

CHAPTER 4

EXPOSURE ASSESSMENT STRATEGIES

1. **INTRODUCTION.** This chapter outlines the process for assessing occupational exposures. Exposure assessment is part of the industrial hygiene survey process where work operations and materials used are qualitatively assessed to determine exposure potential. Based on these qualitative exposure assessments, the work operations and hazards that are deemed to have significant exposure potential are identified which require evaluation using collected sampling data to quantitatively assess their exposure profiles. When exposures and processes are stable, sufficient exposure monitoring results may be obtained to allow statistical analysis to assist in exposure assessment. However, in many Navy processes exposure monitoring opportunities may be too infrequent or the process may be too variable to allow collection of a statistically valid number of measurements. In such cases, the industrial hygienist must exercise sound professional judgment, after considering the available information, and make an exposure assessment with a well-documented rationale. The strategy presented here is based on the strategy presented in reference 4-1 but is not identical to it. One of the major advantages of this strategy is to reduce the number of samples required for decision-making by:
 - a. Recognizing that Similar Exposure Groups (SEGs) with exposures estimated to be significantly less than the Occupational Exposure limit (OEL) (e.g., the 95th percentile exposure point estimate is “no detectable exposure” or “exposure is infrequent, < 10% of OEL”) do not necessarily require sampling just to complete exposure assessments, if there is strong evidence for anticipated negligible exposures such as very low material quantities in use, very short work duration, work methods unlikely to generate significant exposures, or low sampling results from similar work operations.
 - b. Recognizing that SEGs with exposures estimated to significantly exceed the OEL may be controlled without additional sampling;
 - c. Recognizing that 6 to 10 samples may be sufficient to quantitatively assess many exposures, which is a significant reduction from the 11 to 29 samples recommended in previous sampling strategies; and,
 - d. Recognizing that a sampling strategy may be designed to look for trends or based on regulatory requirements.
2. **DEFINITIONS.**
 - a. 8-hour Time Weighted Average (TWA)/8-hour TWA-OEL. The TWA concentration for a normal 8-hour workday and a 40-hour workweek, which cannot be exceeded. It is accepted to be a concentration to which nearly all workers may be repeatedly exposed, day after day, without adverse effects. The average level of a stressor over a specified time period, weighted for the length of time at each measured level. The measurement is usually a concentration of a chemical contaminant or a level of a physical agent (e.g., noise). The duration of the TWA must be specified. The most common industrial hygiene TWA duration is 8 hours, which is the length of the most common workday. A TWA may be determined by a single sample (i.e., the averaging is done by the sampling device throughout the sampled period) or by mathematical combination of one or more consecutive samples.

- b. Action Level (AL). One-half the 8-hour TWA value designated as the OEL unless a specific AL is established in an Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) adopted by the Navy (e.g., 60% of the OSHA standard for inorganic lead). The AL may initiate the implementation of specific actions, such as periodic monitoring, training or medical surveillance if specified by a Navy safety and occupational health (SOH) or OSHA standard.

The necessity for an employee exposure AL is based on variations in the occupational environment (i.e., variations in the employee's daily exposures). As such, the employer should attempt to prove with 95% certainty that no employee's true daily average exposure (i.e., 8-hour TWA) exceeds the standard (References 4-2 and 4-3).

- c. Ceiling (C)-OEL. A contaminant concentration that should not be exceeded during any part of the working exposure. If instantaneous monitoring is not feasible, samples are collected and assessed as a 15-minute TWA exposure, except for those substances that may cause immediate irritation when exposures are short. (Reference 4-4).
- d. Censored Data (Handling of). - The techniques used to adjust data (usually concentration results) that is reported by the laboratory as less than the limit of detection (LOD) for a stressor. (These techniques also apply if Limit of Quantification (LOQ) is reported instead of LOD.) It is currently recommended to adjust all such values by dividing by the square root of 2.
- e. Exceedance Fraction. The exceedance fraction is the fraction of the exposure distribution above the OEL. It is also called the probability of noncompliance.
- f. Excursion Limit (EL)-OEL. Only one stressor, asbestos, currently has an EL. The EL for asbestos was set as a TWA over a 30-minute period, distinguishing it from a Short-Term Exposure Limit (STEL), which has a shorter averaging period. For substances that have an 8-hour TWA-OEL but no short term exposure limits, excursions in worker exposure levels may exceed 3 times the 8-hour TWA-OEL for no more than a total of 30 minutes during a work day, and under no circumstances should exceed 5 times the 8-hour TWA-OEL, provided the 8-hour TWA does not exceed the 8-hour TWA-OEL. (Reference 4-4).
- g. Exposure Assessment Priority (EAP). EAP indicates priority for collecting additional exposure monitoring/information. If enough exposure monitoring/information has been collected already, then the EAP would indicate a lower priority. EAP is a numerical rating, ranging from 1 to 125, which is obtained by multiplying the health risk rating (HRR) times the Uncertainty Rating, with 1 being the lowest priority and 125 being the highest priority. This system is discussed in paragraph 4.d.(4) and Figure 4.2 of this chapter.
- h. Exposure Profile. An exposure profile is a characterization of the day-to-day variability of exposures of a SEG. A qualitative exposure profile may be based on professional judgment, whereas a quantitative exposure profile is based on statistics and includes measures of central tendency and measures of variability.
- i. Exposure Effect Rating (EER). EER looks at the exposure frequency and likelihood of exceeding the OEL. EER is an estimate of 95th percentile exposure level relative to an OEL. It is a numerical rating with a scale from 1 to 5, with 1 being the lowest exposure effect and 5 being the highest effect. This system is discussed in paragraph 4.d.(4) and Table 4.3 of this chapter.
- j. Geometric Standard Deviation (GSD). The standard deviation for a lognormal distribution.

- k. Health Effect Rating (HER). HER indicates the expected health effect if the exposure level at the OEL, and so is independent of the actual exposure. It is a numerical rating with a scale from 1 to 5, with 1 being the least health effect and 5 being the greatest effect. This system is discussed in paragraph 4.d.(4) and Table 4.2 of this chapter.
 - l. Health Risk Rating (HRR). HRR is a numerical rating, ranging from 1 to 25, which is obtained by multiplying the EER times the HER. This system is discussed in paragraph 4.d.(4) and Table 4.4 of this chapter.
 - m. Long-Term Average (LTA)-OEL. An occupational exposure limit with an averaging time of at least a week or more, which is intended to protect against chronic effects.
 - n. Minimum Variance Unbiased Estimate (MVUE). Air contaminant sampling data for a SEG is usually lognormally distributed. The best estimate of an average exposure for a lognormal distribution is the arithmetic mean, not the geometric mean as is commonly believed. The MVUE is the preferred estimate of the arithmetic mean of a lognormal distribution.
 - o. Occupational Exposure Limit (OEL). Limits established to protect workers from workplace exposure to certain chemical substances or physical agents. An exposure assessment cannot be made without an OEL. Navy OELs for chemical contaminants include:
 - (1) Substance specific regulations issued by OSHA under section 6(b) of the OSH Act of 1970.
 - (2) Current OSHA PELs, i.e. regulatory standards contained in 29 CFR 1910.1000 Z Tables.
 - (3) Non-Governmental Chemical and Particulate Exposure Standards. It is recognized that OSHA PELs may be less protective than exposure standards that reflect more recent medical evidence and promulgated by reputable organizations devoted to occupational health. Industrial hygienists are ethically bound to evaluate all recognized occupational health risks and provide professional recommendations to minimize or eliminate those risks cost effectively. As part of the Navy's overall desire to manage risk, industrial hygienists may recommend more stringent exposures standards than OSHA PELs contained in 29 CFR 1910.1000, Z Tables. The primary sources for these exposure standards are:
 - (a) Current edition of the American Conference of Governmental Industrial Hygienists Threshold Limit Values® and Biologic Exposure Indices®
 - (b) Exposure standards developed by the American Industrial Hygiene Association
 - (4) Other standards as approved by the Navy Bureau of Medicine and Surgery.
- For further guidance on the appropriate applications of OEL, IHPO should contact their respective regional command or Navy and Marine Corps Public Health Center for assistance.
- p. Operation Codes (OPCODEs). - For years, Navy Industrial Hygiene OPCODEs have been used to denote work operations. With the advent and use of the new Defense Occupational Environmental Health Readiness System - Industrial Hygiene (DOEHRS-IH), processes now need to be defined. See Appendix 3-A of this manual for additional information. See Process.
 - q. Percentile (%ile). The percentage of values in a population that are below a given value. For example, if exactly 90% of all zinc oxide fume exposures from a particular welding

process are less than 4 mg/m^3 , then 4 mg/m^3 is the 90 percentile exposure level for zinc oxide fume from that process.

