Industrial Hygiene Exposure Assessment Measurements in Washington State

Summary Results from the Division of Occupational Safety and Health (DOSH) Compliance Inspections

2008-2016

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Abstract: This report contains nine years of worker exposure assessment results conducted by industrial hygiene (IH) compliance safety and health officers (CSHOs) in Washington State. Personal exposure assessments including air and noise sampling were conducted at workplaces between 2008-2016.

1. Washington State Department of Labor and Industries, Division of Occupational Safety and Health (DOSH)
2. Washington State Department of Labor and Industries, Safety and Health Assessment and Research for Prevention (SHARP) Program

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DEFINITIONS

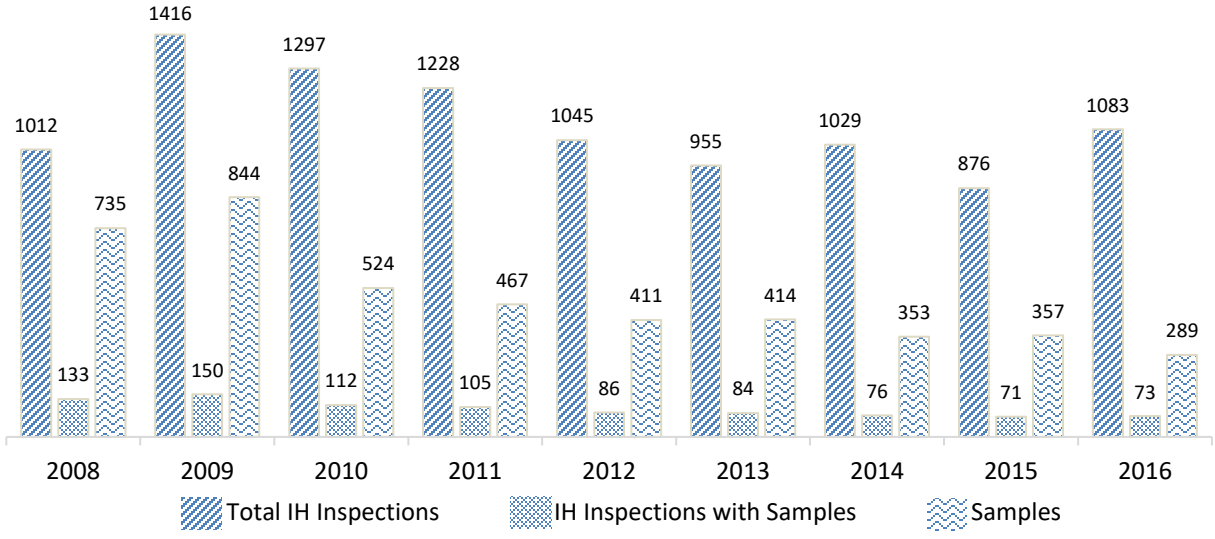
ABLES	Adult Blood Lead Epidemiology Surveillance
ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
dB	Decibels
BLD	Below limit of detection
C	Ceiling limit
CIH	Certified Industrial Hygienist
CSHO	Compliance Safety and Health Officer
DOSH	Division of Occupational Safety and Health
EU	Enforcement unit
EWS	Enforcement weighting system
IH	Industrial Hygiene
L&I	Washington State Department of Labor and Industries
LOD	Limit of detection
Mg/m^3	Milligrams per cubic meter
NAICS	North American Industrial Classification System
NAS	National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PEL	Permissible exposure limit
ppm	Parts per million
SEG	Similar exposure group
SHARP	Safety and Health Assessment and Research for Prevention
STEL	Short-term exposure limit
TWA	Time-weighted average
WA	Washington State

EXECUTIVE SUMMARY

This report contains worker exposure assessment information, hereafter referred to as samples or exposure samples, collected from workers in Washington State between 2008-2016 by industrial hygiene (IH) compliance safety and health officers (CSHOs) employed by the Division of Occupational Safety and Health (DOSH) at the Washington State Department of Labor and Industries (L&I). In addition to supporting compliance efforts, exposure samples provide insight into trends in concentration and severity of workers' exposures to different substances, allow for comparisons among industries and occupations, and provides opportunities for worker exposure prevention.

Over the nine-year period, CSHOs conducted 9941 IH compliance inspections. Among them, 890 (9%) inspections included sample collection, resulting in 4394 exposure samples. The number of total IH inspections annually varied between 876-1416 and averaged approximately 1100 per year (see Figure 1). The number of IH inspections with sampling decreased annually from 133 (13% of total) inspections in 2008 to 73 (7% of total) inspections in 2016. Along with the decrease in the number of inspections with sampling, the number of samples collected and entered annually also decreased from a high of 844 in 2009 to 289 in 2016, or about 60 fewer samples per year. These may have been influenced by IH personnel turnover or staff levels.

Figure 1. Total Industrial Hygiene Inspections[1] and Inspections with Samples by Year[2]



1. Compliance inspections only.
2. Calendar year of inspection closing conference date.

A total of 133 unique exposure substances were sampled by CSHOs. By substance, the three most frequently collected exposure samples were noise, dust, and lead (see Table 1). Noise and dust are exposures common to several industries and tasks. Lead is often associated with specific industries or tasks, including battery manufacturing, abrasive blasting in construction, and working at shooting ranges. The high number of samples for lead is likely the result of emphasis programs, referrals from the Adult Blood Lead Epidemiology Surveillance (ABLES) program, and increased awareness of the health effects of lead on the part of CSHOs, health care providers, and workers.

Table 1. Three Most Frequently Sampled Substances

Substance	Number of Samples
Noise, continuous or intermittent	1381
Particulates not otherwise regulated (respirable and total dust)	399
Lead, inorganic fumes & dusts	188

The three industries with the highest number of exposure samples were automotive body, paint, and interior repair and maintenance; boat building; and sheet metal manufacturing (see Table 2). These three industries are similar in that they all generate multiple exposures, including noise, dust, and chemical substances, that contributed to the overall high number of samples.

Table 2. Three Most Frequently Sampled Industries[1]

Industry	Number of Samples
Automotive body, paint, and interior repair and maintenance (NAICS 811121)	153
Boat building (NAICS 336612)	152
Sheet metal work manufacturing (NAICS 332322)	135

1. Industry classification according to North American Industrial Classification System (NAICS).

The permissible exposure limits (PEL) for airborne contaminants and noise used by DOSH are the primary tool in disease prevention and are an essential part of a workplace comprehensive safety and health program[1]. Exposure severity, defined as the ratio of the measured concentration of a substance to the established PEL for that substance, is an indicator of how hazardous an exposure is to a worker's health. Substances with the highest severities are shown in Table 3. Severity ratios greater than 1.0

indicate that the exposure exceeds its respective PEL and the employer must takes steps to reduce the exposure. Thirty-five of the 133 substances sampled were measured at severity levels greater than 1.0 on at least one occasion. Eighteen of the 98 remaining substances were measured at severity levels between 0.5 and 1.0. This is notable because many professional industrial hygienists consider a severity level equal to or greater than 0.5, or half of the substance PEL, the level at which safety controls are needed to lower workers' exposures.

The five substances with the highest severity levels were respirable silica, noise, dust, nitrous oxide, and hexavalent chromium. These were all measured at over 50 times their respective PELs.

Table 3. Five Highest Severity[1] Exposure Substances

Substance	Maximum Severity
Silica crystalline quartz (respirable fraction)	130
Noise	100
Particulates not otherwise regulated (total dust)	90
Nitrous oxide	80
Chromium (VI) (hexavalent chromium)	51

1. Severity = ratio of the measured concentration to its permissible exposure level.

OBJECTIVES

This primary objective of this report is to summarize DOSH compliance IH exposure sample results collected from workplaces from 2008-2016.

This report does not contain all extracted data due to limits on data table size and page space. Therefore, a user-friendly database tool containing all exposure sampling information was developed for CSHOs and other L&I staff as a supplement to this report. The database tool allows users to quickly find trends in the highest severity or most frequently collected substances. Users can also access summary data on a single industry or substance or very detailed information about a particular exposure.

For example, database users interested in exposures in the manufacturing sector can view all manufacturing workplaces where samples were collected, the number of samples collected for each substance, sample concentration and severity summaries, job titles and tasks for workers sampled, and the health effects associated with each substance. Similar information can be easily obtained for a particular substance.

Other specific aims of this report are to:

- Characterize trends in worker exposures by
    - Substance hazard severity and number of samples collected.
    - Industries, occupations, and tasks.
- Use hazard severity to identify industries and occupations that are in need of exposure controls, follow-up sampling, or medical surveillance.
- Identify and characterize
    - Industries, occupations, and tasks with extreme or consistent worker overexposures.
    - Where workers are exposed to highly toxic and carcinogenic substances.
    - Worker exposures that are new or emerging.
- Provide CSHOs and mangers with easy to access exposure sampling information to help facilitate future worker exposure assessments.
- Provide recommendations to enhance worker exposure assessments, data quality, and data systems.
- Evaluate the current data systems and data quality for use in ongoing timely hazard surveillance.

INTRODUCTION

Workplace injuries can occur suddenly where the source, the effect, and the method of controlling the hazard that caused the injury are readily identifiable. In contrast, workplace exposures are often more complicated to assess and control and may cause both short-term and cumulative health effects, including occupational disease. For example, exposures encountered by a typical auto body repair worker include noise, dusts from body filler, metal fumes from welding, isocyanates in paints, and numerous solvents. Common short-term health effects from exposures to these substances include irritation to eyes, skin, or the respiratory system. Health effects from cumulative exposure to some of these substances include hearing loss, nervous system effects, respiratory disease, and cancer.

IH CSHOs are responsible to ensure that employers mitigate exposures found to be in excess of the substance PELs. Because PELs are based on health effects, CSHOs are also collecting indicators of the health hazards to the workers they sample, other workers with similar exposures, and, in some cases, entire industries. Currently, the exposure sample results and related details of exposure assessments are not widely used beyond the scope of the workplace inspection in which they are collected.

At the national level, there is growing recognition of the value of exposure surveillance in the prevention of acute health effects, as well as for the prevention of exposure-induced chronic disease. A 2018 report released by the National Academies of Science (NAS) includes recommendations at the national level for the National Institute for occupational Safety and health (NIOSH), in consultation with the Occupational Safety and Health administration (OSHA), to place priority on developing a comprehensive approach for exposure surveillance. This would include, for example, data sources such as OSHA's exposure database, NIOSH's Health Hazard Evaluations, and the Mine Safety and Health Administration's (MSHA) Standardized Information System (MISIS)[3]. In addition, NIOSH's National Occupational Research Agenda (NORA) for Respiratory Health has been drafted for the third decade of NORA (2016-2026) and includes strategic objectives that rely on chemical exposure data, such as the advancement of occupational respiratory diseases and exposure surveillance[4].

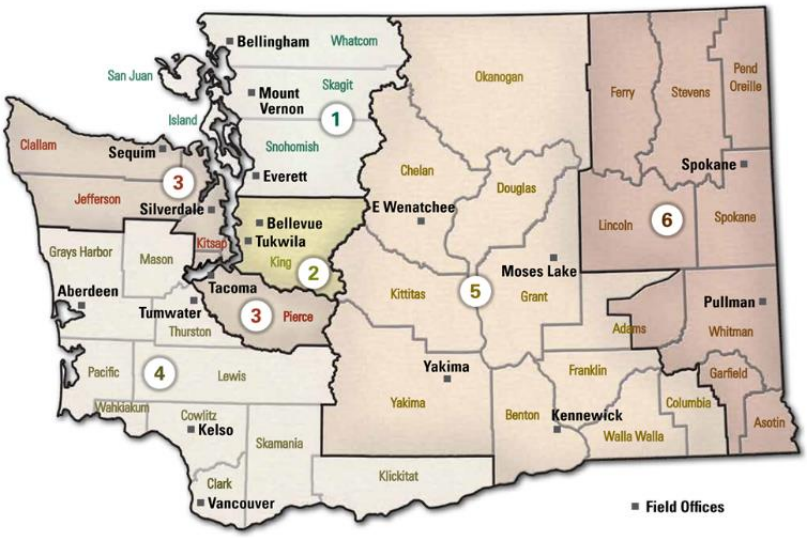
DOSH Organization and Administration

Twenty-two states or territories have OSHA-approved plans that cover workplace safety for private and state and local government workers. Washington's State Plan is administered by L&I's DOSH. State plans must set workplace safety and health standards that are "at least as effective" as OSHA standards. DOSH has adopted most OSHA standards by reference. However, there are also unique DOSH standards. Federal OSHA covers workers not covered by the Washington State Plan.

