodeficiency virus (HIV) (source individual) • HBV and HIV (exposed individual) | Immediately after an exposure incident: <ul style="list-style-type: none"> • Source individual - As soon as feasible, provided consent is obtained as necessary. • Exposed worker - As soon as feasible after consent is obtained. If consent is not obtained for HIV serologic testing at time of baseline blood collection, the sample shall be preserved for at least 90 days, during which time it shall be tested as soon as feasible if consent is obtained. |
| 1910.1044 | 1,2-Dibromo-3-chloropropane (DBCP) | Serum specimen testing for: <ul style="list-style-type: none"> • Serum follicle stimulating hormone (FSH) • Serum luteinizing hormone (LH) • Serum total estrogen (females) Sperm count | For workers in regulated areas: <ul style="list-style-type: none"> • Initial exam • Annually |

TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910)

| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
|---|------------------|---|--|
| <i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i> | | | |
| | | After exposure during emergency situations: <ul style="list-style-type: none"> • Sperm count or above hormone tests if worker has vasectomy or is unable to produce semen. | After exposure during emergency situations: <ul style="list-style-type: none"> • As soon as practicable after exposure and repeated three months after exposure. |
| 1910.1045 | Acrylonitrile | Test of the intestinal tract, including fecal occult blood screening (for all workers 40 years of age or older, and for any other affected workers for whom, in the opinion of the physician, such testing is appropriate). | For workers who are or will be exposed at or above the action level: <ul style="list-style-type: none"> • Initial exam • Annually • Upon termination if worker has not had examination within preceding six months. |

TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910)

| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
|---|--------------------------|---|--|
| <i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i> | | | |
| 1010.1047 | Ethylene oxide (EtO) | Complete blood count testing for: <ul style="list-style-type: none"> • White cell count (including differential cell count). • Red cell count • Hematocrit • Hemoglobin | For workers who are or may be exposed at or above the action level for at least 30 days per year: <ul style="list-style-type: none"> • Initial exam • Annually • At termination, or at reassignment to an area without such exposures. After exposure during emergency situations, as medically appropriate. As soon as possible after notification by a worker: <ul style="list-style-type: none"> • Of development of signs or symptoms indicating possible overexposure. • That worker desires medical advice concerning the effects of current or past exposure to EtO on the worker's ability to produce a healthy child. |
| 1910.1050 | Methylenedianiline (MDA) | <ul style="list-style-type: none"> • Liver function tests • Urinalysis | For workers exposed at or above the action level for at least 30 days per year, subject to dermal exposure at least 15 days per year, or whom employers have reason to believe are being dermally exposed: <ul style="list-style-type: none"> • Initial exam • Annually After exposure during emergency situations and when workers develop signs/symptoms of exposure: <ul style="list-style-type: none"> • Initial exam • Repeat liver function tests on physician's advice. If tests are normal, repeat two to three weeks after initial tests. If both are normal, no further testing is required. |

TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910)

| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
|---|--------------------|--|--|
| <i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i> | | | |
| 1910.1051 | 1,3-Butadiene (BD) | Complete blood count with differential and platelet count. | <p>Annually for workers exposed at or above the action level for at least 30 days per year; or at or above the PELs for at least 10 days per year;</p> <p>Annually for workers even after transfer to non-BD exposure jobs (regardless of when transferred) if work history suggests BD exposure:</p> <ul style="list-style-type: none"> ○ At or above the PELs on ≥ 30 days per year for 10 or more years. ○ At or above the action level for ≥ 60 days per year for 10 or more years. ○ Above 10 ppm for ≥ 30 days in any past year. <p>After exposure during emergency situations</p> <ul style="list-style-type: none"> ● As quickly as possible, but no later than 48 hours after an emergency exposure, then monthly for three months. |

TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS (29 CFR 1910)

| OSHA Standard | Substance | Analyte(s) | Monitoring Frequency |
|---|-------------------------|--|--|
| <i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i> | | | |
| 1910.1052 | Methylene chloride (MC) | <p>The physician or other licensed healthcare professional shall determine the extent of any required laboratory surveillance based on the worker's observed health status and the medical and work history.</p> <p>After exposure during emergency situations (laboratory surveillance as indicated by the worker's health status).</p> | <p>For workers exposed: at or above the action level for at least 30 days per year; at or above the eight-hour TWA PEL or the STEL for at least 10 days per year; or above the eight-hour TWA PEL or STEL for any length of time where a worker has been identified as being at risk from cardiac disease or some other serious MC-related health condition (and requests inclusion in the medical surveillance program):</p> <ul style="list-style-type: none"> • Initial exam • Within 12 months of last surveillance for worker's age 45 years or older, or within 36 months of last surveillance for worker's less than 45 years old. • Upon termination, or reassignment to an area with MC exposure consistently at or below the action level and STEL if the worker has not had surveillance within the preceding six months. • Additional surveillance at frequency (other than above) when recommended in written medical opinion. <p>After exposure during emergency situations.</p> |

APPENDIX C – Procedures for Collecting Wipe Samples

1. General Procedures for Collecting Wipe Samples

Preloading a group of vials with sampling filters (consult the [OR-OSHA Lab Sampling Procedures](#) to determine the appropriate sampling media to use) is a convenient method to carry the sample media to the worksite. Clean disposable gloves should be worn when handling the filters. The gloves should not be powdered.

The following are general recommendations for taking wipe samples. Consult the [OR-OSHA Lab Sampling Procedures](#) for more specific instructions.

- Record each location where a wipe sample was taken. Photographs, sketches, diagrams and other means of noting sampling locations are helpful.
- A new set of clean, disposable, powder-free gloves should be used for each sample to avoid contamination of the filter by previous samples (and the possibility of false positives) and to prevent contact with the substance.
- Withdraw the filter from the vial or package with your fingers or clean tweezers. If a damp wipe sample is desired, moisten the filter with distilled water or other solvent as recommended. Note: For skin sampling use only distilled water. Other solvents may be appropriate for wiping surfaces depending upon the type of chemical being sampled.
- Depending on the purpose of the sample, it may be useful to determine the concentration of contamination (e.g., in micrograms of agent per area). For these samples, it is necessary to record the area of the surface wiped (e.g., 100 cm²).
- Firm pressure should be applied when wiping.
- Using the filter, wipe an area about 100 cm², rubbing the entire area side to side, then up and down. In many cases (such as knobs and levers) it may not be possible to wipe 100 cm². Where a precise determination of the contaminant loading (concentration) is desired, prepare single use 10cm x10cm templates from cardstock or file folders. Cardboard templates may also be obtained from the Oregon OSHA Lab, either 10cm x 10cm or 1ft x 1ft.
- Place the filter in a sample vial or a Whirl-Pak® bag, number it, and note the sample location. Include notes which will provide any additional relevant details regarding the nature of the sample (e.g., "Fred Worker's respirator, inside"; "Lunch table").
- At least one blank filter treated in the same fashion, but without wiping, should be submitted for each sample set.
- Some substances (e.g., isocyanates) are unstable and may require a solution to be added to the vial as soon as the wipe sample is placed in the vial or may require other special

sample handling (e.g., hexavalent chromium). If such instability is suspected, check the [OR-OSHA Lab Sampling Procedures](#) file for sample handling instructions or contact the Oregon OSHA Lab for guidance.

- Submit the samples, each sealed with Lab seal Form 440-1316 to the Oregon OSHA Lab. Properly document the samples by completing the OTIS sampling worksheet.

Successful wipe sampling requires preparation and careful technique. It is best to practice these techniques in the office or other clean area before collecting samples in the field. Practice will enable the CSHO to get a sense of how much to wet the wipe, how delicate the wipes are, how to apply uniform pressure when wiping the surface, how to wipe evenly across the area to be sampled, how to fold the wipe to expose a clean surface for conducting a second pass, how to handle the wipes with tweezers or forceps, and how to avoid contaminating one's gloves while sampling.