- r. Probability of non-compliance (Exceedance Fraction). - See Exceedance Fraction.
- s. Process. – Process is used to denote work operations. In the new DOEHRS-IH, processes are defined in two basic ways: a user defined Process Name and the DOEHRS-IH Process Category/Common Process/Process Method picklists. DOEHRS-IH requires the choice of a Process Name for each work operation. The Process Name is user defined and is what the user typically sees. Since Process Name is user defined, care must be taken to use a business practice that ensures accurate and consistent Process Names are created. The DOEHRS-IH Process Category/Common Process/Process Method picklists are in the form of a three tiered process pulldown picklist. The DOEHRS-IH Process Methods from the picklist are the equivalent of the old OPCODEs. It is very important that proper selections are made from these DOEHRS-IH picklists and they are accurate and consistent for the process under consideration in order to facilitate future data mining. See Appendix 3-A of this manual for further information.
- t. Qualitative Exposure Assessment. This is a working exposure assessment of a SEG that is based on professional judgment and/or limited (less than six) industrial hygiene samples.
- u. Quantitative Exposure Assessment. This is a working exposure assessment of a SEG that is based on the statistical analysis of at least six industrial hygiene samples.
- v. Short-Term Exposure Limit (STEL)-OEL. A 15-minute TWA exposure that should not be exceeded at any time during the workday. The STEL is often associated with an 8-hour TWA-OEL in cases where there are recognized acute effects from a substance whose toxic effects are primarily chronic. The STEL may also be a separate independent OEL. Exposures above the 8-hour TWA-OEL up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. In addition, there should be at least 60 minutes between successive exposures in this range. (Reference 4-4).
- w. Similar Exposure Group (SEG). A group of employees who experience such similar exposures to stressors, that if one of the employees was monitored, the results of the monitoring could be used to predict the exposures of the remaining members of the group. Individuals within the group generally conduct the same work processes, use the same equipment, have the same job description, and are exposed to the same stressors at similar frequencies and durations. For Navy use, the initial definition of a SEG should be a combination of a shop, process, and a stressor. However, keep in mind that SEGs can certainly include one or more shops, and/or one or more processes, depending on the situation. The definition of every SEG includes one or more stressors. However, each stressor will often be assessed separately.
- x. Uncertainty Rating. Uncertainty Rating considers confidence in existing controls and exposure characterizations. It is a numerical rating with values ranging from 1 to 5, with 1 being the highest confidence and 5 being the lowest confidence. This system is discussed in paragraph 4.d.(4) and Table 4.5 of this chapter.
- y. Upper Tolerance Limit (UTL). An upper confidence limit of a point estimate of an exposure profile. A limit below which we can assert with a specified level of confidence that a specified fraction of exposures will lie. For example, for a given exposure distribution, we may calculate the value below which we are 95 percent confident that 95 percent of exposures will lie. This value is sometimes called $UTL_{95\%,95\%}$.

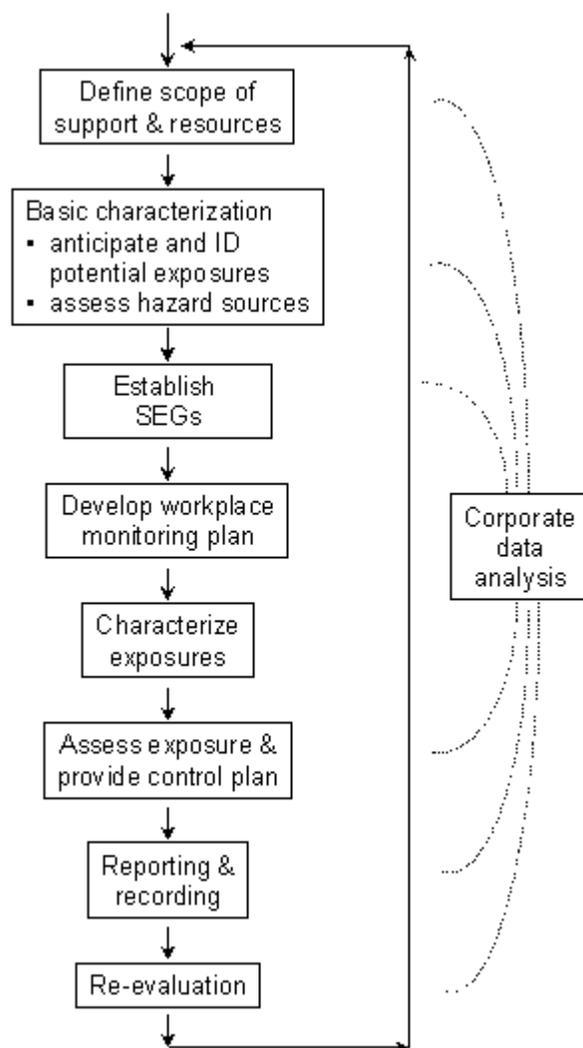
- z. Working Exposure Assessment. Using statistics as an aid to decision making, the working exposure assessment is the classification of occupational exposures as acceptable, uncertain, or unacceptable based largely on whether and how the confidence intervals around an exposure profile point estimate and the OEL overlap.
3. **SUMMARY**. The following is a summary of the exposure assessment strategy outlined in this chapter, which is adapted from reference 4-1. Since this summary is very brief and the subject is complex, the industrial hygienist should read the full discussion in this chapter as well as reference 4-1.
- a. Identify, based on existing information, scientific references, professional judgment, etc. SEGs for the various stressors present in the workplace.
 - b. Develop a best estimate of the SEG's 95th percentile exposure and the uncertainty associated with that estimate. If sufficient and satisfactory data are available, calculate the $UTL_{95\%,95\%}$.
 - c. Identify the appropriate OELs for each exposure. Unless there is reason to believe otherwise, assume Navy OELs have high certainty.
 - d. If the exposure profile has a high degree of certainty and the 95th percentile exposure point estimate and the $UTL_{95\%,95\%}$ is less than the OEL, the exposure is considered acceptable and no routine exposure monitoring is recommended. At least qualitative reassessment is required when circumstances affecting exposure change and/or at the frequency specified in Chapter 2 of this manual.
 - e. If both the exposure profile and the OEL have high degrees of certainty and 95th percentile exposure point estimate is greater than the OEL, the exposure is considered unacceptable and requires control.
 - f. Where the 95th percentile exposure point estimate is less than the OEL and the $UTL_{95\%,95\%}$ is greater than the OEL, the exposure is considered acceptable with some level of uncertainty thereby requiring additional information gathering.
 - g. SEGs with uncertain exposures should be subjected to exposure monitoring to collect 6 to 10 random samples for further estimation of the SEG's exposure.
 - h. The additional data collected by exposure monitoring should be fed back into the exposure assessment process at the basic characterization step to refine the exposure assessment and reclassify, if necessary, the SEG's exposure as acceptable, uncertain, or unacceptable. Some SEGs will continue to have uncertain exposures and should be scheduled for annual exposure monitoring.
4. **EXPOSURE ASSESSMENT STRATEGY**.
- a. Chapter 8 of reference 4-5 lists the five major steps of a functional occupational exposure assessment program. These are (1) basic characterization, (2) exposure assessment (including defining SEGs and exposure profiles, and qualitative/semi-quantitative exposure assessment), (3) further information gathering (including exposure monitoring, quantitative exposure assessment, and decision making), (4) communication and documentation, (5) reassessment. Reference 4-1 should be used as the basic reference for exposure assessment and its chapters address each of these five major steps as indicated in Table 4.1 below. The industrial hygienist is expected to consult reference 4-1 for a detailed explanation of the exposure assessment process.