DOSH is responsible for conducting workplace inspections and the enforcement of occupational safety and health standards, including those for worker exposures. CSHOs inspect workplaces for hazardous conditions and issue citations where violations of occupational safety and health standards exist. Inspections may be the result of regular scheduling, imminent danger reports, fatalities, and worker complaints or referrals.

DOSH is staffed by an L&I assistant director, a statewide compliance manager, and eight regional compliance managers. Regional offices cover distinct geographic areas (see Figure 2) in the state and employ IH CSHOs. More information on enforcement in Washington can be found on the Washington State Plan website at www.osha.gov/dcsp/osp/stateprogs/washington.html

Figure 2. Map of the Six L&I Geographic Regions and Location of Field Offices



DOSH Authority

The Revised Code of Washington (RCW) establishes the power of the director of L&I to supervise the administration and enforcement of all laws regarding employment and relating to the health of employees. The director's representatives (e.g. CSHOs) are authorized to enter the factory, plant, establishment, construction site, or other area, workplace, or environment where work is performed by an employee of an employer. CSHOs are authorized to inspect, survey, and investigate any such workplace and all pertinent conditions, structures, machines, apparatus, devices, equipment, and materials therein, and to question privately any such employer, owner, operator, agent, or employee.

Project Rationale

Every year, DOSH CSHOs perform an average of 1,100 IH inspections in a variety of industry sectors. During some inspections, CSHOs collect samples to better characterize workers' exposures to hazards. CSHOs enter exposure sample results and information collected to characterize the workplace and exposure scenario into a system that generates an inspection report and transfers the information to an administrative database. Currently, there is no efficient method for CSHOs or managers to access and analyze the industrial hygiene sample results from inspections after the information is entered into the system.

Easier access to organized and summarized exposure sampling data would help managers and CSHOs work more efficiently and effectively. Locating and browsing individual inspection reports is time consuming, and the administrative database is difficult to query. A centrally available, easy to query database containing exposure sampling information from all inspections could inform them of particular industries, job titles, and tasks that are at risk for high exposures to hazardous substances. It would help them make decisions about which substances may be present at hazardous levels and whether to conduct sampling or not. It may also point to industries where exposure sampling and prevention is needed.

METHODS

CSHO Training

L&I employs about 125 CSHOs, 35 of which are IH CSHOs. CSHOs are trained to recognize and evaluate workplace hazards. They also work with employers to correct hazards and protect employees from hazardous exposures. DOSH provides an initial nine weeks of training, which includes three weeks covering the fundamentals of IH. This training includes the principals of air sampling, including hands-on sampling activities and instrument calibration, as well as using real-time air monitoring equipment for a variety of common workplace exposure substances.

Inspection Types

Generally, there are two types of compliance inspections: those initiated by an accident, complaint or referral; and those initiated based on an employer's workplace injury and illness history. DOSH prioritizes workplace inspections in response to accidents, complaints and referrals over those initiated by industrial insurance claim record and inspection history. Inspections initiated by a complaint or a referral are limited in scope to the items mentioned in the allegation. In some cases, there is sufficient evidence to allow the scope to expand to include the entire workplace. An inspection opened due to an employer's injury and illness history always includes an examination of the entire worksite.

CSHOs may also perform inspections at workplaces within industries that occupational health research has identified as having particular hazardous exposures. These inspections are sometimes classified under a national or statewide emphasis program. Personal sampling may be performed at these visits to assess the employee exposure to potential chemical hazards. For the 2008-2016 period, there were emphasis programs to determine workplace exposures to the substances lead and isocyanates in various industries, and to evaluate exposures in the primary metal manufacturing industry groups (NAICS Code 3311-3315), which includes metal smelters and foundries

Exposure Assessment Sampling Criteria

When evaluating workplace personal exposures, CSHOs rely upon observation, risk analysis, screening tools (if available), and conversations with the employees and employer to determine if personal

exposure sampling is required. When developing a sampling strategy, CSHOs utilize the worst-case sampling approach where they identify and collect samples from workers experiencing the highest exposures among a group of workers with exposures to the same substance or in a similar exposure group (SEG). CSHOs have a limited amount of time at each jobsite, and the worst-case approach can best determine whether workplace exposures are in excess of their established PELs, which are set to reduce workers' risks for illness and disease. Worst-case sampling strategy may, in theory, upwardly bias sample results when compared with a more comprehensive sampling strategy. When collecting exposure samples, CSHOs also document the number of employees with similar exposures to those being sampled.

During a sampling event, CSHOs observe employees' work practices, and note potential sources of exposure. If, during observation, an employee is determined to be in imminent danger of a harmful exposure, such as approaching a STEL, or working in a large cloud of potentially hazardous dust without any engineering or respiratory controls, a CSHO will intervene and may stop the work all together. Ultimately, because the intention is to protect the worker from hazardous exposures, the intervention may subsequently render air sampling less representative of the actual work environment because the exposure was pre-emptively reduced.

CSHOs commonly assess worker exposures by collecting full-shift 8-hour and short-term 15-minute samples for acutely toxic substances. When CSHOs suspect worker exposure is hazardous, they strive to collect a full shift's sample to accurately characterize the exposure. When working in the field, certain issues may prevent CSHOs from collecting a full 8-hour sample, such as a sampling pump malfunction, or an employee who only works in the exposed area in the afternoon portion of the shift. When this occurs, for compliance purposes, CSHOs must assume the non-sampled time has zero exposure. Therefore, a CSHO who collects an exposure sample for only three hours must average the three hours of exposure with five hours of zero exposure for comparison to the established 8-hour full shift PEL. It was not possible to determine whether the exposure samples in this report resulted from a full 8 hours of sampling, or a shorter interval of sampling. Any assumption of zero exposure for unmeasured time has the potential to decrease the exposure sample result for the employees at the workplace.

All safety and health inspection findings are subject to appeal by employers. Employers have the right to contest all aspects of the inspection results, including IH sampling. As a result, all sampling information, such as instrument calibration before and after sampling, air volume and time sampled, and other

sampling method details must be well documented and defensible. Any citations that rely upon evidence from IH sampling results may be thoroughly scrutinized during the appeal.

Sampling and Analytic Methods

The DOSH IH Laboratory in Olympia, WA performs analysis on all IH exposure samples collected by L&I CSHOs. The IH Laboratory uses validated analytic methods, similar to those used by OSHA and NIOSH, for every regulated substance covered by DOSH standards as well as for some substances that are not covered and have no established PELs, such as hexamethylene diisocyanate (HDI). In this case, the OEL for HDI promulgated by the California Department of Industrial Relations was used to assess exposures to HDI. The laboratory maintains annual accreditation from the American Industrial Hygiene Association (AIHA).

The IH laboratory also coordinates annual calibration of all field sampling equipment, including real-time monitors used for screening purposes. Increasingly, CSHOs have conducted real-time monitoring to screen for potential over-exposures in the field, as the technology for that equipment has improved. Real-time data can be used to justify further, more in-depth sampling, or to rule out the existence of a potential hazard. Exposures to some substances such as asbestos are assessed primarily through bulk sampling of materials, therefore personal exposure sampling for asbestos is infrequent.

Data

Data System

Once exposure sampling results are collected and analyzed by the laboratory, CSHOs manually input the sample results into a data system used for generating inspection reports, citations, and notices from the results of the inspections, which are then sent to employers after the inspection process is complete. All data and related information manually entered by CSHOs can be accessed from an administrative database. This database was used to access the exposure data used in this report and to develop the separate IH exposure database tool. The IH Laboratory maintains a separate sample database, which is independent from the administrative database, and the two are not currently linkable by common sample IDs. Therefore, elements in the laboratory database, such as sample collection time and volume, and quality control samples, are not available in the dataset that was extracted for this report.

After an inspection is officially closed, inspection reports and the exposure sample results contained within are publicly accessible records by request. In cases where reports contain private health information of employees, that information is redacted before reports are released.

Data Extraction Methods and Criteria

Exposure sample data were extracted from the L&I administrative database on June 27, 2017. The data were limited by inspection closing conference date, type of sample, and samples collected by compliance IH staff. Closing conference dates were between January 1st, 2008 and December 31st, 2016. The sample types included 15-minute short-term exposure limit (STEL) and 8-hour time-weighted average (TWA) worker exposure samples, also referred to as a personal breathing zone (PBZ) samples, and excluded all other sample types: area, bulk, biologic, and wipe.

Samples collected using real-time methods were included in the dataset. However, real-time samples that were determined to be collected for screening and not for worker exposure assessment purposes were later deleted.

Data Quality Assurance

Following the initial extraction of exposure data, several steps were taken to ensure the data were extracted correctly from the database. The first step involved the authors and a DOSH data specialist extracting multiple datasets independently for comparison. The independently extracted datasets were compared by the number of exposure samples and the number of inspections. The data extracts were confirmed to match.

Three certified industrial hygienists (CIH) then reviewed the dataset to evaluate individual exposure samples. Individual samples were reviewed for consistency and accuracy, among other characteristics. The review entailed identifying obvious and suspected errors in the dataset, and manually reviewing inspection reports and laboratory reported sample results so corrections and edits could be made.

To enable comparison between and within substances, units for all samples of the same substance were confirmed or recalculated to be consistent. For example, noise exposure sample results were entered by

CSHOs in both decibels and dose. To make the noise results consistent and comparable, all results were converted to units of decibels.

The dataset was also checked for accuracy of sample results and substance names, and corrected where needed. The reported sample averaging times in STEL or 8-hour TWA were also frequently in need of correcting after reviewing reports. Most errors encountered appeared to be the result of manual data entry errors.

Data Analysis

The majority of exposure sample data analysis included examining and comparing substance severities. The severity is defined as the ratio of the measured exposure to the substance PEL. The maximum severity for a substance indicates the highest measurement and indicates how much the measurement exceeded the PEL. For example, an 8-hour TWA exposure measurement of 1.5 ppm to formaldehyde with a PEL of 0.75 ppm would result in severity of 2.0. The median severity for a substance indicates the exposure measurement in the center of the distribution of all measurements; the measurement at which half of all exposures are below and half are above. If the median severity for a substance is 0.6 and there were a total of 30 samples collected, 15 of those exposures are equal to or greater than 60% of the substance PEL.

Another method of data analysis included calculating the 95th percentile ($X_{0.95}$) exposure for each substance. The 95th percentile is the point at which 95% of exposure measurements are included. The 95th percentile provides insight about the high end of the exposure distribution and is especially useful when assessing exposures to substances that cause acute health effects like hydrogen sulfide. For acute acting substances, high exposures are more important in terms of health risks than average exposures.

The 95th percentile exposures were also used to organize all substance 8-hour TWA and STEL measurements into AIHA exposure categories. AIHA's exposure categories provide a structure and assessment strategy that recommends comparing the 95th percentile exposure to OELs for SEGs and controlling the exposure distribution of each SEG so that the 95th percentile exposure is less than the OEL over time. The exposure data collected by DOSH do not originate from true SEGs but the AIHA exposure categories are a useful method to organize and prioritize substances.

RESULTS

Table 4 shows the total number of IH inspections during which samples were collected and the total number of samples collected in each L&I region (See Figure 2 for a map of the six L&I regions). In general, the number of IH compliance inspections where sampling was conducted and the number of samples collected have declined in most regions over the period. The exception is Region 2 where the number of inspections decreased by slightly less than 30% and the number of sample collected in the region remained fairly constant over the period.

Table 5 shows the distribution of samples by substance and year for those substances where 20 or greater total samples were collected. Substances like noise, dust, and lead with the highest number of samples are commonly found in several industries. The high number of noise samples is likely the result of at least two factors; it is ever-present at workplaces and the method for collecting noise samples uses an electronic logging device.

Table 6 shows the total number of IH inspections conducted and those inspections where samples were collected broken down by industry sector and L&I region. Note that the total number of inspections "With Samples" for each region matches the total number of inspections in Table 5. Industry sectors with the highest average percentage of inspections with samples were manufacturing (22%), arts, entertainment, and recreation (16%), other services (15%). A high number of inspections were conducted in construction but the percent with samples was relatively low at 6%. Region 2 conducted the highest number of total IH inspections and the highest number of inspections with samples. This is due to multiple factors, including Region 2 typically had double the number of CSHOs as other regions and is in King County, which has a high density of workplaces. Within Region 2, approximately 40% of all inspections were in the construction (26%) and manufacturing (15%) industry sectors, which likely reflects the industry profile in the region.

Table 7 shows the number of samples collected in each region broken down by industry sector. All regions collected the highest proportion of samples in the manufacturing sector. In Region 6, 63% of samples were collected in the manufacturing sector. Regions 2 and 3 collected a higher proportion of samples in the construction sector than other regions.