APPENDIX D – Combustible Dust Bulk Sampling

Combustible dust sampling is conducted where the potential for rapid burning (deflagration) or violent burning with rapid release of pressure (explosion) is suspected due to the presence of accumulations of settled dust. **Non-ferrous metals are especially hazardous and must be collected according to CSHO safety and health program policies and procedures.** In general, a thickness greater than 1/32 of an inch is cause for concern when the surface area covered by settled dust exceeds 5% of the floor area in a given room. The 5% factor should not be used if the floor area exceeds 20,000 square feet (ft²), in which case a 1,000 ft² layer of dust is the upper limit. Accumulations on overhead beams, joists, ducts, the tops of equipment, and other surfaces, including vertical surfaces, should be included when determining the dust coverage area. Note that the available surface area of bar joists is approximately five percent of the floor area and the equivalent surface area for steel beams can be as high as 10%. Additional detail is included in the program directive for the National Emphasis Program (NEP): Combustible Dust, [A-268](#).

Examples of combustible dust include but are not limited to:

- Metal dust such as aluminum and magnesium
- Wood dust
- Coal and other carbon dusts
- Plastic dust and additives
- Biosolids
- Other organic dust such as sugar, flour, paper, soap, and dried blood
- Certain textile materials

Examples of industries that handle combustible dusts: agriculture, food products, chemicals, textiles, forest and furniture products, wastewater treatment, metal processing, tire and rubber manufacturing plants, paper products, pharmaceuticals, wastewater treatment, recycling operations (metal, paper, and plastic), and coal handling and processing facilities.

Examples of OSHA standards applicable to combustible dust hazards:

- 1910.22, Walking-Working Surfaces
- 1910.176(c), Materials Handling and Storage
- 1910.272, Grain Handling Facilities
- 1910.307, Electrical, Hazardous (Classified) Locations
- 1910.269(v)(11)(xii), Electric Power Generation, Transmission, Distribution
- 1910.1200, Hazard Communication Standard
- ORS 654.010, the General Duty Clause, may used to cite deflagration, other fire, or explosion hazards where combustible dust hazards exist within dust control systems or other containers.

Personal Protective Equipment (PPE): To conduct combustible dust sampling, CSHOs shall wear non-spark producing clothing such as natural fiber (e.g., cotton). CSHOs should also be equipped with flame-resistant (FR) clothing as appropriate. Other PPE for the reduction of static electric discharge includes conductive gloves and electrostatic dissipative (ESD) footwear

without metal eyelets. Note: CSHOs should not rely on ESD footwear as being effective in all environments. Accumulation of debris, wax, and other high resistivity materials will compromise the conductivity of any floor. Conductive footwear should not be used where the potential for electric shock by line voltage exists.

Cameras: In areas classified as requiring intrinsically safe equipment, use only cameras that are intrinsically safe. If not available, either portray the scene with a sketch or use the zoom lens to take photos from a safe location. In areas that are not classified, the low energy levels produced by use of a regular camera will not normally present a hazard when dust concentrations in the air are below an OSHA PEL. If the dust levels in the air necessitate the use of a respirator, DO NOT USE YOUR CAMERA.

Safe Practices:

If CSHOs find that there are potential combustible dust hazards, dust samples must be safely collected. Written statements should be taken from workers and employers regarding the properties of the combustible metals and any hazardous conditions present, such as but not limited to:

- Any history of fires/explosions/deflagrations involving combustible metals of concern (e.g. aluminum, magnesium, titanium, tantalum, niobium, zirconium, others). *If a fire, explosion, or deflagration has previously occurred at the establishment related to the handling of a combustible metal, document the occurrence and circumstances involved through the interview process. If a material has shown to be combustible at the establishment, there may not be a need for obtaining a bulk sample.*
- The experienced consistency/size fraction of the combustible metals of concern. *Interview the workers charged with emptying the collection bins beneath the dust collection devices. Document their experience regarding the particle size of the metal being collected. Common materials and their size are:*
 - *White granulated sugar: 450 to 600 microns*
 - *Table salt: 100 microns*
 - *Flour: 1 to 100 microns*
 - *Sand: 50 plus microns*
 - *Talcum powder: 10 microns*
- The results of any previous combustible metals sampling conducted or commissioned by the employer. *If the employer has previously conducted combustibility testing, obtain the results for the file.*
- Safety Data Sheet (SDS) identification of metal material(s), SDS warnings or other instructions. *Obtain SDSs for the materials being utilized at the establishment for the file.*
- Do not collect a sample from an area unless a safe means of access is available.
- Take all precautions necessary to avoid the generation of a dust cloud while collecting a sample.