Table 4.1 - Navy and AIHA Exposure Assessment Comparison

OPNAVINST 5100.23 Series Exposure Assessment Steps	Corresponding Chapters in Reference 4-1
Basic Characterization	Chapter 3 - Basic Characterization and Information Gathering
Exposure Assessment (includes defining SEGs, defining exposure profiles for each SEG using qualitative or semi-quantitative methods (e.g., screening samples, Bayesian Decision Analysis, etc.) , judging acceptability of each exposure profile, recommending controls using less than 6 samples, and setting of priorities.)	Chapter 4 - Exposure Assessment: Establishing Similar Exposure Groups Chapter 5 - Exposure Assessment: Defining and Judging Exposure Profiles Chapter 22 - Health Hazard Control
Further Information Gathering (as needed, and typically a follow-on to qualitative/semi-quantitative assessments to further define “Uncertain” exposure characterizations. Includes an exposure monitoring strategy to collect at least 6 samples for quantitative exposure assessment, data interpretation, and decision making – including recommending control strategies).	Chapter 6 - Further Information Gathering Chapter 7 - Quantitative Exposure Data: Interpretation, Decision Making, and Statistical Tools Chapter 22 - Health Hazard Control
Communication and Documentation (Recommendations and reporting)	Chapter 9 - Recordkeeping and Reporting
Reassessment (Reevaluation)	Chapter 8 – Reassessment

- b. The exposure assessment strategy of reference 4-1 represents a movement away from the traditional compliance assessment strategy toward a strategy that determines whether exposures are obviously acceptable, are obviously unacceptable, or for which there is insufficient information to make such a determination (i.e., uncertain exposures). The benefit is that information about the full exposure distribution is developed instead of just the upper extreme exposures and that sampling effort can be focused where it is most needed (i.e., the uncertain exposures). This strategy promises to provide quality information with a minimum number of samples.
- c. DoD Industrial Hygiene Exposure Assessment Model (Figure 4.1). From reference 4-6 - The DoD Industrial Hygiene Working Group, chartered under the DoD Safety and Occupational Health Committee and Defense Environmental Security Council, was requested by the DOEHRS Project Management Office to develop a process model for DoD industrial hygiene. The model was needed to guide development of the DOEHRS-IH module by providing a description of the process that DOEHRS-IH supports.

Figure 4.1 - DoD IH Exposure Assessment Process



d. Model Elements.

- (1) **Define Scope of Support and Resources** - Successful occupational health programs require professional supervision and oversight by qualified occupational health professionals. The primary sources of support services are hospitals and medical clinics. The occupational health/industrial hygiene components of those medical activities are responsible for providing complete occupational health support to all commands within their assigned area of responsibility. Chapter 3 of reference 4-5 provides a staffing level that allows implementation of all medical components of the SOH Program at a high level of quality consistent with progressive management of the Navy's industrial and fleet support programs.
- (2) **Basic Characterization** - Basic characterization is accomplished during the walkthrough survey and records reviews. Several items that affect occupational exposures (i.e., workplace, work force, stressors, controls, etc.) must be fully described and a review of existing data must be conducted. The objective of basic characterization is to identify combinations of process, personnel, and stressors that can be used to define groups of workers with like exposures that are referred to as a SEG.

- (a) Workplace. Description of the workplace involves documenting the processes or operations that are performed and inventorying the chemical, physical, and biological agents that are present in those processes or operations. Although production processes and operations are often well characterized, the industrial hygienist should not neglect to characterize the associated maintenance and repair work that often results in significant exposures.
1. Processes and operations may be partially characterized by obtaining copies of process flowcharts or standard operating procedures. However, it is essential that the process or operation be observed in progress to understand fully the potential occupational exposures involved and to verify that the documents are an accurate reflection of the current process or operation. Informal discussions with workers, supervisors, engineers, and activity safety professionals are an important part of understanding the workplace.
 2. An inventory of chemical, physical, and biological stressors should be collected to allow classification according to their potential hazard. All routes of exposure (i.e., inhalation, ingestion, skin absorption) should be considered. As OELs for airborne exposures are reduced, the contribution from dermal exposure may become more significant. For guidance regarding dermal exposure assessments, contact the Navy and Marine Corps Public Health Center.
- (b) Work force. A combination of review of the activity's personnel classification system, worker/supervisor interviews, and direct observation are required to characterize the work force accurately.
1. In describing the work force, it is important that the industrial hygienist recognizes that identical job titles are not reliable predictors of similar exposures. For example, exposures to welders vary greatly depending on the type of welding they do. A breakdown of workers by department or shop may be useful but within a department or shop there is often a variety of processes (e.g., welding, abrasive blasting, grinding) or tasks (e.g., administrative, quality assurance, production, supervision) performed that result in different exposures. Obviously, departments and shops are structured for business management reasons not for occupational exposure considerations. A process-based or a task-based work force classification is often needed to arrive at the best selection of a SEG.
 2. Differences in work tasks and tempo between shifts also should be considered.
- (c) Stressors. Working from the list of stressors previously developed, the following information, as applicable, should be developed for each: quantity, relevant physical properties (e.g., vapor pressure, particle size distribution), health effects, and OELs.
1. The applicable OEL for Navy use should be selected based on the policy in Chapter 16 of reference 4-5. This policy is summarized earlier in the OEL definition of this chapter.
 2. Care must be taken in determining what the appropriate exposure averaging time is, as this will determine which type of OEL is appropriate (e.g., Ceiling, STEL, 8-hour TWA).