Table 8 shows the total number of inspections and inspections with samples broken down into industries sorted from high to low by number of inspections with samples. Within the five most sampled industry sectors, the five industries with the highest number of inspections with samples are listed. Industries where a high percentage of inspections included samples likely reflect sampling for hazardous substances common to the industry. For example, the majority of samples collected in the cut stone and stone product manufacturing industry were for silica and dust, which are commonly emitted from the stone cutting processes. The majority of samples collected in the metal service centers and other metal merchant wholesalers industry were for noise while the majority of samples collected in the wood kitchen cabinet and countertop manufacturing industry were for solvents.

Table 9 shows the distribution of samples across industries and years sorted from high to low by the total number of samples collected in each industry sector and industry. The number of samples collected decreased in most industries over the study period. The high number of samples collected in steel foundries in 2016 is the summation of 17 individual metals and gases sampled two or three times each and likely collected as part of a national emphasis program (NEP) on primary metals. Similarly, the 55 samples collected in the transportation and warehousing sector in 2015 were five solvents sampled ten times each during one inspection and a few other random samples.

Table 10 shows the number of samples collected for each substance where the maximum severity was greater than or equal to the substance PEL. The median severity is the halfway point in a sample distribution. For example, a median severity of 1.0 indicates that half of the samples collected were equal to or exceeded the PEL.

Table 11 shows substances with maximum severity greater than or equal to one-half of the PEL and less than the PEL. However, a severity below the PEL (<1.0) does not mean that the exposure level is safe, especially for carcinogens, highly toxic substances such as methyl bromide, or sensitizers such as TDI.

Table 12 shows all samples organized into categories of equal to or greater than half of the substance PEL and equal to or greater than the PEL. The number of samples in each category may not equal the total number of samples collected, as some samples may have been less than half of the PEL. This table is useful in identifying substances where a high percentage of samples exceeded half of the PEL or PEL. An example of this is nitrous oxide where 59% of the samples collected exceeded the PEL.

Table 13 classifies substances by AIHA categories based on the 95th percentile exposure concentration of each substances relative to the OEL for the substance. This categorical structure was originally published by AIHA to help IHs manage exposures among SEGs[1,6]. The 95th percentile exposure is that in which 95% of the measurements are included and represents a high-end exposure. AIHA's exposure assessment strategy recommends that the exposure distribution of each SEG should be controlled so that the 95th percentile exposure is less than the OEL over time.

A limitation of using the AIHA categories is that these samples were not collected from homogenously exposed SEGs of workers as was specified in the guidelines when AIHA developed the categories. Another limitation is the policy of worst-case scenario sampling by CSHOs likely results in high measurements and may overestimate the true 95th percentile exposure. Alternately, there is a possibility that low measurements are not entered and therefore missing from the exposure distributions.

Despite the limitations, the exposure categories provide a useful construct for organizing and communicating the exposure data. The substances in category 5 range from 6 to 1382 exposure measurements, with a median of 54 measurements per substance. This indicates that for many substances in category 5, the 95th percentile exposure is not based on just one or a few high exposures.

Table 14 describes typical actions or controls recommended by AIHA for each exposure category[6]. For example, exposures that are in category 5 are in need of immediate engineering controls, assessment of effectiveness of respiratory protection, and possible process shut-down pending the outcome of an assessment.

Table 15 uses the American Conference of Governmental Industrial Hygienists (ACGIH)[7] carcinogen categories and substance-specific health effects basis to organize the substances in category 5 of Table 13.

Table 16 shows the number of samples for substances with high maximum severity and the industries where those samples were collected. The maximum severity is for only one sample within each substance and industry combination. For example, one sample for respirable quartz silica was measured at 130 times the PEL. Industries where high exposures were measured can easily be identified by substance.

Table 17 shows the substances with highest severity measurements and the job titles for workers from whom samples were collected. Job titles such as abrasive blaster and metal fabricator are associated with high severity exposures for multiple substances. The combination of high number of samples and high median severity indicate worker job titles that are likely consistently overexposed to the particular substance. The job title of spray painter is an example where half of the 51 exposure samples collected for HDI were at or above a severity of 1.0.

Table 18 shows all noise exposure samples and the industry in which they were collected. The largest number of noise samples was collected in manufacturing where the maximum and median exposure severities were relatively high.

Table 19 shows noise exposures where the maximum severity was equal to or greater than 2.0 (twice the PEL) for different job titles sorted from high to low by maximum severity. This table demonstrates that elevated noise exposures are ubiquitous across many job titles. Workers exposed to noise in excess of regulatory exposure limits should be enrolled in a hearing conservation program.

Table 20 shows results for respirable crystalline silica samples where the maximum exposure severity was equal to or greater than 1.0 for the industry sectors. Job titles where maximum severity was equal to or greater than 0.1 are listed within each industry sector. Breathing in crystalline silica can cause incurable lung diseases such as silicosis and lung cancer. Employers in these industries should adopt appropriate exposure controls and implement work practices to help reduce exposures to silica. Workers in the positions listed in this table should be assessed for the need for respiratory protection and medical surveillance.

Table 21 shows results for all hexavalent chromium samples within industry sectors according to job titles. Approximately half of the job titles listed were associated with exposure severities in excess of the PEL. Breathing in hexavalent chromium can cause lung, nasal, and sinus cancer. Contact with the skin can cause allergic dermatitis and ulcers. Employers in these industries should adopt appropriate exposure controls and implement work practices to help reduce exposures to hexavalent chromium. Workers in the positions listed in this table should be assessed for the need for respiratory and dermal protection.

Table 22 shows results for samples of total dust where maximum exposure severity is equal to or greater than 1.0 for industry sectors. Job titles where maximum severity was equal to or greater than 1.0 are

listed within each industry sector. Breathing in dust can cause respiratory tract irritation and several respiratory diseases. Employers in these industries should adopt appropriate exposure control devices and implement work practices to help reduce exposures to dust. Workers in the positions listed in this table should be assessed for the need for respiratory protection.

Table 23 shows results for lead exposures where maximum exposure severity is equal to or greater than 0.5 for industry sectors. Job titles where exposure severity is equal to or greater than 0.5 are listed within each industry sector. Breathing in lead can cause lead poisoning and serious health effects. Employers in these industries should adopt appropriate exposure controls and implement work practices to help reduce exposures to lead. Workers in the positions listed in this table should be trained on the hazards of lead, assessed for the need for respiratory and dermal protection, and the need for medical monitoring of blood lead levels.

Table 24 shows results for methylene chloride samples where maximum exposure severity is equal to or greater than 0.5 for industries. Breathing in methylene chloride can cause chemical intoxication and death. Workers who feel effects such as confusion, lightheadedness, nausea, or headache should seek fresh air immediately. Methylene chloride can also burn the skin on contact and is a probable human carcinogen. Employers in these industries should strongly consider switching to non-methylene chloride containing substances or using effective exposure controls and implementing exposure-reducing work practices. Workers should be assessed for the need for respiratory and dermal protection.

Table 25 shows results for nitrous oxide samples where maximum exposure severity is equal to or greater than 0.5 for industries. Breathing in nitrous oxide can cause lightheadedness, headache, nausea, and vomiting. In cases of higher exposure, oxygen supply to the brain is interrupted and death can occur. Employers such as those in the dental industry, should install nitrous oxide gas scavenging systems to collect waste gas and implement work practices to limit worker exposures.

Table 26 shows results for carbon monoxide (CO) samples where maximum exposure severity is equal to or greater than 0.5 for industries. CO, when breathed in, causes effects similar to methylene chloride and nitrous oxide and has resulted in many worker deaths. A primary difference between carbon monoxide and other chemicals is that carbon monoxide has no odor and is therefore non-detectable by humans. Employers should fit forklifts and other CO emitting machines with catalytic converters to control CO. Employers should consider substituting electrical equipment for CO emitting gas powered

equipment. Employers should also provide fresh air via building general ventilation to control CO at safe levels and install continuous monitors with alarms to measure CO levels and warn workers if safe levels are exceeded.

Table 27 shows results for all isocyanate exposures according to job titles. The majority of isocyanate samples were collected from spray painters and spray foam applicators. Among spray painters, nearly half of the 68 samples collected exceeded the PEL. In some sampling instances, the job title of painter indicated the task was done using a roller or brush. Others lacked this detail making it impossible to know if a painter was actually spray painting or painting with a brush or roller, leading to possible misclassification. This is notable because the maximum and median severity of exposures among workers described as painters was higher than expected.

Table 28 shows results for isocyanate samples where maximum exposure severity is equal to or greater than 0.5 for industry sectors. Within each industry sector, the individual isocyanate substances and job titles are listed along with their maximum exposure severities. Isocyanates are respiratory and dermal sensitizers and known to cause work-related asthma and other respiratory diseases. The maximum severity level of 0.5 is the level considered by industrial hygienists to be in need of exposure control and reduction. Because isocyanates are potent sensitizers, the level at which control and reduction is needed should be lower than 0.5.

Table 29 shows the maximum severities for all confirmed human carcinogens, suspected human carcinogens and confirmed animal carcinogens. Personal exposure to any level of carcinogen is considered to increase the risk of cancer. All substances in this table should be targeted for exposure control.

Table 30 shows the maximum severities for all confirmed human carcinogens, suspected human carcinogens and confirmed animal carcinogens that have skin designations. In this context, the skin designation means that the substance has the potential for significant contribution to the overall exposure by the cutaneous route.

Table 31 shows the maximum severities for all confirmed and suspected human carcinogens and the task descriptions associated with the maximum severity exposures.

DISCUSSION

This report and the exposure database tool are intended for a variety of users. CSHOs can use them to review and anticipate common and hazardous exposures in industries in which they will conduct inspections. They can also be used by CSHOs as references for sampling methods and health effects associated with the substance they will sample. Regional managers can review the trends in sampling in industries in their region, and to help advise CSHOs in the area of sampling determination and strategy. Statewide managers can use sampling data to investigate if distributions of the type and number of samples are representative of the type of exposures occurring in industries throughout the state and to develop policies and strategies to prevent exposures to address newly identified, highly toxic, and carcinogenic substances.

The database tool was designed to be simple and logical for CSHOs and other users to navigate. It has capacity to quickly display high-level summary data or drill down to individual exposure measurements starting from lists of industry sectors or substance types.

The tool was also developed to serve as a test of the viability of establishing a more timely ongoing surveillance system to monitor and communicate exposure trends and to potentially identify new and emerging hazards to workers. The system has the potential to be updated regularly, as sample results are available for extract from the database immediately after being entered by CSHOs. A potential lag in time between entry of exposure data and use in the database tool may result due to potential errors needing manual correction, as encountered in the original data extract. It is likely that the exposure database tool could be updated on an annual basis.

There are several limitations to the interpretation of these exposure sampling results. One is that samples were not collected as part of a designed study. Common study designs are those where exposures are compared between well-controlled and poorly controlled environments, or before and after the implementation of exposure control measures. In contrast, the majority of samples in this report were collected in response to complaints or referrals about workplace exposures or where obvious over exposures were observed. Furthermore, most samples were collected during single visits to worksites, which provides only a snapshot of exposures at any site and time. Another limitation is that, due to the intended use of sampling results in enforcing PELs, CSHOs do not have a strong incentive to enter samples where the results are reported as lower than the PEL or BLD

(essentially zero). Lastly, unlike occupational injury data where injury rates are estimated using the number of injury cases among populations at risk, IH exposure samples do not have a common basis for broad comparison to allow them to be easily presented as rates.

Observed decreases in the number of samples collected and entered annually by CSHOs may be the result of several factors. One factor is that industries and workplaces may have adopted exposure control methods and work practices that are known to industrial hygienists to reduce worker exposures and thus decrease the need for exposure sampling. Another is the increased use of real-time screening tools by CSHOs may be contributing to the observed decline in the number of IH exposure samples collected.

RECOMMENDATIONS

The following recommendations are based on thorough review of the administrative database used to manage and store DOSH IH exposure data, related data systems, IH inspection reports, and the work experience and professional judgement of the authors.