- Use conductive nonsparking tools when collecting samples. If possible, bond and ground the tools.
- Do not use plastic bags, as they cannot be sealed tightly enough to avoid sample leakage or moisture loss, and may cause a bellows effect resulting in airborne exposure during sample handling.

Sample Collection Equipment may include:

- Natural bristle hand brushes for collecting settled dust.
- Non-sparking conductive dust pans (aluminum) for collecting settled dust.
- Non-spark producing sample container (1-Liter nonconductive plastic bottle, obtained locally or from the Oregon OSHA Lab).
- Non-spark producing funnel for filling sample containers.
- Non-spark producing scoops for removing dust from cyclone containers or other ventilation equipment.

Sampling locations:

- Observe and document areas where the dust layer exceeds 1/32 inch in thickness, approximately the thickness of a small paper clip.
- Collect separate samples from:
 - Equipment and floors where dust has accumulated. Note that samples collected at floor level present a significantly reduced potential for dust cloud generation.
 - “High spaces” such as roof beams, open web beams, and other ceiling supports; tops of pipes, railings, ductwork, conduit, electrical boxes/panels and other horizontal surfaces located as high in the overhead as possible. Samples collected from elevated surfaces present a significantly greater potential for dust cloud generation from the inadvertent falling of material. High spaces are the preferred location for collecting samples, so long as there is a means of safe access.
 - The interior (i.e., bins and/or bags) of a dust collector.
 - Within ductwork.
- Avoid taking samples in close proximity of recognized ignition sources such as open flames, motors, electrical equipment, equipment bearings, etc.

Procedures:

- Use the correct equipment for collecting dust samples (see sample collection equipment above).

- Avoid contaminating the sample with other substances (some contaminants lead to underreporting of the explosiveness of the dust sampled).
- Collect at least 1 Liter of dust per sample.
 - One sample of each type dust is sufficient.
 - Each type dust must be collected as separate sample.
 - Dust from several locations can be pooled into one sample container IF it is all the same type of dust.
 - Several tests are conducted from the same bulk sample.
- If possible, collect the sample from the highest elevated horizontal surfaces in the plant. Finer particles more easily ignite and tend to collect on elevated surfaces.
- Determine if there is a hybrid mixture of combustible dust with a flammable gas or vapor.
- If it is grain dust, send an additional sample for percent (%) combustible analysis.
- Affix a Lab seal Form 440-1316 to the container. To seal the bottle, apply one end of the seal to the center of the lid, and run the seal down the edge of the lid and as far down the side of the bottle as it will reach.
- Document where, when, and how dust is used and/or generated. Document the description of the operation and the requested tests on the OTIS sampling worksheet as follows:
 - When requesting analyses for fire or explosion hazards that may result from housekeeping, ORS 654.010, or Division 2, Subdivision E (Means of Egress) violations, write K_{st} .
 - Where 1910.307 (Hazardous Locations) violations are a concern, write “Potential Class II Dust.” This test must be done to support a citation for Class II hazardous (classified) locations. Note: This test only applies to electrical ignition sources in Class II locations. When in doubt, contact the Oregon OSHA Lab.
- The Enforcement manager must review the sampling plan and the number of samples being submitted. Management approval is required due to the resource intensive nature of these laboratory tests.
- Ship the sample with the paperwork to the Oregon OSHA Lab. Note: No special DOT shipping requirements apply; however, when shipping metal dusts, especially dusts involving aluminum or magnesium, CSHOs should verify with the shipping company whether any special requirements apply.