- (d) Records review. To complete the basic characterization, a review of relevant records must be performed. The types of records typically considered are safety and health surveys, results of environmental monitoring, results of industrial hygiene monitoring, results of biological monitoring, personnel injury or illness reports, and engineering control assessments.
- (3) **Establish SEGs** - This is a three-step process where (1) the information gathered in basic characterization is used to define a SEG, (2) an exposure profile is determined for the SEG, and (3) the exposure for each group is judged to be acceptable, uncertain, or unacceptable.
- (a) Defining the SEG. A SEG may be defined by either observing the workplace and work force or by separating the work force based on the results of sampling data. The observational approach is more common since in many cases there is insufficient sampling data available to use that approach. In a mature industrial hygiene program, current and past exposure monitoring results are used to refine the definition of each SEG as necessary. There can be many ways to define a SEG depending on the particular situation. However, there are six common bases for defining SEGs. For Navy use, the initial definition of a SEG should be a combination of a shop, process, and a stressor. However, keep in mind that SEGs can certainly include one or more shops, and/or one or more processes, depending on the situation. The definition of every SEG includes one or more stressors. However, each stressor will often be assessed separately.
1. Determining SEGs through observation.
- a. Combination of shop, process, and stressor. In this scenario, all workers involved in a process are considered equally exposed. This may be because the stressor is evenly dispersed throughout the workroom, or all process workers perform all tasks with essentially the same frequency and duration. In reality, this is not a common occurrence. For example, consider the combination of process-mortar mixing and stressor-calcium hydroxide within a masonry shop.
- b. Combination of shop, process, job title, and stressor. Addition of a worker's job title may help refine a SEG that is not adequately described by only shop, process and stressor. However, the types of work tasks performed by persons having the same job title can vary greatly. Consider "laborers", a job title, working at a process that may perform different work tasks (e.g., bag dumping of raw materials, removal of finished product, clean up of both) and may have very different exposures to the same stressor. For example, consider the combination of process-mortar mixing, job title-laborer, and stressor-calcium hydroxide within a masonry shop.
- c. Combination of shop, process, job title, work task, and stressor. Including a specific work task in the SEG definition, in addition to shop, process, job title, and stressor, more precisely defines the SEG. This separates the population into those performing a single work task with exposure to one or more specific stressors. For example, consider the combination of process-mortar mixing, job title-laborer, work task-dumping bags of dry mortar into the mixer, and stressor-calcium hydroxide within a masonry shop.

- d. Combination of shop, process, work task, and stressor. Where job titles do not exist (e.g., small employers) or are not distinctive, job title may be eliminated from use in defining a SEG. This often occurs in manufacturing processes where work task alone keeps workers at a location with specific types of exposures. For example, consider the combination of process-mortar mixing, work task-dumping bags of dry mortar into the mixer, and stressor- calcium hydroxide within a masonry shop.
- e. Work teams. When work teams share responsibilities and flexible duties, the significance of job title and work task in defining a SEG may be blurred. Reasonable adjustments to defining a SEG may be made as follows:
- (1) If work locations are permanently assigned, the location is substituted for job title;
 - (2) If workers change locations after working one day at a specific location, the work team is substituted for the job title and the work location is substituted for the work task; and
 - (3) If workers rotate through the various locations during each day, the team is substituted for the job title and the work task may be ignored unless exposures will be assessed against a Ceiling or STEL OEL. When the latter is done, the work location is substituted for the work task.
- f. Non-repetitive work. Much of the work performed in the Navy is batch processes, job shop-type work, or research and development. People performing this type of work are difficult to categorize into SEGs. Professional judgment must be used in establishing SEGs for such work or pursuing alternate exposure assessment strategies. One strategy is to assess compliance with OELs by assessing worst case exposures. Another strategy is to consider each project as a distinct process and define SEGs for each project. This leads to a large exposure monitoring effort since many short-term projects must be sampled. Reassessment (discussed later in this chapter) may provide data to refine the definition of SEGs for non-repetitive work that may reduce sampling after initial data is collected. Again, such situations are best addressed by industrial hygiene professionals with substantial experience that provides a strong basis for accurate professional judgment.
2. Determining SEGs by sampling. Although not recommended in most cases, due to the high cost in terms of labor and analysis and the difficulty in executing a massive sampling campaign, SEGs may be defined by sampling results. Since one of the primary reasons for defining SEGs is to reduce the sampling requirements, it is best done by observation rather than sampling. If sampling is to be used, samples should be collected at random and multiple samples must be collected for each individual to be able to calculate the within-worker and between-worker variability. When sufficient data is available, the rule of thumb is that within a properly defined SEG the 97.5 percentile exposure should be approximately twice the 2.5 percentile exposure. In other words, 95% of the exposures should span a doubling of concentration. As the 97.5 percentile exposure recedes from the OEL, maintaining this exposure spread in a SEG becomes less critical. For example,

a spread of a factor of four between the 2.5 percentile and 97.5 percentile exposures is of little consequence if the 97.5 percentile exposure is still less than one tenth of the OEL.

- (4) **Develop Workplace Monitoring Plan (Exposure Monitoring Plan)** - The exposure monitoring plan should be constructed using the following strategy. The industrial hygienist is encouraged to use professional judgment as appropriate to identify additional SEGs for monitoring as dictated by local circumstances rather than be driven solely by the process described below. Conversely, the industrial hygienist should not feel compelled to expand monitoring beyond those SEGs selected by the process if professional judgment does not identify additional SEGs.

(a) Deciding which SEGs need exposure monitoring/further information.

1. Using statistics as an aid to decision making, the Working Exposure Assessment is the classification of occupational exposures as acceptable, uncertain, or unacceptable based largely on whether and how the confidence intervals around the exposure profile point estimate and the OEL overlap. Using the Working Exposure Assessment categories of acceptable, unacceptable, and uncertain, the industrial hygienist will particularly want to target uncertain exposures for exposure monitoring/further information gathering.
 - a. If the exposure profile has a high degree of certainty and the 95th percentile exposure point estimate and the $UTL_{95\%,95\%}$ is less than the OEL, the exposure is considered acceptable and no routine exposure monitoring is recommended. At least qualitative reassessment is required when circumstances affecting exposure change and/or at the frequency specified in Chapter 2 of this manual.
 - b. If both the exposure profile and the OEL have high degrees of certainty and 95th percentile exposure point estimate is greater than the OEL, the exposure is considered unacceptable and requires control.
 - c. Where the 95th percentile exposure point estimate is less than the OEL and the $UTL_{95\%,95\%}$ is greater than the OEL, the exposures are considered acceptable with some level of uncertainty thereby requiring additional exposure monitoring/information gathering.

(b) Prioritizing which SEGs need exposure monitoring/further information.

1. Assigning a Health Effect Rating/HER to a SEG. Since different stressors produce different health effects, it is logical to use the gradation in health effects to help determine priorities for intervention. There are a number of different health effect rating systems, only one of which will be proposed here. The health effects categories presented in the Table 4.2 below are those described in DOEHRS-IH. The DOEHRS-IH Health Effect Rating Health Effect is essentially the same as that presented in reference 4-1 for Health Effect Rating, except DOEHRS-IH has ratings from 1 to 5 rather than 0 to 4. 1 indicates the least health effect and 5 indicates the greatest effect

Table 4.2 - Health Effect Ratings

Health Effect Rating/Category	Health Effects	Health Effects Codes (OSHA)
5/Very High	Acute life-threatening or disabling injury or illness	<p>Health Hazard: HE1 - Regulated carcinogens; HE2 – Chronic (cumulative) toxicity - known or suspect human (IARC Group1 & Group 2A, ACGIH A1 & A2) carcinogens, mutagens; HE17 - Chemical asphyxiants, anoxiants; HE11 – Respiratory effects - acute lung damage, edema</p> <p>Safety: Death, Loss of facility or asset</p> <p>Noise: Immediate hearing loss, impulse noise</p>
4/High	Chronic irreversible health effects of concern	<p>Health Hazard: HE3 – Chronic toxicity - long term organ toxicity other than nervous, respiratory, hematologic, or reproductive; HE5 – Reproductive hazards - teratogens, or other impairment; HE7 – Nervous system disturbances - other than narcosis; HE10 - Respiratory effects (other than irritation) - cumulative lung damage; HE9 - Respiratory effects (other than irritation) – respiratory sensitization – asthma or other</p> <p>Safety: Major property damage</p> <p>Noise: Noise induced hearing loss, permanent and temporary threshold shifts, will eventually lead to permanent hearing loss</p>
3/Moderate	Severe reversible health effects of concern	<p>Health Hazard: HE14 – Irritation of eyes, nose, throat, skin – marked; HE6 - Nervous system disturbances - cholinesterase inhibition; HE12 - Hematologic disturbances – anemias; HE13 - Hematologic disturbances – methemoglobinemia, anemias; HE4 - Acute toxicity - Short-term high risk effects (non-IDLH)</p> <p>Safety: Minor property damage</p>
2/Low	Reversible health effects of concern	<p>Health Hazard: HE15 – Irritation of eyes, nose, throat, skin – moderate; HE16 – Irritation of eyes, nose, throat, skin – mild; HE8 - Nervous system disturbances - narcosis</p> <p>Safety: Minimal threat to personnel, property, first aid, minor supportive medical treatment, but still a violation of a standard.</p>
1/Negligible	Nuisance health effects (Reversible health effects of little concern or no known or suspected adverse health effects)	<p>Health Hazard: HE19 - Generally low risk health effects - nuisance particulates, vapors or gases; HE 20 - Generally low risk health effects – odor</p> <p>Safety: No violation of a standard.</p>