The authors recommend that DOSH closely monitor the amount and type of worker exposure sampling being conducted and consider developing a multi-approach exposure sampling plan. The plan should:

- Promote exposure sampling and allow CSHOs the time necessary to do so. OSHA's enforcement weighting system (EWS) implemented in 2016[5] provides an example. OSHA's system accounts for the varying amounts of time and resources required by different types of safety and health enforcement activities by assigning enforcement unit (EU) values to specific categories of inspections / investigations. For example, all inspections count as EU, personal sampling inspections count as two EUs, and exposure hazard inspections count as three EUs.
- Expand or maintain a level of sampling representative of the size of particular industries or workplaces in which overexposures have been documented.
- Anticipate and identify where exposures to toxic substances that have not been assessed or measured may be occurring in Washington, and develop emphasis programs to characterize those exposures.
- Rank acute and chronic substances by toxicity and develop and promote substance specific strategies based on rankings for workplaces in an effort to reduce exposures.

- Consider developing exposure assessment strategies for unregulated substances that have high toxicity.
- Emphasize and allow time for CSHOs to do follow-up assessments in instances of overexposures that are extreme in magnitude or to toxic substances. Follow-up assessments will allow CSHOs to assess whether employers have implemented necessary exposure controls and may not necessarily require exposure sampling. Among all IH compliance inspections in the period, there were 454 (~5% of the total) designated as 'follow-up' inspections. CSHOs may conduct follow-up inspections when they have difficulty certifying proper abatement by employers. Eighteen of the 454 follow-up inspections had sample results entered. Seven of the eighteen samples collected on follow-up inspections exceeded the substance PEL.
- Actively review IH inspections where exposure samples were collected and aggregate statewide data for systematic review.

The authors also recommend that to protect worker health, DOSH address outdated PELs and substances without PELs. The majority of the approximately 500 substance PELs have not been updated in Washington since their adoption in 1992. Since then, much new information has been generated about health effects of substances at exposure levels lower than current PELs. To achieve this, DOSH could:

- Develop and implement a strategy to address updating PELs, starting with the highest severity substances identified and other key information.
- Engage in rulemaking to update existing or adopt PELs for substances without PELs.
- Adopt the OSHA Annotated Table Z-1 that includes recommended and consensus OELs for substances established by Cal/OSHA, NIOSH, and ACGIH.
- Promote the voluntary adoption of lower OELs by industries and workplaces and provide guidance on the methods of control and attainment.

The training team is responsible for the internal training of CSHOs.

The training team should:

- Emphasize the importance of IH exposure assessment sampling in protecting workers. In addition to shifts in resources, the observed decline in sample frequency may also be contributed to a decrease in the emphasis of the importance of exposure sampling to CSHOs.
- Make efforts to provide refresher training and training on new and modified IH sampling tools and techniques. IH sample collection is extremely technical and the skills required to do so warrant refresher training. As new exposure sampling methods are developed and validated and existing methods modified, all IH CSHOs should be trained on the methods in a timely manner.
- Create an instructional and reference document for CSHOs to use for entry of IH exposure substance information into the administrative database. This will help reduce the number of inconsistencies and errors especially among substance units, sample averaging times, and appropriate PELs/STELs.
- Emphasize the importance of accurately describing the job description and task of workers being sampled that best describes the nature of the work they do and the source and determinants of the exposure. This is important even when exposures are low or negative and especially valuable for future users of these data.

DOSH Regional Managers are responsible for overseeing compliance operations for S&H inspections in a defined regional area in the state.

DOSH Regional Managers should:

- Create written policies and procedures to ensure complete and consistent entry of exposure sample data into the administrative database. Policies should include entry of all sample results, including those below LODs and below regulatory levels. Policies may include exceptions such as the omission of results from a multi-substance sample, a metals screen for example, where only one or a few are target substances.
- Direct CSHOs to identify screening measurement results as separate from actual compliance sample results entered into the administrative database. This needs to be coordinated with the addition of a flag or other data element that can be used by CSHOs to indicate it as a screening sample.
- Consider allowing extra time between inspection opening and closing dates for inspections involving IH exposure sampling. IH sampling often requires CSHOs to make an additional visit to

the workplace to conduct sampling. CSHOs also need extra time to coordinate sampling equipment, sample shipment, and to interpret and enter sample information.

- Consider requiring CSHOs to document written determination to or not to collect exposure samples and enter their determination into inspection reports.
- Direct CSHOs to consistently enter noise exposures in units of dbA when reporting. The PEL is expressed in dbA. A separate variable can be created in the administrative database to auto calculate noise dose based on the exposure level. This will reduce inconsistencies and errors in the entry and review of noise exposures.

CSHOs are responsible for assessing workplace compliance with established S&H rules.

CSHOs should:

- Use all available reference materials and review historical exposure sampling data prior to sample collection and entry of sample data to ensure consistency and accuracy in data.
- Enter all exposure sample results into the administrative database including those lower than regulatory limits and the LODs.
- Document written determination to or not to collect exposure samples and enter the determination into inspection reports.
- Communicate unexpected, unique, toxic, or extreme overexposures to employers as soon as possible. CSHOs should also relate this information to supervisors and other CSHOs in a timely manner.
- Document exposure sample method information in the inspection report. This information should contain sufficient detail to allow the sample collection to be easily understood and reproduced by other CSHOs. In addition to substance name and results, where applicable, CSHOs should document essential sampling parameters such as the number of individual samples collected, the sampling time, flow rate, and volume of air collected for each sample.
- Document exposure sample modifying information in the inspection report. This information can allow other CSHOs to understand the unique determinants of the exposure. Information to be considered for documentation should include if the worker sampled represented the high, low, or average exposure for a group of workers; if the exposure was the result of a single continuous task or source or one of a few among many; if the exposure was the result of factors,

such as work practices, that could easily be modified to reduce the magnitude or duration of exposure; and any other ideas the CSHO may have that would help characterize the exposure.

The L&I IH laboratory is responsible for analyzing and reporting IH sample results and calibrating IH equipment.

The IH lab should:

- Report sample results to CSHOs in the same units as the substance PELs.
- Remove duplicates of substance names and substances such as those with 'SKIN' designation that have no regulatory limits or are no longer relevant from list of substances.
- Aggregate substances that share the same CAS# that are currently listed separately with multiple substance names.
- Create and assign identification numbers common to lab samples and sample results reported to CSHO in order to link samples between the separate databases used by the lab and CSHOs. The identification numbers should be able link samples collected on single and multiple filters or tubes that represent full-shift exposures.
- Restrict the choices of substances available to CSHOs during sample data entry to only those substances included in a specific method.

DOSH Supervisors oversee teams of IH CSHOs.

Supervisors should:

- Ensure that CSHOs enter all sample data according to DOSH policies.
- Ensure that all IH sample data information including units, PELs, STELs and other relevant information is entered accurately.
- Review CSHO justification for IH sampling or non-sampling, especially in instances of complaints and referrals for overexposures and industries and workplaces with known high exposures.

The IT team is responsible for maintaining the administrative database and data entry system used by CSHOs.

The IT team should implement several quality assurance improvements including:

- Remove data entry options from the system that are no longer relevant.
- Consult with current IH staff regarding reviewing and updating the data entry system.
- Ensure data elements such as substance codes and associated descriptions auto populate in the data entry system where possible.
- Configure the data entry system so that each substances corresponds with the correct substance-specific PEL or STEL level and units.
- Add options for CSHOs to enter following sampling parameters:
    - The flow rate, duration, and volume for single and composite samples.
    - The standard analytic error (SAE).
    - A below limit of detection (BLD) indicator.
    - A screening indicator to document if screening was done.
    - A code for noise dosage.

TABLES

IH Inspections and Samples by Year, L&I Region, and Industry

Table 4. IH Inspections with Samples by L&I Region[1] and Year[2]

L&I Region		2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Region 1	Inspections	14	34	34	29	13	9	12	11	7	**163**
	Samples	100	142	156	77	65	23	62	92	22	**739**
Region 2	Inspections	45	28	32	27	34	33	22	25	32	**278**
	Samples	185	148	136	85	128	144	121	111	160	**1218**
Region 3	Inspections	24	52	14	11	12	12	14	6	10	**155**
	Samples	184	335	63	61	50	68	67	28	51	**907**
Region 4	Inspections	18	11	8	13	10	10	5	6	4	**85**
	Samples	73	62	36	75	51	25	16	11	9	**358**
Region 5	Inspections	14	9	10	8	4	9	19	16	10	**99**
	Samples	71	65	44	38	22	47	62	65	11	**425**
Region 6	Inspections	18	16	14	17	13	11	4	7	10	**110**
	Samples	122	92	89	131	95	107	25	50	36	**747**

1. See Figure 2 for map of the six L&I geographic regions.
2. Calendar year of inspection closing conference date.

Table 5. Substances[1] with Equal to or Exceeding 20 Total Samples by Year[2]

Substance	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Noise, continuous or intermittent	230	280	177	150	143	95	126	105	75	**1381**
Particulates not otherwise regulated (total dust)	46	30	40	25	38	18	18	7	18	**240**
Lead, inorganic fumes & dusts (as Pb)	42	17	33	22	12	21	15	20	6	**188**
Silica crystalline quartz (respirable fraction)	28	54	18	21	7	10	4	7	11	**160**
Particulates not otherwise regulated (resp. dust)	14	40	23	28	9	19	7	12	7	**159**
Carbon monoxide (CO)	21	13	12	30	3	27	16	4	14	**140**
Acetone	20	29	11	2	4	9	12	14	7	**108**
Chromium (vi) (hexavalent chromium)	11	12	13	13	9	20	11	5	8	**102**
Xylene (o-m-,and p-isomers)	24	31	11	1	6	5	7	10	5	**100**
Welding fumes (total particulate)	9	24	6	10	7	14	9	7	10	**96**
Petroleum distillates (naphtha, rubber solvent)	17	25	7	2	6	3	8	18	6	**92**
Toluene	21	21	10	1	1	1	8	11	5	**79**
Silica,crystalline cristobalite (respirable fraction)	9	32	9	15	1	6	2		5	**79**
Formaldehyde	14	7	5	2	17	1	11	11	10	**78**
Iron oxide fume	8	11	16	7	8	15	2		8	**75**
Ethyl benzene	18	23	6		6	3	7	7	1	**71**
N-butyl acetate	15	27	9		2	1	3	3	4	**64**
Hexamethylene diisocyanate (HDI)	13	4	11	17	2	5	3	1	2	**58**
Methylene bisphenyl isocyanate (MDI)	2	8	9	4	4	5	12	8	3	**55**
Manganese fume (as Mn)	1	5	6	3	11	12	4	1	10	**53**
Methylene chloride (dichloromethane)	8		8	7	8	11		3	2	**47**
Nitrous oxide			3	23	12	2		1	5	**46**
2-butanone (MEK)	10	25	1	2		1			3	**42**
Styrene (phenylethylene)	8	10	1	1	4	2	8	6	1	**41**
Octane	4	6	1			1	3	19	4	**38**
Wood dust, all soft/hard woods, except w.red cedar	4	18	2	1	5					30
Arsenic & inorganic compounds	12	4			6	5		1	1	29
Aluminum (as al), welding fumes	5	5	5	1	2	1	3		6	28
Hexone (MIBK)	10	6	4		5		1	2		28
Ozone	7	8	1	1	1		7	1		26
Nickel, metal & insoluble compounds (as Ni)		1	1	1	9	7			3	22
Chromium, metal & insoluble salts (as Cr)	3	1	1	2	6	6			3	22
Copper dusts & mists (as Cu)			3	2	7	4			4	20
Heptane			1				5	13	1	20
Substances with less than 20 total samples (99)	101	67	60	73	50	84	41	60	41	577
Total	**735**	**844**	**524**	**467**	**411**	**414**	**353**	**357**	**289**	**4394**

1. Number of samples for all substances is available in internal database.
2. Calendar year of inspection closing conference date.