Note - Navy industrial hygienists must use professional judgment and available reference material in assigning a Health Effect Rating to a stressor. For chemical stressors, the procedures specified in the National Paint and Coatings Association's (NPCA) Hazardous Materials Identification System (HMIS) may be helpful. The NPCA HMIS system is completely different from the DoD Hazardous Materials Information System (HMIS) and the two should not be confused nor are they interchangeable.

2. Assigning an Exposure Effect Rating/EER to a SEG. In addition to HERs, the exposure categories below should also be used to help prioritize which SEGs require exposure monitoring/further information. The exposure effects categories presented in the Table 4.3 below are those described in DOEHRS-IH. The DOEHRS-IH Exposure Effect Rating IH Exposure Hypothesis is essentially the same as that presented in reference 4-1 for Exposure Rating, except DOEHRS-IH adds the “Negligible” category and has ratings from 1 to 5 rather than 1 to 4. 1 indicates the lowest exposure effect and 5 indicates the highest exposure effect. Since Navy industrial hygienists typically use the 95th percentile exposure point estimate, the 95th percentile should be compared to the OEL or 50% of the OEL for the IH Exposure Hypothesis.

Table 4.3 - Exposure Effect Ratings*

Exposure Effect Rating/ Category	IH Exposure Hypothesis*	Exposure Profile
5/ Very High	Expected to be at or above the OEL	Gross frequent contact with agents at very high concentrations; Materials have high vapor pressure or dustiness
4/ High	Likely to be an exposure, but between 50% OEL and OEL	Likely contact with agent at high concentrations or infrequent contact at very high concentrations; Materials have significant vapor pressure or dustiness
3/ Moderate	Exposure frequently < 50% OEL, or generally between 10-50% of OEL	Occasional contact with agent at moderate concentrations or infrequent contact at high concentrations; Materials have low vapor pressure or dustiness
2/ Low	Exposure infrequent, < 10% of OEL	Infrequent contact with agents
1/ Negligible	No detectable exposure	Current science cannot determine that there is exposure to agent

*Use 95th percentile exposure point estimate

Note – There may be special cases where a more restrictive upper point estimate be used based on the stressor of interest (e.g., STELs for highly toxic compounds).

3. Determining the Health Risk Rating/HRR for a SEG. HRR is a numerical rating, ranging from 1 to 25, which is obtained by multiplying the HER times the EER. DOEHRS-IH calculates the HRR as an intermediate step in calculating the EAP, but does not display the HRR. Table 4.4 below illustrates the calculations performed by DOEHRS-IH as a matrix.

Table 4.4 – Health Risk Ratings

		Exposure Effect Rating/Category				
		1/ Negligible	2/ Low	3/ Moderate	4/ High	5/ Very High
Health Effect Rating/ Category	5/Very High	5	10	15	20	25
	4 /High	4	8	12	16	20
	3 /Moderate	3	6	9	12	15
	2 /Low	2	4	6	8	10
	1/Negligible	1	2	3	4	5

4. Determining the Uncertainty for a SEG. Unlike the previously used rating system, DOEHRS-IH adds an additional Uncertainty Rating matrix that considers confidence in existing controls and exposure characterizations. It is a numerical rating with values ranging from 1 to 5, with 1 being the highest confidence and 5 being the lowest confidence. The matrix and choices can be seen in Table 4.5 below.

Table 4.5 - Uncertainty Ratings

		Confidence in Hazard and Exposure Characterization		
		Low	Medium	High
Confidence in Existing Controls	Low	5	4	3
	Medium	4	3	2
	High	3	2	1

Confidence in Hazard and Exposure Characterization.

Low –The exposure characterization is based solely upon a qualitative review of the workplace. No quantitative data available for this or similar activities.

Medium - The exposure characterization is based upon a detailed administrative and onsite review of activities within the workplace and application of professional judgment supported by application of objective based engineering principles. Screening samples or initial air sample results are within acceptable limits but not totally conclusive. Comparison to similar, characterized DoD and/or private sector operations (qualitative or quantitative).

High –The exposure characterization is based on sufficient quantitative evaluation or detailed technical reports where environmental factors do not influence exposures. Further quantification is not required. The source of the hazard does not have the potential to generate significant exposures.

Confidence in Existing Controls.

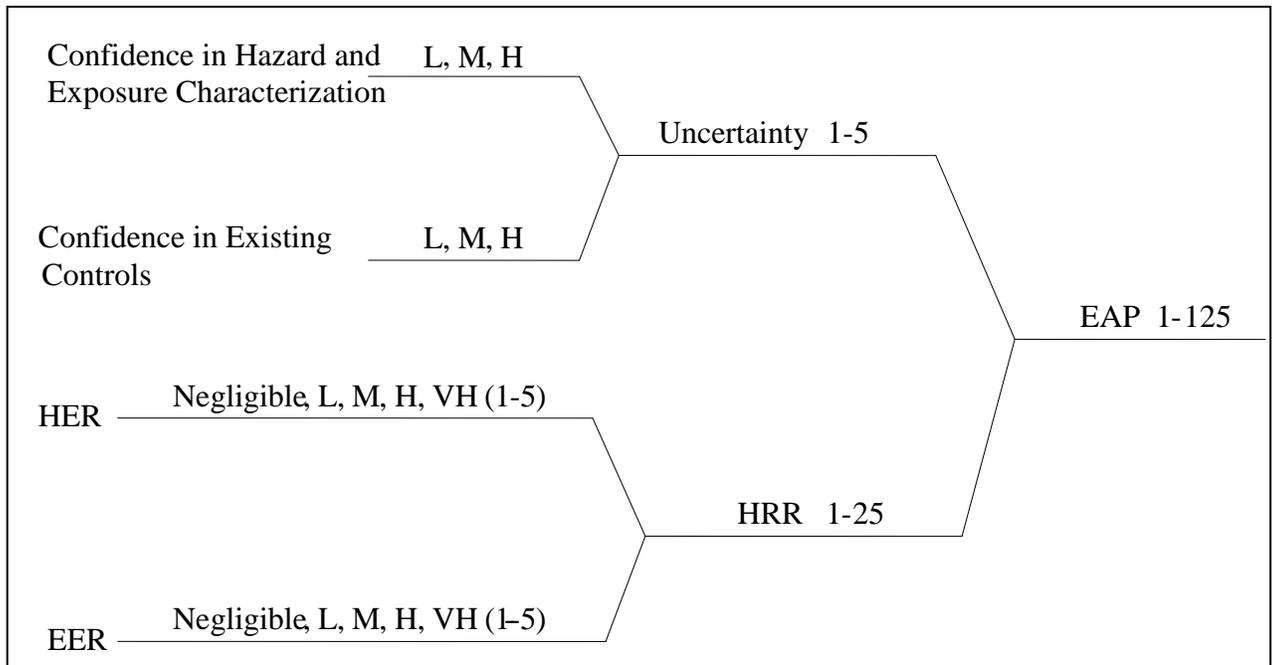
Low – Controls inadequate to control exposures. Controls in a poor state of repair/non-operational/not actively used.

Medium – Controls will control worker exposures to acceptable levels when regularly and properly used. (e.g. – administrative controls and/or PPE)

High – Engineering controls/work practice controls in place and fully operational. Evaluations completed to demonstrate adequate exposure control.

5. Determining the Exposure Assessment Priority/EAP for a SEG. Unlike the previously used rating system, DOEHRS-IH adds the additional step of calculating the EAP from the HRR and Uncertainty Rating. EAP is a numerical rating, ranging from 1 to 125, which is obtained by multiplying the HRR times the Uncertainty Rating, with 1 being the lowest priority for exposure assessment and 125 being the highest priority. This entire process is illustrated in Figure 4.2 below for determining the overall EAP for additional monitoring/information gathering. Figure 4.2 is from the DOEHRS-IH Student Guide Chapter 19.

Figure 4.2 – Exposure Assessment Priority Process



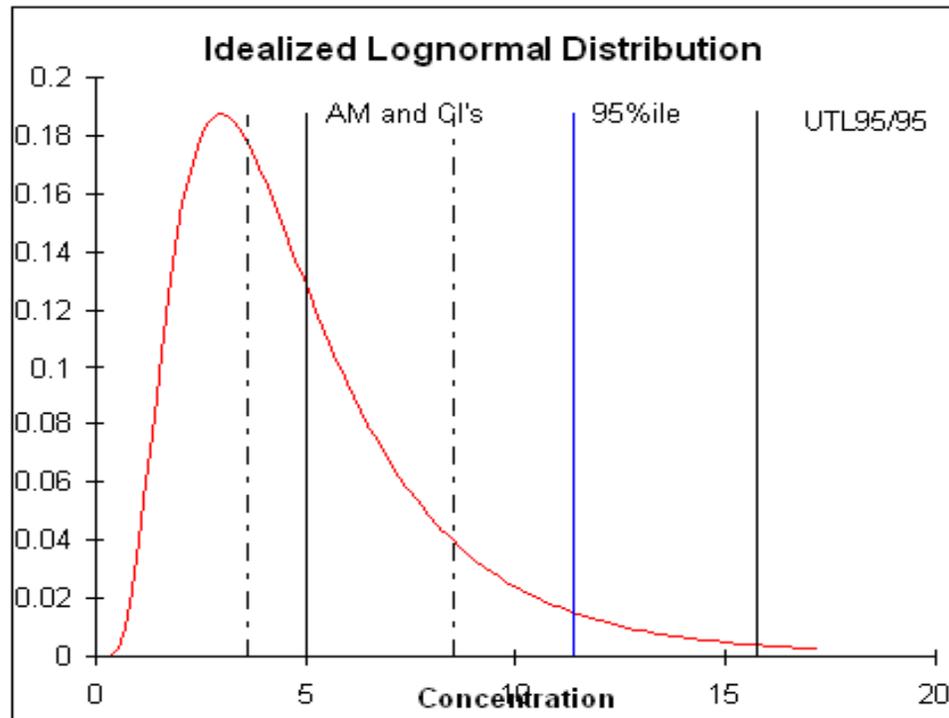
(c) Mechanics of exposure monitoring.

1. General. Usually, exposure monitoring is performed for three reasons: profiling, compliance, and diagnostic. Exposure data may be required to establish an exposure profile or to determine if an established exposure profile is still valid. This type of monitoring relies on statistically valid random sampling. Monitoring may be conducted to determine if exposures are in compliance with an OEL. This type of monitoring usually focuses on worst case scenarios. Stressor levels may be measured to provide information used to control the exposure (e.g., identifying stressor "hot spots").
2. The following discussion covers monitoring as it relates to exposure profiles.
 - a. Basic monitoring considerations. The following factors should be considered when deciding how and when exposure monitoring should be conducted:
 - (1) Exposure pathway. The industrial hygienist should select a monitoring method that is appropriate for the significant exposure pathways (i.e., inhalation, skin absorption, or ingestion).
 - (2) Sampling duration. It is important that the duration of monitoring be an appropriate mirror of the averaging time of the OEL for that stressor (e.g., full-shift monitoring for 8-hour TWA-OELs, 15 minute sample duration for STEL-OELs).
 - (3) Seasonal variations. If seasonal changes in working conditions (e.g., doors shut in the winter and open in the summer) will affect exposures, sampling should address those differences. Either sampling should cover all seasons or each season's exposure should be documented.
 - (4) Differences between shifts. If exposures are expected to differ between shifts, either the different shifts should be different SEGs or all shifts should be sampled.
 - b. How many samples? The industrial hygienist should collect 6 to 10 samples from randomly selected members of a SEG. Six samples is the minimum needed to provide reasonable certainty and more than 10 samples provide only a small amount of increased certainty per extra sample collected.
 - c. Random sampling for profiling. The 6 to 10 samples recommended above must be collected randomly to allow statistically valid inferences to be drawn. Random selection gives the best chance of documenting variability in the population of all exposures. To randomly select the persons to be sampled and the dates and shift on which they will be sampled the following actions should be followed:
 - (1) Determine the time period over which sampling will be conducted (e.g., a year, a season, a month). Very long time periods (e.g., a year, several months) delay the interpretation of the data and risk a change in the exposures during the sampling campaign. Very short time periods (e.g., one week) risk not revealing the true variation of exposures.

2. Surrogate data. When more relevant data is not available, exposure data from another stressor with similar physical properties and used in a similar or the same process may be considered. Such data is sometimes used to estimate the airborne concentration of other chemicals in a mixture when the airborne concentration of only one of the chemicals is known. Exposure data from another process using the same stressor may also be considered. Such data must be tempered with good professional judgment.
 3. Modeling. Exposures may be estimated based on models that consider the chemical and physical properties of a stressor along with the effect of existing controls and estimated generation and removal rates. When used, model parameters should be selected to arrive at a conservative estimate of exposure. The industrial hygienist should remember that all models are imperfect and must be used with a critical eye and sound professional judgment. Modeling based on environmental release data from a process can also help estimate exposures.
- (b) Assigning an initial Exposure Effect Rating/EER. EERs for chemical stressors with Ceiling, STEL, and 8-hour TWA OELs and for physical stressors (e.g., noise) can be associated to stressors with established SOH standards. EERs are useful to begin characterizing the exposure profile. The EERs and categories are the same as those presented previously in Table 4.3. EERs should be based on the 95th percentile exposure point estimate, and assigned assuming that no personal protective equipment is worn. Exposure measurements for the SEG should meet the requirements for randomness, stationary population and normal or lognormal distribution. Generally, to minimize uncertainty and maximize efficiency, a sample size of 6-10 measurements is usually sufficient. Table 4.3 addresses only airborne exposures; however, if dermal exposures are expected to be a significant contribution to overall exposure, adjustments to the EER should be made.
- (c) Comparing the SEG's exposure profile and its uncertainty to the OEL and its uncertainty. By comparing the exposure profile to the OEL, considering the uncertainties around both the exposure profile and OEL, one may judge the exposure and assign the SEG a Working Exposure Assessment of acceptable, unacceptable, or uncertain. This requires considering how much uncertainty exists about whether the OEL is adequately protective and the exposure estimate is accurate. The idea is to determine those exposures for which there is high, low, or unknown potential for exceeding the OEL. Those categories correspond to a Working Exposure Assessment of unacceptable, acceptable, or uncertain risk of exceeding the OEL.
1. Considering the uncertainty around the OEL. For SOH standards, one should assume that there is a high degree of certainty that the SOH standard is correctly set and, therefore, adequately protective (i.e., low uncertainty and a small confidence interval). The industrial hygienist should consider whether recent scientific evidence increases the uncertainty around a SOH standard and compensate appropriately in the exposure assessment. One indicator of uncertainty is if more recent OELs are lower than the existing SOH standard.
 2. Considering the uncertainty around the exposure estimate. While developing the exposure profile, the industrial hygienist should have developed at least a subjective estimate of the uncertainty around the exposure estimate. The industrial hygienist is reminded that all exposure models are imperfect.