Table 6. Total IH Inspections and Inspections with Samples by Industry[1] Sector and L&I Region[2]

Industry Sector	Region 1 Inspections		Region 2 Inspections		Region 3 Inspections		Region 4 Inspections		Region 5 Inspections		Region 6 Inspections	
	Total	With Samples	Total	With Samples	Total	With Samples	Total	With Samples	Total	With Samples	Total	With Samples
Accommodation and Food Services (NAICS 62)	155	1	98	4	140	3	224	2	86	2	57	2
Administrative and Support and Waste Management and Remediation Services (NAICS 56)	137	10	420	17	120	16	180	1	71	3	74	7
Agriculture, Forestry, Fishing and Hunting (NAICS 11)	41	4	14		43	2	85	4	354	13	32	3
Arts, Entertainment, and Recreation (NAICS 71)	25	4	28	8	19	3	27	2	15	1	10	2
Construction (NAICS 23)	224	17	786	42	267	24	232	2	155	10	117	7
Educational Services (NAICS 61)	3	2	53	4	37	2	25	1	15	1	19	2
Finance and Insurance (NAICS 52)	5		11	1	3		7		2		3	
Health Care and Social Assistance (NAICS 62)	112	12	193	12	166	2	132	2	91	6	109	5
Information (NAICS 51)	4		12	2	4		15	2	4		2	1
Management of Companies and Enterprises (NAICS 55)							1					
Manufacturing (NAICS 31-33)	279	72	446	88	232	65	319	38	176	29	143	46
Mining, Quarrying, and Oil and Gas Extraction (NAICS 21)	7				1		4		1			
Other Services (except Public Administration) (NAICS 81)	74	20	194	37	128	13	157	11	59	9	56	7
Professional, Scientific, and Technical Services (NAICS 54)	48	1	99	4	32	1	37	2	17		19	2
Public Administration (NAICS 92)	22	3	55	3	65	2	67	2	60	2	27	2
Real Estate and Rental and Leasing (NAICS 53)	45		115	4	53	2	66	1	30	1	17	
Retail Trade (NAICS 44-45)	107	6	199	16	138	8	117	6	78	9	68	8
Transportation and Warehousing (NAICS 48-49)	28	5	104	7	31	5	30	1	48		19	
Utilities (NAICS 22)	3		16		3		9		14	2	1	
Wholesale Trade (NAICS 42)	57	6	185	29	42	7	89	8	79	11	62	16
Total	**1376**	**163**	**3028**	**278**	**1524**	**155**	**1823**	**85**	**1355**	**99**	**835**	**110**

1. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
2. See Figure 2 for map of the six L&I geographic regions.

Table 7. Samples by Industry[1] Sector and L&I Region[2]

Industry Sector	Region 1		Region 2		Region 3		Region 4		Region 5		Region 6		Total	
Manufacturing **(NAICS 31-33)**	372	50%	452	37%	376	41%	184	51%	180	42%	468	63%	**2032**	**46%**
Construction **(NAICS 23)**	62	8%	227	19%	238	26%	33	9%	41	10%	22	3%	**623**	**14%**
Wholesale Trade **(NAICS 42)**	23	3%	109	9%	55	6%	34	9%	48	11%	116	16%	**385**	**9%**
Other Services (except Public Administration) **(NAICS 81)**	79	11%	122	10%	74	8%	31	9%	41	10%	33	4%	**380**	**9%**
Retail Trade **(NAICS 44-45)**	24	3%	74	6%	42	5%	15	4%	22	5%	52	7%	**229**	**5%**
Administrative and Support and Waste Management and Remediation Services **(NAICS 56)**	30	4%	59	5%	52	6%	1	0%	18	4%	16	2%	**176**	**4%**
Transportation and Warehousing **(NAICS 48-49)**	64	9%	23	2%	19	2%	2	1%					**108**	**2%**
Health Care and Social Assistance **(NAICS 62)**	32	4%	23	2%	5	1%	6	2%	18	4%	6	1%	**90**	**2%**
Agriculture, Forestry, Fishing and Hunting **(NAICS 11)**	15	2%			3	0%	9	3%	35	8%	3	0%	**65**	**1%**
Public Administration **(NAICS 92)**	13	2%	29	2%	11	1%	2	1%	3	1%	4	1%	**62**	**1%**
Arts, Entertainment, and Recreation **(NAICS 71)**	16	2%	25	2%	8	1%	6	2%	1	0%	4	1%	**60**	**1%**
Professional, Scientific, and Technical Services **(NAICS 54)**	6	1%	21	2%	1	0%	10	3%			5	1%	**43**	**1%**
Accommodation and Food Services **(NAICS 62)**	1	0%	13	1%	8	1%	11	3%	2	0%	7	1%	**42**	**1%**
Educational Services **(NAICS 61)**	2	0%	16	1%	9	1%	2	1%	8	2%	2	0%	**39**	**1%**
Real Estate and Rental and Leasing **(NAICS 53)**			18	1%	6	1%	3	1%	6	1%			**33**	**1%**
Information **(NAICS 51)**			5	0%			9	3%			9	1%	**23**	**1%**
Utilities **(NAICS 22)**									2	0%			**2**	**0%**
Finance and Insurance **(NAICS 52)**			2	0%									**2**	**0%**
Total	**739**		**1218**		**907**		**358**		**425**		**747**		**4394**	

1. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
2. See Figure 2 for map of the six L&I geographic regions.

Table 8. IH Inspections in Industry[1] Sectors and Industries

Industry Sector Industry	Total IH Inspections	Inspections with Samples
Manufacturing (NAICS 31-33)	**1595**	**338 (21%)**
Boat building	49	18 (37%)
Cut stone and stone product manufacturing	36	17 (47%)
Machine shops	47	13 (28%)
Wood kitchen cabinet and countertop manufacturing	30	13 (43%)
All other miscellaneous fabricated metal product manufacturing	30	10 (33%)
Other Industries in Manufacturing Sector (139)	1403	267 (19%)
Construction (NAICS 23)	**1782**	**102 (6%)**
Painting and wall covering contractors	202	13 (6%)
All other specialty trade contractors	140	12 (9%)
Framing contractors	94	10 (11%)
Masonry contractors	40	9 (23%)
New single-family housing construction (except operative builders)	198	7 (4%)
Other Industries in Construction Sector (18)	1108	58 (5%)
Other Services (except Public Administration) (NAICS 81)	**668**	**97 (15%)**
Automotive body, paint, and interior repair and maintenance	155	33 (21%)
Commercial and industrial machinery and equipment repair and maintenance	55	7 (13%)
General automotive repair	81	7 (9%)
Drycleaning and laundry services (except coin-operated)	34	7 (21%)
Other personal and household goods repair and maintenance	40	6 (15%)
Other Industries in Other Services Sector (15)	303	37 (12%)
Wholesale Trade (NAICS 42)	**514**	**77 (15%)**
Recyclable material merchant wholesalers	76	17 (22%)
Metal service centers and other metal merchant wholesalers	15	6 (40%)
Fresh fruit and vegetable merchant wholesalers	38	5 (13%)
Industrial machinery and equipment merchant wholesalers	27	5 (19%)
Farm supplies merchant wholesalers	41	3 (7%)
Other Industries in Wholesale Trade Sector (27)	317	41 (13%)
Administrative and Support and Waste Management and Remediation Services (NAICS 56)	**1002**	**54 (5%)**
Landscaping services	104	25 (24%)
Janitorial services	119	8 (7%)
Solid waste collection	29	4 (14%)
Temporary help services	80	3 (4%)
Carpet and upholstery cleaning services	24	2 (8%)
Other Industries in Admin. and Supp. and Waste Mgmt. and Rem. Srvs. Sector (11)	646	12 (2%)
Retail Trade (NAICS 44-45)	**707**	**53 (7%)**
Health Care and Social Assistance (NAICS 62)	**804**	**39 (5%)**
Agriculture, Forestry, Fishing and Hunting (NAICS 11)	**569**	**26 (5%)**
Arts, Entertainment, and Recreation (NAICS 71)	**124**	**20 (16%)**
Transportation and Warehousing (NAICS 48-49)	**260**	**18 (7%)**
Public Administration (NAICS 92)	**296**	**14 (5%)**
Accommodation and Food Services (NAICS 62)	**760**	**14 (2%)**
Educational Services (NAICS 61)	**152**	**12 (8%)**
Professional, Scientific, and Technical Services (NAICS 54)	**252**	**10 (4%)**
Real Estate and Rental and Leasing (NAICS 53)	**326**	**8 (2%)**
Information (NAICS 51)	**41**	**5 (12%)**
Utilities (NAICS 22)	**46**	**2 (4%)**
Finance and Insurance (NAICS 52)	**31**	**1 (3%)**
Mining, Quarrying, and Oil and Gas Extraction (NAICS 21)	**13**	
Management of Companies and Enterprises (NAICS 55)	**1**	
Total	**9943**	**890 (9%)**

1. Industries categorized according to North American Industrial Classification System (NAICS version 2007).

Table 9. Samples in Top 5 Industry[1] Sectors and Industries by Year[2]

Industry Sector Industry	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Manufacturing (NAICS 31-33)	**333**	**352**	**252**	**247**	**215**	**181**	**135**	**162**	**155**	**2032**
Boat building	22	41		8	11		13	49	8	152
Sheet metal work manufacturing	18	24			30	63				135
Wood kitchen cabinet and countertop manufacturing	36	49	14		5	4		10	6	124
Cut stone and stone product manufacturing	46	38	17	9				5		115
Steel foundries (except investment)		13	19			1	16		47	96
Other Manufacturing industries (139)	211	187	202	230	169	113	106	98	94	1410
Construction (NAICS 23)	**101**	**222**	**56**	**55**	**56**	**21**	**71**	**26**	**15**	**623**
Framing contractors	56	5	4	6	2		17			90
Other building finishing contractors		85								85
Painting and wall covering contractors	10	12	11		33	1	17		1	85
All other specialty trade contractors	11	25			4	11	2	6	1	60
Tile and terrazzo and tile contractors	2	34	5				14			55
Other Construction industries (18)	22	61	36	49	17	9	21	20	13	248
Wholesale Trade (NAICS 42)	**55**	**69**	**29**	**35**	**34**	**95**	**12**	**37**	**19**	**385**
Recyclable material merchant wholesalers	21	26	5		1	32	3	11	4	103
Metal service centers and other metal merchant wholesalers	16		7			11	4			38
Industrial machinery and equipment merchant wholesalers	7	16			4	9				36
Fresh fruit and vegetable merchant wholesalers			3			17	1	9	1	31
Sporting and rec. goods and supplies merchant wholesalers						20				20
Other Wholesale Trade industries (27)	11	27	14	35	29	6	4	17	14	157
Other Services (except Public Admin.) (NAICS 81)	**108**	**64**	**76**	**46**	**14**	**9**	**22**	**19**	**22**	**380**
Automotive body, paint, and interior repair and maintenance	47	39	41	12		4	6	2	2	153
Commercial and industrial machinery and equipment	26	4	2			2				34
General automotive repair	4		13				9		3	29
Other personal and household goods repair and maintenance		4	5		7		4	3		23
Cemeteries and crematories		7	5	9						21
Car washes	13	4			2			2		21
Other Services industries (14)	18	6	10	25	5	3	3	12	17	99
Retail Trade (NAICS 44-45)	**51**	**67**	**43**	**13**	**8**	**17**	**10**	**7**	**13**	**229**
Other building material dealers	8	43	12						6	69
Sporting goods stores	6	5	14			8	2			35
New car dealers	7	5		7		1			6	26
Automotive parts and accessories stores			12			1		4		17
Paint and wallpaper stores	6	4						2		12
Other Retail Trade industries (16)	24	10	5	6	8	7	8	1	1	70
Administrative and Support and Waste Management and Remediation Services (NAICS 56)	**6**	**36**	**19**	**15**	**29**	**14**	**19**	**8**	**30**	**176**
Transportation and Warehousing (NAICS 48-49)	**10**		**3**	**4**	**11**	**9**	**14**	**55**	**2**	**108**
Health Care and Social Assistance (NAICS 62)	**12**	**6**	**6**	**25**	**12**	**8**	**9**	**2**	**10**	**90**
Agric., Forestry, Fishing and Hunting (NAICS 11)	**27**	**12**	**2**		**1**	**3**	**11**	**7**	**2**	**65**
Public Administration (NAICS 92)		**2**	**12**			**13**	**21**	**3**	**11**	**62**
Arts, Entertainment, and Recreation (NAICS 71)	**8**	**2**	**9**	**3**	**11**	**3**	**7**	**15**	**2**	**60**
Professional, Scientific, and Tech. Svcs. (NAICS 54)	**12**		**1**	**3**	**14**	**13**				**43**
Accommodation and Food Services (NAICS 72)		**5**	**2**	**5**	**1**	**1**	**17**	**4**	**7**	**42**
Educational Services (NAICS 61)		**2**	**6**	**13**	**2**	**9**	**5**	**1**	**1**	**39**
Real Estate and Rental and Leasing (NAICS 53)	**3**	**4**		**3**		**13**		**10**		**33**
Information (NAICS 51)	**9**	**1**	**8**		**1**	**4**				**23**
Utilities (NAICS 22)						**1**		**1**		**2**
Finance and Insurance (NAICS 52)					**2**					**2**
Total	**735**	**844**	**524**	**467**	**411**	**414**	**353**	**357**	**289**	**4394**

1. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
2. Calendar year of inspection closing conference date.