3. Making the Working Exposure Assessment. In making the Working Exposure Assessment, the industrial hygienist must decide whether and how the subjective and/or objective confidence intervals around the exposure profile and the OEL do or do not overlap. That overlap or lack of overlap determines the Working Exposure Assessment. When there is no overlap the exposure is clearly either acceptable or unacceptable depending on whether it is above or below the OEL. When there is overlap, the Working Exposure Assessment will be either uncertain or unacceptable. For Navy OELs, which are mainly 8-hour TWAs, STELS, and Ceiling values, the target parameter is the 95th percentile exposure point estimate and the uncertainty is described by the 95% confidence upper tolerance limit around the 95th percentile value (i.e., UTL_{95%,95%}). Assuming that SOH standards have a high degree of certainty, Working Exposure Assessments may be assigned to the EERs of SEGs as follows:
- a. Acceptable exposures. Exposures where there is no overlap of the exposure profile and the OEL confidence intervals, and the OEL is greater than the 95th percentile exposure point estimate and the UTL_{95%,95%} of the SEG's exposure profile. A SEG with an EER of 1, 2, 3, or 4 and with high certainty about the exposure profile and the OEL may be considered an acceptable exposure.
 - b. Uncertain exposures. Exposures where there is overlap of the exposure profile and OEL confidence intervals, and the 95th percentile exposure point estimate is less than the OEL but the UTL_{95%,95%} is greater than the OEL. A SEG with an EER of 2, 3 or 4 may be considered an uncertain exposure if the upper tail of its exposure profile may approach the OEL. The available information is unable to predict with certainty whether overexposure will occur. The exposure is considered uncertain thereby requiring additional monitoring/information gathering.
 - c. Unacceptable exposures. Exposures where the 95th percentile exposure point estimate of the SEG's exposure profile is greater than the OEL. A SEG with an EER of 5 may be considered an unacceptable exposure. The exposures of these SEGs are expected to exceed the OEL and need to be controlled.

Figure 4.3 – Idealized Lognormal Distribution



(6) **Assess Exposures and Provide Control Plan** - Once 6 to 10 random samples have been collected, the data needs to be analyzed and decisions made. Analysis must be performed on data with the same averaging time (e.g., all 8-hour TWA samples, all STEL samples). That analysis should be performed in the following manner:

(a) Dealing with results below the analytical limit of detection (LOD).

1. 8-hour TWA sampling data. Navy industrial hygienists should adjust results that are less than the LOD prior to calculating the 8-hour TWA. Results that are less than the LOD are considered censored data. There are techniques to handle such censored data. At times in the past, the use of such techniques has been referred to as censoring.) When a less than LOD result has been adjusted using these techniques, the result is no longer expressed as a "less than" value. This adjusted result can then be used in calculating the 8-hour TWA. (The resulting TWA is likewise not expressed as "less than" the calculated value.)
2. STEL and Ceiling value data. Navy industrial hygienists will commonly encounter STEL and Ceiling value data sets with censored data that need to be adjusted prior to analysis.
3. Techniques for handling censored data. The following actions are recommended for preparing data sets with less than LOD result values for statistical analysis. Remember that once adjusted, the result value no longer carries the "less than" qualifier.
 - a. If 50% or more of the results are less than the LOD, the industrial hygienist should adjust the sampling protocol to obtain data that is greater than the LOD. Alternatively, contact the Navy and Marine Corps Public Health Center, Industrial Hygiene Department, (757) 953-0700, for assistance in analyzing such data.

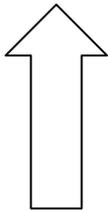
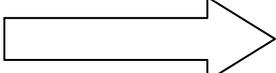
- b. For consistency, Navy industrial hygienists should divide less than LOD results by the square root of 2. Consult reference 4-1 for further information for the handling and analysis of censored data.
- (b) Verifying that the exposure monitoring data are lognormally distributed. Use the Shapiro Wilk test (sometimes referred to as the W-test) to determine if the exposure monitoring data is lognormally distributed. A log probability plot will also check for lognormality.
1. If the data is not lognormal, either the SEG is not correctly defined or the exposure population is not stationary. In that case, the SEG must be redefined. This does not mean to discard the data; rather it means regroup the data into two or more SEGs. For example, if the exposure population was not stationary, separate the sample results into two groups, one for the samples taken before the exposures changed and one for the samples taken after the exposures changed. In that case, additional samples will have to be taken and added to the group containing samples after the exposure changed to provide a total sample size of 6 to 10 samples. After that is done, return to the beginning of this paragraph and begin the data analysis with this new data set.
 2. If the data is lognormally distributed, continue the data analysis.
- (c) Verifying that the exposure population was stationary. If the population of exposures changed during exposure monitoring, the monitoring results cannot be interpreted as a whole. Plot the results sequentially as they were taken and look for trends either upward or downward. If a trend is evident, the data should be separated into two or more groups based on noticeable changes in exposure over time. If no trends are apparent, assume the exposure population is stationary and continue the data analysis.
- (d) Determining the descriptive statistics of the data. Calculate the sample median, range, maximum value, minimum value, arithmetic mean (using the minimum variance unbiased estimate [MVUE]), and standard deviation. From the log transformed statistics, calculate the geometric mean and the GSD.
- (e) Determining if the SEG is correctly defined. If the variability of the data is large (i.e., GSD >3), this may be an indication that either the SEG is not properly defined or the process is out of control. The industrial hygienist should determine if this is the case and, if so, adjust the definition of the SEG to decrease the variability and collect any additional exposure monitoring data required.
- (f) Estimating the exposures in the upper tail. For determining what Exposure Effect Rating category describes a SEG, focus on the 95th percentile exposure in the upper tail. These upper tail values are used to assess exposures that are compared to 8-hour TWA-OELs, STEL-OELs, and Ceiling-OELs and are what the Navy currently uses. The Industrial Hygiene Statistics Spreadsheet supplied with reference 4-1 may be used. This is an Excel® spreadsheet and requires the user to have Microsoft Excel® installed on their computer to run it. Another alternative is to calculate parameters using DOEHRs-IH SEG Assessment.
1. Determine the 95th percentile exposure
 2. Determine the UTL_{95%,95%}.
 3. Determine the exceedance fraction/probability of noncompliance.