Substances by Exposure Severity

Table 10. Substances with Max. Severity[1] Equal to or Exceeding PEL[2]

Substance	Samples	Maximum Severity	Median Severity
Silica crystalline quartz (respirable fraction)	160	130	1.6
Noise, continuous or intermittent	1381	100.4	1.0
Particulates not otherwise regulated (total dust)	240	90.5	0.2
Nitrous oxide	46	80.0	2.5
Chromium (VI) (hexavalent chromium)	102	51.3	0.3
Hexamethylene diisocyanate (HDI)	58	21.9	1.0
Particulates not otherwise regulated (resp. dust)	159	15.6	0.2
Iron oxide fume	75	13.1	0.2
Methylene bisphenyl isocyanate (MDI)	55	12.2	0.3
Lead, inorganic fumes & dusts (as Pb)	188	10.0	0.2
Isophorone diisocyanate	13	8.7	1.6
Welding fumes (total particulate)	96	8.4	0.5
Manganese fume (as Mn)	53	5.6	0.4
Methyl methacrylate	14	4.6	0.02
Silica,crystalline cristobalite (respirable fraction)	79	4.4	1.0
Petroleum distillates (naphtha, rubber solvent)	92	4.3	0.08
Ozone	26	3.9	0.3
Formaldehyde	78	3.9	0.1
Perchloroethylene (tetrachloroethylene)	6	3.7	0.4
Styrene (phenylethylene)	41	3.6	0.2
Hexane	19	3.5	0.03
Methylene chloride (dichloromethane)	47	3.4	0.3
Toluene	79	2.8	0.04
Wood dust, western red cedar	6	2.6	1.4
2-butanone (MEK)	42	2.5	0.2
Cadmium dust (as Cd)	13	2.0	0.1
Ammonia (NH_3)	6	1.8	0.3
Xylene (o-m-,and p-isomers)	100	1.7	0.02
N-butyl alcohol	6	1.7	0.08
Wood dust, all soft/hard woods, except w.red cedar	30	1.5	0.2
Talc (containing no asbestos)	1	1.5	-
Aluminum(as Al), metal (total dust)	6	1.4	0.03
Aluminum (as Al), welding fumes	28	1.3	0.2
Cyclohexanone	1	1.1	-
Arsenic & inorganic compounds	29	1.0	0.06
N-butyl acetate	64	1.0	0.02

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Permissible exposure limit.

Table 11. Substances with Max. Severity[1] Equal to or Exceeding One-half PEL[1] and Less than PEL

Substance	Samples	Maximum Severity	Median Severity
Carbon monoxide (CO)	140	0.9	0.1
Isopropyl acetate	13	0.8	0.2
Carbon dioxide (CO_2)	7	0.8	0.3
Copper dusts & mists (as Cu)	20	0.8	0.01
2-butoxyethanol	9	0.8	0.1
Wood dust, softwood	4	0.8	0.4
Wood dust, hardwood (nonallergenic)	10	0.7	0.2
Toluene-2,4-diisocyanate (TDI)	8	0.7	0.4
Methyl (n-amyl) ketone (2-heptanone)	10	0.7	0.07
Hexone (MIBK)	28	0.7	0.03
Copper fume (as Cu)	9	0.7	0.03
Isobutyl acetate	8	0.6	0.01
Acetone	108	0.6	0.02
Magnesium oxide fume (total particulate)	17	0.6	0.01
Methyl bromide	11	0.6	0.1
Ethyl benzene	71	0.5	0.01
Vanadium	16	0.5	0.1

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Permissible exposure limit.

Table 12. All Substance Samples Equal to or Exceeding One-half PEL[1] and PEL

Substance	Samples	0.5 ≤ Severity[2] <1.0		Severity ≥1.0	
		n	%	n	%
Noise, continuous or intermittent	1381	353	26%	662	48%
Particulates not otherwise regulated (total dust)	240	17	7%	59	25%
Lead, inorganic fumes & dusts (as Pb)	188	25	13%	52	28%
Silica crystalline quartz (respirable fraction)	160	22	14%	68	43%
Particulates not otherwise regulated (respirable dust)	159	24	15%	88	55%
Carbon monoxide (CO)	140	8	6%	0	0%
Acetone	108	1	1%	0	0%
Chromium (VI) (hexavalent chromium)	102	14	14%	26	25%
Xylene (o-m-,and p-isomers)	100	3	3%	1	1%
Welding fumes (total particulate)	96	23	24%	20	21%
Petroleum distillates (naphtha, rubber solvent)	92	4	4%	5	5%
Silica,crystalline cristobalite (respirable fraction)	79	9	11%	22	28%
Toluene	79	2	3%	6	8%
Formaldehyde	78	15	19%	7	9%
Iron oxide fume	75	3	4%	23	31%
Ethyl benzene	71	1	1%	0	0%
N-butyl acetate	64	4	6%	0	0%
Hexamethylene diisocyanate (HDI)	58	7	12%	27	47%
Methylene bisphenyl isocyanate (MDI)	55	3	5%	9	16%
Manganese fume (as Mn)	53	10	19%	13	25%
Methylene chloride (dichloromethane)	47	5	11%	11	23%
Nitrous oxide	46	4	9%	27	59%
2-butanone (MEK)	42	6	14%	7	17%
Styrene (phenylethylene)	41	6	15%	6	15%
Wood dust, all soft/hard woods, except w.red cedar	30	2	7%	2	7%
Arsenic & inorganic compounds	29	1	3%	1	3%
Aluminum (as Al), welding fumes	28	3	11%	1	4%
Hexone (MIBK)	28	1	4%	0	0%
Ozone	26	2	8%	3	12%
Copper dusts & mists (as Cu)	20	1	5%	0	0%
Hexane	19	2	11%	2	11%
Magnesium oxide fume (total particulate)	17	1	6%	0	0%
Vanadium	16	2	13%	0	0%
Methyl methacrylate	14	0	0%	2	14%
Isopropyl acetate	13	2	15%	0	0%
Isophorone diisocyanate	13	1	8%	5	38%
Cadmium dust (as Cd)	13	1	8%	2	15%
Methyl bromide	11	1	9%	0	0%
Wood dust, hardwood (nonallergenic)	10	2	20%	0	0%
Methyl (n-amyl) ketone (2-heptanone)	10	1	10%	0	0%
2-butoxyethanol	9	1	11%	0	0%
Copper fume (as Cu)	9	1	11%	0	0%
Toluene-2,4-diisocyanate (TDI)	8	3	38%	0	0%
Isobutyl acetate	8	1	13%	0	0%
Carbon dioxide (CO_2)	7	2	29%	0	0%
Perchloroethylene (tetrachloroethylene)	6	2	33%	1	17%
Ammonia (NH_3)	6	1	17%	1	17%
Wood dust, western red cedar	6	1	17%	4	67%
Aluminum (as Al), metal (total dust)	6	0	0%	1	17%
N-butyl alcohol	6	0	0%	1	17%
Wood dust, softwood	4	2	50%	0	0%
Cyclohexanone	1	0	0%	1	100%
Talc (containing no asbestos)	1	0	0%	1	100%

1. Permissible exposure limit

Table 13. All Substance in AIHA[1] Exposure Categories

Exposure Category	Criteria (%OEL)	Substances	Exposure Description
0	$X_{0.95}$[2] ≤ 1%	2-ethoxyethanol, Barium-soluble, Carbon tetrachloride, Chlorine dioxide, Cyclohexylamine, Diesel exhaust, Diethylenetriamine, Furfural, Hydrogen fluoride, Hydrogen sulfide, Iodine, Isobutyl alcohol, Methane, Methyl cellosolve, Methyl cellosolve acetate, Methyl ethyl ketone peroxide, Morpholine, Naphthalene, Nickel, Nitrogen dioxide, Silicon-respirable, Tert-butyl alcohol, Titanium, Methylcyclohexane, Ethyl acetate, N-propyl acetate, Heptane, Chromium-soluble (Cr)	**Trivial to nonexistent**—little to no exposure, with little to no inhalation contact.
1	1% < $X_{0.95}$ ≤ 10%	Zinc, Alpha methyl styrene, Zinc oxide fume, Hydrogen cyanide, Pentane, Molybdenum, Octane, Nickel-metal & insoluble (Ni), Silica-amorphous, Aluminum oxide, Methyl alcohol, Titanium dioxide, Nitric acid, Calcium oxide, VM & P naphtha, Oil mist-mineral, Methyl isoamyl ketone, Asbestos, Calcium, Diacetone alcohol (4-hydroxy-4 methyl-2 pentanone), Hydrogen chloride	**Highly controlled**—minimal exposure, with little to no inhalation contact.
2	10% < $X_{0.95}$ ≤ 50%	Chromium-insoluble (Cr), Phenol, Ethyl benzene, Phosphoric acid, Zinc oxide , Isopropyl alcohol, Stoddard solvent, Arsenic, Tin , Antimony , Ethylene oxide, Chromic acid & chromates (CrO3), Sulfur dioxide, Ethanolamine, Hexamethylene diisocyanate (HDI) monomer, Acetone, Benzene, Sulfuric acid, Trichloroethylene, 2-pentanone, Trimethylbenzene, Propylene glycol monomethyl ether, Cobalt, Sec-butyl alcohol, Cadmium fume, Portland cement-respirable, Iron salts, Beryllium & compounds, Methacrylic acid, Ethyl alcohol , Sodium hydroxide, Hexone (MIBK), Xylene (o-m-,and p-isomers), Glutaraldehyde	**Well-controlled—** frequent contact at low concentrations and rare contact at high concentrations.
3	50% < $X_{0.95}$ ≤ 100%	N-butyl acetate, Vanadium, Carbon monoxide, Methyl bromide, Magnesium oxide fume (total particulate), Arsenic & inorganic compounds, Aluminum welding fumes, Copper dusts & mists, Isobutyl acetate, Copper fume, Methyl (n-amyl) ketone (2-heptanone), Toluene-2,4-diisocyanate (TDI), Wood dust-hardwood nonallergenic, Wood dust-softwood, 2-butoxyethanol, Carbon dioxide, Isopropyl acetate	**Controlled**—frequent contact at low concentrations and infrequent contact at high concentrations.
4	100% < $X_{0.95}$ ≤ 200%	Wood dust-all soft/hard except w.red cedar, Petroleum distillates , Cyclohexanone, Toluene, Aluminum metal-total dust, Talc , 2-butanone (MEK), N-butyl alcohol, Ammonia , Formaldehyde	**Poorly controlled**—Exposed at high or very high concentrations.
5	$X_{0.95}$ > 200%	Styrene, Cadmium dust (Cd), Methylene chloride, Wood dust-western red cedar, Lead, Ozone, Silica crystalline cristobalite-respirable, Particulates-respirable dust, Welding fumes-total particulate, Manganese fume, Hexane, Perchloroethylene, Noise, Methylene bisphenyl isocyanate (MDI), Methyl methacrylate, Iron oxide fume, Chromium (VI) , Particulates-total dust, Isophorone diisocyanate, Silica crystalline quartz-respirable, Hexamethylene diisocyanate (HDI), Nitrous oxide	**Uncontrolled**—Exposed at very high concentrations.

1. American Industrial Hygiene Association.
2. The 95th percentile exposure includes 95% of the measurements for each substance and represents a high-end exposure.

Table 14. Recommended Actions or Controls Based on AIHA[1] Exposure Categories

Exposure Category	Recommended Actions or Controls
0	No action
1	General or chemical specific hazard communication
2	Chemical specific hazard communication
3	Chemical specific hazard communication, Exposure surveillance, Medical surveillance, Work practice evaluation
4	Chemical specific hazard communication, Exposure surveillance, Medical surveillance, Work practice evaluation, Engineering controls, Respiratory protection
5	Immediate engineering controls or process shutdown, Validate that respiratory protection is appropriate

1. American Industrial Hygiene Association.

Table 15. Health Effects[1] of AIHA[2] Exposure Category 5 Substances

Exposure Category	Health Effects	Substance
5	Confirmed Human Carcinogen-A1	Chromium (VI)
	Suspected Human Carcinogen-A2	Cadmium dust (Cd), Silica crystalline cristobalite-respirable, Silica crystalline quartz-respirable
	Confirmed Animal Carcinogen (Unknown relevance to human)-A3	Methylene chloride, Lead
	Asthma	Wood dust-western red cedar
	Respiratory Irritation	Styrene, Ozone, Particulates-respirable dust, Particulates-total dust, Welding fumes-total particulate, Methyl methacrylate, Methylene bisphenyl isocyanate (MDI), Hexamethylene diisocyanate (HDI)
	Central Nervous System Impairment	Methylene chloride, Manganese fume, Hexane, Perchloroethylene, Nitrous oxide
	Respiratory System Sensitization	Methylene bisphenyl isocyanate (MDI), Hexamethylene diisocyanate (HDI), Isophorone diisocyanate
	Pneumoconiosis (dust-related lung disease)	Iron oxide fume
	Kidney Damage	Cadmium dust (Cd)

1. Health effects assigned by American Conference of Governmental Industrial Hygienists (ACGIH).
2. American Industrial Hygiene Association.

Table 16. Top 10 Substances with Highest Severity[1] Exposure by Top 3 Industries[2]

Substance Industry	Number of Samples	Maximum Severity
Silica crystalline quartz (respirable fraction)		
Construction, mining, and forestry machinery and equipment rental	3	130
Showcase, partition, shelving, and locker manufacturing	5	25.4
Lessors of residential buildings and dwellings	3	16.0
Noise, continuous or intermittent		
Painting and wall covering contractors	4	100.4
Automotive body, paint, and interior repair and maintenance	24	39.2
Power boiler and heat exchanger manufacturing	5	32.9
Particulates not otherwise regulated (total dust)		
All other specialty trade contractors	2	90.5
Metal coating, engraving (except jewelry and silverware)	5	42.9
Automotive body, paint, and interior repair and maintenance	7	36.0
Nitrous oxide		
Offices of dentists	41	80.0
Offices of physicians (except mental health specialists)	3	0.4
Chromium (VI) (hexavalent chromium)		
Painting and wall covering contractors	3	51.3
Steel foundries (except investment)	10	13.7
Machine tool (metal cutting types) manufacturing	3	12.9
Hexamethylene diisocyanate (HDI)		
Automotive body, paint, and interior repair and maintenance	38	21.9
All other motor vehicle parts manufacturing	6	18.9
All other specialty trade contractors	1	17.8
Particulates not otherwise regulated (respirable dust)		
Construction, mining, and forestry machinery and equipment rental	3	15.6
Metal coating, engraving (except jewelry and silverware)	2	9.4
Painting and wall covering contractors	1	8.5
Iron oxide fume		
Paint and wallpaper stores	1	13.1
Metal coating, engraving (except jewelry and silverware)	2	13.0
Machine tool (metal cutting types) manufacturing	7	6.1
Methylene bisphenyl isocyanate (MDI)		
Surgical and medical instrument manufacturing	1	12.2
Boat building	3	5.5
Car washes	1	4.4
Lead, inorganic fumes & dusts (as Pb)		
Storage battery manufacturing	10	10.0
Automotive body, paint, and interior repair and maintenance	5	8.1
Painting and wall covering contractors	10	6.5

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).

Table 17. Top 10 Substances with Highest Severity[1] Exposure by Top 3 Job Titles[2]

Substance Job Title	Samples	Max. Severity	Median Severity
Silica crystalline quartz (respirable fraction)			
Abrasive blaster	4	130.0	4.6
Countertop installer	2	25.4	14.0
Maintenance	3	16.0	7.6
Noise, continuous or intermittent			
Abrasive blaster	13	100.4	6.8
Metal fabricator	149	32.9	0.9
Sawmill worker	32	29.9	3.9
Particulates not otherwise regulated (total dust)			
Abrasive blaster	12	90.5	15.3
Recycler	7	18.3	0.4
Mason	1	15.0	-
Nitrous oxide			
Dental assistant	36	80.0	2.0
Dentist	7	11.3	4.5
Receptionist	1	5.4	-
Chromium (VI) (hexavalent chromium)			
Sander	3	51.3	2.2
Painter	2	16.7	8.5
Foundry worker	17	13.7	0.2
Hexamethylene diisocyanate (HDI)			
Spray painter	51	21.9	1.0
Bathtub refinisher	1	17.8	-
Painter	4	11.2	9.1
Particulates not otherwise regulated (respirable dust)			
Abrasive blaster	8	15.6	0.8
Powder coater	3	9.4	0.8
Recycler	3	6.6	3.0
Iron oxide fume			
Abrasive blaster	4	13.1	7.9
Metal fabricator	40	6.1	0.2
Foundry worker	13	3.2	1.5
Methylene bisphenyl isocyanate (MDI)			
Painter	2	12.3	6.3
Boat builder	3	5.5	2.8
Detailer	1	4.4	-
Lead, inorganic fumes & dusts (as Pb)			
Battery technician	10	10.0	2.1
Abrasive blaster	8	8.1	0.9
Painter	13	3.4	0.5

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Job titles assigned by compliance safety and health officers.

High Severity, High Toxicity, and Carcinogenic Substance Exposures

Table 18. Noise Exposure Severity[1] by Industry[2] Sector

Industry Sector	Samples	Max. Severity	Median Severity
Construction	123	100.4	0.8
Other Services (except Public Administration)	124	39.1	0.7
Manufacturing	654	32.9	1.1
Educational Services	16	14.0	0.9
Public Administration	29	9.2	0.9
Wholesale Trade	142	9.0	0.9
Real Estate and Rental and Leasing	16	4.6	1.2
Retail Trade	59	4.5	0.7
Administrative and Support and Waste Management and Remediation Services	99	4.0	1.2
Arts, Entertainment, and Recreation	36	3.3	0.9
Agriculture, Forestry, Fishing and Hunting	24	3.3	0.7
Accommodation and Food Services	23	3.0	0.8
Health Care and Social Assistance	10	2.9	0.6
Transportation and Warehousing	17	2.0	0.8
Professional, Scientific, and Technical Services	8	2.0	1.1
Utilities	1	0.1	-
Total	**1381**		

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).

Table 19. Noise Exposure where Severity[1] ≥ 2.0 by Job Title[2]

Job Title	Samples	Max. Severity	Median Severity
Abrasive blaster	13	100.4	6.8
Metal fabricator	151	32.9	0.9
Sawmill worker	32	29.9	3.9
Painter	5	28.6	1.9
Foundry worker	20	27.5	3.2
Machine Operator	187	14.9	0.9
Cadet	1	14.0	-
Range safety officer	16	12.9	2.1
Paper machine operator	5	11.7	2.0
Laborer	102	9.9	1.4
Maintenance	21	9.8	0.8
Boat mechanic	8	9.2	4.3
Salesperson	5	9.0	1.6
Aircraft technician	7	7.8	1.0
Agriculture worker	41	7.5	1.0
Spray painter	17	6.5	0.6
Auto body technician	18	6.0	0.3
Mason	18	5.3	0.7
Warehouse worker	3	5.3	2.1
Landscaper	131	5.1	1.2
Woodworker	75	4.8	0.9
Polisher	10	4.5	1.0
Technician	43	4.5	0.8
Stone fabricator	65	4.3	1.0
Assembler	45	4.1	1.1
Police officer	6	3.8	1.6
Auto Detailer	14	3.0	1.1
Security Guard	12	3.0	1.5
Driver	23	2.9	0.4
Carpenter	5	2.9	1.8
Plastic fabricator	17	2.7	1.1
Recycler	28	2.7	1.0
Manager	6	2.5	0.9
Animal care technician	19	2.4	0.6
Boat builder	28	2.3	1.0
Car wash attendant	4	2.2	1.8
Air Traffic groundcrew	3	2.0	1.4

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Job titles assigned by compliance safety and health officers.

Table 20. Crystalline Silica[1] Exposure where Severity[2] ≥ 1.0 by Industry[3] and Job Title[4]

Industry Sector Job Title	Samples	Max. Severity	Median Severity
Real Estate and Rental and Leasing	**6**		
Abrasive blaster	2	130.0	69.1
Maintenance	3	16.0	7.6
Painter	1	0.8	-
Manufacturing	**74**		
Countertop installer	2	25.4	14.0
Stone fabricator	39	11.4	1.5
Foundry worker	11	4.3	0.6
Machine Operator	4	1.4	1.1
Laborer	11	1.3	0.4
Mason	3	0.4	0.1
Spray painter	3	0.2	0.2
Technician	1	0.1	-
Construction	**62**		
Stone fabricator	23	15.7	3.1
Mason	16	10.0	0.3
Laborer	18	6.6	0.5
Abrasive blaster	2	1.1	1.0
Tilesetter	2	0.3	0.2
Driver	1	0.1	-
Agriculture, Forestry, Fishing and Hunting	**3**		
Agriculture worker	3	2.7	2.1
Administrative and Support and Waste Management and Remediation Services	**2**		
Laborer	1	2.2	-
Landscaper	1	0.6	-
Other Services (except Public Administration)	**2**		
Auto Detailer	2	1.2	0.7
Total	**149**		

1. Respirable fraction
2. Severity = ratio of the measured concentration to its permissible exposure level. Includes all job titles in industries where silica was measured ≥1.0.
3. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
4. Job titles assigned by compliance safety and health officers.

Table 21. Hexavalent Chromium Exposure (all) Severity[1] by Industry[2] and Job Title[3]

Industry Sector Job Title	Samples	Max. Severity	Median Severity
Construction	**7**		
Sander	1	51.3	-
Painter	1	16.7	-
Spray painter	1	3.2	-
Metal fabricator	4	0.3	0.2
Manufacturing	**71**		
Foundry worker	17	13.7	0.2
Metal fabricator	35	12.9	0.2
Spray painter	16	3.5	0.6
Sander	2	2.2	1.6
Maintenance	1	0.0	-
Health Care and Social Assistance	**4**		
Spray painter	4	3.2	0.6
Wholesale Trade	**12**		
Torch cutter	4	2.3	0.1
Metal fabricator	6	1.4	0.4
Aircraft technician	2	0.5	0.3
Transportation and Warehousing	**4**		
Spray painter	2	0.8	0.6
Technician	1	0.1	-
Metal fabricator	1	0.1	-
Professional, Scientific, and Technical Services	**3**		
Pipefitter	3	0.7	0.4
Other Services (except Public Administration)	**1**		
Painter	1	0.4	-
Total	**102**		

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
3. Job titles assigned by compliance safety and health officers.

Table 22. Total Dust Exposure where Severity[1] ≥ 1.0 by Industry[2] and Job Title[3]

Industry Sector Job Title	Samples	Max. Severity	Median Severity
Construction	**3**		
Abrasive blaster	1	90.5	-
Mason	1	15.0	-
Spray painter	1	9.4	-
Manufacturing	**79**		
Abrasive blaster	4	42.9	5.0
Metal fabricator	40	7.1	0.4
Assembler	2	6.7	3.4
Powder coater	5	4.3	0.6
Foundry worker	18	3.6	1.2
Spray painter	3	2.3	0.3
Fiberglass fabricator	1	1.9	-
Torch cutter	1	1.8	-
Boat builder	5	1.5	1.0
Other Services (except Public Administration)	**8**		
Abrasive blaster	6	36.0	19.4
Boat builder	2	2.6	2.1
Wholesale Trade	**16**		
Recycler	6	18.3	1.5
Torch cutter	7	1.9	0.3
Agriculture worker	2	1.6	1.0
Laborer	1	1.4	-
Retail Trade	**7**		
Abrasive blaster	1	11.9	-
Metal fabricator	4	1.5	0.4
Fiberglass fabricator	1	1.3	-
Pasteurizer	1	1.1	-
Agriculture, Forestry, Fishing and Hunting	**3**		
Agriculture worker	3	3.8	3.4
Transportation and Warehousing	**2**		
Sander	2	1.6	1.0
Total	**118**		

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
3. Job titles assigned by compliance safety and health officers.

Table 23. Lead Exposure where Maximum Severity[1] ≥ 0.5 by Industry[2] and Job Title[3]

Industry Sector Job Title	Samples	Max. Severity	Median Severity
Manufacturing	**41**		
Battery technician	10	10.0	2.1
Machine Operator	9	3.2	0.2
Assembler	13	1.6	0.2
Metal fabricator	9	1.1	0.5
Other Services (except Public Administration)	**6**		
Abrasive blaster	5	8.1	1.4
Metal fabricator	1	1.0	-
Construction	**16**		
Abrasive blaster	1	6.5	-
Painter	12	3.4	0.8
Metal fabricator	3	1.0	0.8
Wholesale Trade	**11**		
Torch cutter	11	2.9	0.4
Retail Trade	**32**		
Range safety officer	32	2.7	0.4
Arts, Entertainment, and Recreation	**20**		
Range safety officer	20	2.4	0.04
Administrative and Support and Waste Management and Remediation Services	**1**		
Metal fabricator	1	0.7	-
Public Administration	**10**		
Police officer	6	0.5	0.03
Range safety officer	4	0.5	0.4
Total	**137**		

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
3. Job titles assigned by compliance safety and health officers.