4. Determine the one-sided 95% upper confidence limit ($UCL_{1,95\%}$) for the exceedance fraction/probability of noncompliance.
- (g) Refining a SEG's Working Exposure Assessment. The industrial hygienist is reminded that statistics are an aid to decision making and that the ultimate decision should be based on a combination of professional judgment and statistics. The results of exposure monitoring are fed back into the exposure assessment process at the basic characterization step. The following are guidelines for revising the Working Exposure Assessment based on exposure monitoring results of 6 or more randomly collected samples when compared to a Navy OEL, which is an 8-hour TWA, a STEL, or a Ceiling value:
1. If the 95th percentile exposure point estimate is greater than the OEL, the exposures may be unacceptable. Professional judgment along with all available information should be used by the industrial hygienist to make a final determination. For a SEG with an unacceptable exposure, controls may be instituted without additional sampling prior to introducing the controls. If the SEG is not selected for control actions, significant additional exposure monitoring should be conducted to better quantify the SEG's exposure distribution. Such processes should receive a high priority for additional exposure monitoring/information gathering.
 2. If the 95th percentile exposure point estimate and $UTL_{95\%,95\%}$ is less than the OEL, the exposures would be considered acceptable and the operation may be monitored at the discretion of the industrial hygienist as necessary to ensure that the exposure profile has not changed.
 3. If the 95th percentile exposure point estimate is less than the OEL, but the $UTL_{95\%,95\%}$ is greater than the OEL, the exposures would be considered as acceptable with some uncertainty thereby requiring additional information gathering. This SEG should be scheduled for annual exposure monitoring as long as it remains uncertain. Due to the small initial sample size (i.e., 6 to 10) $UTL_{95\%,95\%}$ less than the OEL may not be achievable from the first round of exposure monitoring. This depends on the geometric mean and GSD of the exposure population. The lower the geometric mean is as a percentage of the OEL and the lower the GSD is, the fewer the number of samples that are needed to satisfy the acceptance criteria.
- (h) Control of unacceptable or uncertain exposures.
1. Prioritizing SEGs for control of unacceptable or uncertain occupational exposures.
 - a. SEGs determined to have unacceptable exposures need to be controlled.
 - b. SEGs with EERs of 5 (expected unacceptable exposures) should be examined and have a higher priority for control, if needed.
 - c. For prioritizing SEGs with unacceptable or uncertain exposures, the methods described for determining EER, HRR and EAP (discussed earlier in this chapter), to prioritize the need for exposure monitoring/further information to develop an exposure monitoring plan, can also be used for a rough prioritization for controls. EER compares exposure estimates with the OEL; HRR combines health effect (HER) with exposure (EER); EAP combines uncertainty of exposure characterization and controls with the HRR. This standardized rating system provides a priority scheme for

instituting controls and/or the need for additional exposure monitoring/information gathering.

- (1) If the HRR is high and the Uncertainty Rating is low there may be no need for additional exposure monitoring/information gathering, and the SEG would have a higher priority for control. (In some cases, periodic exposure monitoring may be required to comply with regulatory requirements.)
- (2) If the HRR is low and the Uncertainty Rating is high, additional exposure monitoring/information gathering may be more appropriate.
- (3) If the HRR is high and the Uncertainty Rating is high, short term controls may be needed along with additional exposure monitoring/information gathering.
- (4) Consideration for controls could begin at HRRs 12 with low uncertainty, for example. Where there is higher uncertainty, there would be a higher priority for additional exposure monitoring/information gathering. Table 4.6 is based on a priority scheme from reference 4-1 and the DOEHRS-IH priority matrices and illustrates a potential plan of prioritizing the institution of controls and/or additional exposure monitoring/information gathering.

**Table 4.6 – Prioritizing Control and Additional Exposure Monitoring/
Information Gathering for SEGs**

 Health Risk Rating Priority for Control	25	50	75	100	125
	24	48	72	96	120
	23	46	69	92	115
	22	44	66	88	110
	21	42	63	84	105
	20	40	60	80	100
	19	38	57	76	95
	18	36	54	72	90
	17	34	51	68	85
	16	32	48	64	80
	15	30	46	60	75
	14	28	42	56	70
	13	26	39	52	65
	12	24	36	48	60
	11	22	33	44	55
	10	20	30	40	50
	9	18	27	36	45
	8	16	24	32	40
	7	14	21	28	35
	6	12	18	24	30
	5	10	15	20	25
	4	8	12	16	20
	3	6	9	12	15
	2	4	6	8	10
	1	2	3	4	5
Uncertainty Rating 					
Need for Additional Exposure Monitoring/Information Gathering					
Exposure Assessment Priority Rating Legend:					
	No Controls or Additional Exposure Monitoring/Information Needed				
	Additional Exposure Monitoring/Information Needed				
	Controls Needed				
	Controls and Additional Exposure Monitoring/Information Needed				

(5) However, prioritization schemes should NOT displace professional judgment, experience, or the evaluation of the particular situation. The industrial hygienist's knowledge is essential in proposing and prioritizing recommendations for controls and/or additional exposure monitoring/information gathering.

2. Actions after controls are implemented. After any new occupational exposure controls are implemented, the SEG's Working Exposure Assessment should be changed to uncertain and exposure monitoring should be conducted as described in this chapter. This new information should be used to update the exposure assessment starting with the basic characterization step.
3. Actions after additional exposure monitoring/information gathering. After any additional exposure monitoring/information gathering, the data should be used to refine and revise the exposure assessment starting with the basic characterization step.

(7) Reporting and Recording

- (a) Reports. Industrial hygiene survey reports are provided to the appropriate customer(s) in the manner outlined in Chapter 2 of this document.
- (b) Exposure assessments. Exposure assessments must be well documented by the industrial hygienist and retained in the industrial hygienist's files but the details of the assessment should not be reported to the customer due to the volume of material involved. Instead, a summary chart/list showing the SEGs and the final exposure assessment category assigned would be appropriate.
- (c) DOEHRS-IH. This program provides a recordkeeping system to define SEGs, exposure profiles, and working exposure assessments; document exposure monitoring; perform qualitative or quantitative exposure assessments; and document decision making and recommendations.

(8) Re-evaluation

- (a) Qualitative reevaluation. Although SEGs with acceptable exposures are not usually candidates for routine exposure monitoring, they require at least a qualitative reevaluation be conducted at least at the frequency stated in reference 4-5. Information from the reevaluation should be fed back into the exposure assessment process at the basic characterization step and all the elements of the exposure assessment should be updated.
- (b) Quantitative reevaluation. Although not required, a program to validate Working Exposure Assessments of acceptable with exposure monitoring data is recommended for 5% to 10% of these SEGs. Such data collection should not interfere or compete with the more important tasks of exposure monitoring of uncertain exposures or control of unacceptable exposures. Information from the reevaluation should be fed back into exposure assessment process at the basic characterization step and all the elements of the exposure assessment should be updated.
- (c) Changes. Any changes in the OEL, the workplace, or the work force that may affect exposures should be evaluated before or at the time the change occurs. Information or exposure monitoring results from the reevaluation should be fed back into the exposure assessment process at the basic characterization step and all the elements of the exposure assessment should be updated.

5. REFERENCES.

4-1 AIHA: *A Strategy for Assessing and Managing Occupational Exposures*, Third Edition, edited by William Bullock and Joselito Ignacio, Fairfax, VA: AIHA Press, 2006.

4-2 Leidel, N. A. and Busch, K. A.: *Statistical Design and Data Analysis Requirements*. In: Patty's Industrial Hygiene and Toxicology, 3rd ed., Vol. III, Part A, edited by R. L. Harris, L. J. Cralley and L. V. Cralley. New York: John Wiley & Sons, Inc. 1994. pp. 453-582.

4-3 Leidel, N. A., Busch, K. A. and Lynch, J. R.: *Occupational Exposure Sampling Strategy Manual*. DEW/NIOSH Pub. No. 77-173. Washington, D.C.: Government Printing Office. 1977

4-4 ACGIH. *TLVs® and BEIs, Threshold Limit Values for Chemical Substances and Physical Agents*. Cincinnati, OH: American Industrial Hygiene Association. Latest edition.

4-5 OPNAVINST 5100.23 Series <http://doni.daps.dla.mil/allinstructions.aspx>

4-6 The DOD Industrial Hygiene Working Group Report 2000-1, "*DoD Industrial Hygiene Exposure Assessment Model*," 2000