Table 24. Methylene Chloride Exposure in Industries[1] with Max. Severity[2] ≥ 0.5

Industry Job Title[3] Task Description	Samples	Max. Severity
Painting and wall covering contractors		
Furniture stripper		
Applied Flo-strip to wood pieces at flow over table inside ventilated hood	2	0.5
Painter		
Brush applied 80 percent methylene chloride product to wood panels	1	3.5
Drywall and insulation contractors		
Painter	2	
Roller applied Jasco to carpet adhesive on concrete floor, then manually mopped and scraped up the loosened adhesive/stripper mixture		3.0
Dental equipment and supplies manufacturing		
Technician		
Sprays red whisper glue made by imperial adhesives. Glue contains 60% methylene chloride by weight	4	2.2
Nonupholstered wood household furniture manufacturing		
Woodworker		
Brush applied methylene chloride-based paint remover to a diving board	1	1.6
Sporting and recreational goods and supplies merchant wholesalers		
Screen printer		
Cleans screens of emulsion with pressure washer and brushes	1	0.1
Operates auto screen printing machine	1	0.2
Operates manual screen printer	1	0.3
Organize orders, tape screens, spot clean garments	1	1.3
Screen print numbers on manual machine and clean up with xylene	2	0.3
Testing laboratories		
Chemist		
Prepares and performs laboratory analysis on soil samples	3	<0.1
Using methylene chloride to extract samples under the lab fume hood	1	0.5
Technician		
Dry, test for fuels, spike samples. Pour methylene chloride into samples	2	1.3
Manage lab staff, prepare samples	3	0.3
Prepare samples, pour methylene chloride	2	0.2
Urethane and other foam product (except polystyrene)		
Foam applicator		
Used spray adhesive to apply reinforced material to foam cushion	1	0.8
Not available	3	1.3
Reupholstery and furniture repair		
Upholsterer		
Sprayed methylene chloride-based adhesive using compressed air pot/gun to glue foam during re-upholstery activities	1	0.8

1. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
2. Severity = ratio of the measured concentration to its permissible exposure level. The WA State Permissible Exposure Limits for methylene chloride are 25 ppm for 8-hr time-weighted average and 125 ppm for 15-min short-term exposure limit. Max. severities less than 0.5 shown because ≥0.5 filter is applied at industry level, not job title or task.
3. Job titles and task assigned by compliance safety and health officers.

Table 25. Nitrous Oxide Exposure where Max. Severity[1] ≥0.5 by Industry[2], Job, and Task[3]

Industry Job Title Task Description	Samples	Max. Severity
Offices of dentists		
Dental assistant		
Oral surgery. Scavenging system present	1	80.0
Dental cleaning and examination of patients' teeth	1	64.0
N_2O/O_2 = 50/50. Procedure = root canal, filling. Scavenging system utilized	2	30.7
Dental cleaning and examination of patients' teeth	1	25.7
(blank)	6	15.9
Set up N_2O gas, and assists the doctor during dental procedures	1	14.8
Regular dental procedures. Scavenging system present	1	6.5
Oral surgery assistant. Scavenging system present	1	6.5
Dental procedure using N_2O	1	6.1
Assist dentist	1	5.9
Assists with various procedures	1	5.7
Root canal	1	2.7
Works closely with the dentist and may have an exposure to nitrous oxide gas similar to that of the dentist	1	2.5
Assist the dentist in procedures	1	2.4
Assist dentist with oral surgery, monitor patients, administer N_2O	3	1.6
Scavenging system utilized during administration of N_2O	1	1.6
Oral surgery dental assistant. Scavenging system present	1	1.3
No exhaust ventilation system in place for the waste anesthetic gas	1	1.1
Dental procedure using N_2O	1	0.9
Dentist		
Oral dental surgery. Scavenging system present	1	11.3
Not available	2	8.8
Regular dental procedures. Scavenging system present	1	4.7
Conducts restorative dental procedures on patients' teeth. Supervises work of dental hygienist and dental assistant	1	4.5
Drilling teeth, filling cavities, administering N_2O	2	0.6
Receptionist		
Arranges patient dental appointments. Receives payments	1	5.4

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
3. Job titles and task assigned by compliance safety and health officers.

Table 26. Carbon Monoxide Exposure where Max. Severity[1] ≥0.5 by Industry[2], Job, and Task[3]

Industry / Job Title / Task Description	Samples	Max. Severity
Industrial supplies merchant wholesalers		
Forklift operator, general warehouse	1	0.9
Lessors of miniwarehouses and self-storage units		
Laborer	1	0.9
Corrugated and solid fiber box manufacturing		
Forklift operator		
Moves and loads finished cardboard product	1	0.8
Moves and loads finished cardboard products	2	0.7
Moves and loads finished cardboard goods	1	0.4
Machine operator		
Operates and maintains a Supermax die cutter	1	0.6
Operates and maintains a Bobst folder-gluer	1	0.5
Potato farming		
Agriculture worker		
Operating forklift 10-15 times per day - moving potato crate	1	0.6
Other noncitrus fruit farming		
Forklift operator		
Run LPG forklifts in cold rooms	1	0.5

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
3. Job titles and task assigned by compliance safety and health officers.

Table 27. Isocyanate Exposure Severity (all) by Job Title[1]

Job Title	Samples	Max. Severity	Median Severity
Spray painter	68	21.9	0.9
Bathtub refinisher	2	17.8	9.3
Painter	6	12.3	9.1
Boat builder	3	5.5	2.8
Detailer	1	4.4	-
Foam applicator	17	1.6	0.1
Auto body technician	6	1.2	0.4
Framer	1	0.6	-
Cabinet maker	3	0.3	0.3
Plastic fabricator	2	0.1	0.1
Machine operator	3	0.1	0.0
Assembler	7	0.0	0.0
Carpenter	1	0.0	-
Auto technician	1	0.0	-
Insulation installer	1	0.0	-
Salesperson	1	0.0	-
Screen printer	2	0.0	0.0
Technician	6	0.0	0.0
Total	**131**		

1. Job titles and task assigned by compliance safety and health officers.

Table 28. Isocyanate Exposure (all) where Max. Severity[1] ≥0.5 by Industry[2] and Task[3]

Industry Sector Task Description Isocyanate	Max. Severity
Construction	
Hexamethylene diisocyanate (HDI)[4]	17.8
Bathtub and countertop refinishing	
Toluene-2,4-diisocyanate (TDI)[5]	0.7
Bathtub and countertop refinishing	
Methylene bisphenyl isocyanate (MDI)[6]	0.6
Priming and spray painting steel beams and parts.	
Manufacturing	
Hexamethylene diisocyanate (HDI)	18.9
Painting large rigs inside a cross draft LEV booth	
Methylene bisphenyl isocyanate (MDI)	12.3
Sprays Scorpion product with 33.7% free MDI.	
Isophorone diisocyanate[5]	4.4
Painter	
Toluene-2,4-diisocyanate (TDI)	0.7
Other Services (except Public Administration)	
Hexamethylene diisocyanate (HDI)	21.9
Repairing and prepping cars for painting.	
Isophorone diisocyanate	8.7
Preps autos for painting.	
Methylene bisphenyl isocyanate (MDI)	4.4
Sprays truck bed liner. Details cars.	
Retail trade	
Methylene bisphenyl isocyanate (MDI)	1.2
Preps pick-ups and applies bedliner.	

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. Industries categorized according to North American Industrial Classification System (NAICS version 2007).
3. Job titles and task assigned by compliance safety and health officers.
4. PEL = 0.005ppm (CAL OSHA / CA Dept. of Industrial Relations).
5. PEL = 0.005ppm TWA / 0.02 STEL (WA State DOSH).
6. PEL = 0.02 STEL (WA State DOSH).

Table 29. Carcinogenic Substance Exposure Severity[1]

ACGIH[2] Carcinogen Classification Substance	Samples	Max. Severity
A1-Confirmed Human Carcinogen	**206**	
Chromium (VI) (hexavalent chromium)	102	51.3
Arsenic & inorganic compounds	29	1.0
Nickel, metal & insoluble compounds (as Ni)	17	0.0
Beryllium & compounds	16	0.4
Benzene	16	0.2
Asbestos (all forms)	7	0.1
Chromic acid & chromates (as CrO^{+3})	6	0.2
Silica, amorphous, precipitated and gel	4	0.0
Arsenic & organic compounds (as As)	4	0.1
Trichloroethylene	2	0.2
Chromium, soluble chromic, chromous salts (as Cr)	2	0.0
Silicon (respirable fraction)	1	0.0
A2-Suspected Human Carcinogen	**270**	
Silica, crystalline quartz (respirable fraction)	160	130.0
Silica, crystalline cristobalite (respirable fraction)	79	4.4
Cadmium dust (as Cd)	13	2.0
Cadmium fume (as Cd)	9	0.3
Sulfuric acid	7	0.2
Ethylene oxide	1	0.2
Carbon tetrachloride	1	0.0
A3-Confirmed Animal Carcinogen (Unknown relevance to humans)	**405**	
Lead, inorganic fumes & dusts (as Pb)	186	13.4
Ethyl benzene	71	0.5
Methylene chloride (dichloromethane)	45	3.5
Hexone (MIBK)	28	0.7
Cobalt, metal, fume & dust (as Co)	17	0.3
Vanadium	16	0.5
2-butoxyethanol	9	0.8
Toluene-2,4-diisocyanate (TDI)	8	0.7
Naphthalene	8	0.0
Perchloroethylene (tetrachloroethylene)	6	3.7
Ethyl alcohol (ethanol)	6	0.4
Cyclohexanone	1	1.1
Alpha methyl styrene	1	0.0
Iron oxide fume	1	0.0
Toluene	1	0.0
Furfural	1	0.0

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. American Conference of Governmental Industrial Hygienists.

Table 30. Dermal Carcinogenic Substance Exposure Severity[1]

ACGIH[2] Carcinogen Classification Substance	Samples	Max. Severity
A1-Confirmed Human Carcinogen	**16**	
Benzene	16	0.2
A2-Suspected Human Carcinogen	**1**	
Carbon tetrachloride	1	0
A3-Confirmed Animal Carcinogen (Unknown relevance to humans)	**18**	
Cyclohexanone	1	1.1
Toluene-2,4-diisocyanate (TDI)	8	0.7
Naphthalene	8	0
Furfural	1	0

1. Severity = ratio of the measured concentration to its permissible exposure level.
2. American Conference of Governmental Industrial Hygienists.

Table 31. Confirmed and Suspected Human Carcinogen Exposure Severity by Job Description

Substance Task Description	Class[1]	Max. Severity[2]
Silica crystalline quartz (respirable fraction)	A2	
Abrasive blasting of heavy equipment parts for paint prep		130.0
Cutting, grinding and polishing countertops		25.4
Grinding moisture barrier and concrete floor surface		16.0
Chromium (vi) (hexavalent chromium)	A1	
Applying primer containing strontium chromate to aircraft parts		51.3
Sanding older aircraft parts		16.7
Stick welding stainless steel propeller		13.7
Silica, crystalline cristobalite (respirable fraction)	A2	
Grinding dry stone using hand tools in enclosed room with exhaust units		4.4
Cutting and grinding dry granite using hand-held angle grinders		3.2
Fabricating stone countertops using hand-held angle grinders		2.8
Cadmium dust (as Cd)	A2	
Urea plastic media blasting of auto parts inside ventilated enclosure		2.0
Garnet media blasting of auto parts inside ventilated enclosure		0.7
Spraying powder coat on parts while inside booth		0.1
Arsenic & inorganic compounds	A1	
Sandblasting a navy ship		1.0
Welding garbage containers		0.3
Torch cutting scrap metal outdoors at recycling facility		0.2
Beryllium & compounds	A1	
Abrasive blasting		0.4
Cadmium fume (as CD)	A2	
Welding garbage containers		0.3
Plasma cutting steel plates		0.2
Trichloroethylene	A1	
Supervising laboratory equipment production		0.2
Supervising laboratory equipment production, operating of the dip tank		0.1
Sulfuric acid	A2	
Working in immediate vicinity of the sulfuric acid tank		0.2
Operating barrel zinc line		0.2
Cleaning facility		0.2
Chromic acid & chromates (as CrO3)	A1	
Mixing paint and hand painting flanges inside paint booth (not operating)		0.2
Welding, grinding of aluminum alloy with general ventilation only		0.1
Welding stainless steel using local exhaust system		0.1
Ethylene oxide	A2	
Sterilizing instruments using EtO gas ampoules		0.2
Arsenic & organic compounds (as As)	A1	
Sandblasting metal parts at 90-100 psi		0.1

1. American Conference of Governmental Industrial Hygienists Carcinogen Classification (A1=confirmed human carcinogen, A2=suspected human carcinogen).
2. Severity = ratio of the measured concentration to its permissible exposure level.

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