Section 1 – General Workplace Exposure Assessment Basics


The first step in assessing occupational exposures in a workplace is “information gathering.” Information is gathered on the workplace, work force, and environmental agents. This information is used to establish exposure groups and then assess worker exposures. At a minimum, information gathered should include an understanding of:

- Operations, processes, and facilities;
- Work force, tasks, and division of labor;
- Chemical, physical, and biological agents in the workplace;
- How and when workers are exposed to the environmental agents;
- Exposure controls present in the workplace, including engineering controls, administrative controls, work practice controls, and personal protective equipment;
- Quantities of the environmental agents;
- Chemical and physical properties of the environmental agents; and
- Potential health effects of the environmental agents, mechanism of toxicity, and OELs associated with each agent.

Basic Characterization builds on the traditional “walk-through” survey industrial hygienists have practiced for many years. Information is gathered to support judgment of occupational exposures, priority setting, and development of health hazard controls.

Information from the Basic Characterization creates the context for the assessment and helps tie various parts together.

To assess exposures and evaluate health risks, industrial hygienists must have sufficient comprehension of many factors. At a minimum, the following questions must be answered:

- What are the chemical, physical, and biological agents in the work environment? In what quantities?
- What health effects are associated with excessive exposure to the environmental agents?
- What are the occupational exposure limits (OELs) for each agent?
- How the work force is organized, staffed, and assigned tasks?
- What are the significant sources of exposure and how do workers interact with them? What processes, operations, tasks, and work practices pose significant sources of exposure to environmental agents?
- What are the process conditions? Temperature? Transfer points? Operating
speed? Energy inputs?
• What controls are in place, how are they used, and how effective are they?

Gathering Workplace Information
Workplace information may be gathered from a variety of sources. Many existing programs, such as Process Safety Management (PSM) and Preventative Maintenance (PM) programs, can contain valuable information to build the workplace characterization. Data found in a PHA (process hazards analysis) can provide a framework for starting basic characterization. Governmental reporting systems (such as US Environmental Protection Agency SARA reports), and company-specific engineering and purchasing systems may contain useful information about processes, chemicals, quantities of raw materials and finished products, equipment, and controls. Workplace operating procedures are an excellent source of information about the process, materials, tasks, and workflow.

Gathering Work Force Information
The goal of work force characterization is to understand the division of labor and work practices relative to the exposure sources. Detailed knowledge of routine and non-routine work assignments, work schedules, and tasks must be acquired and documented. Work force characterization should be based on a variety of resources, including the plant roster, job descriptions, worker interviews, management interviews and, most important, careful observation of work practices and the workplace.

Gathering Information on Environmental Agents
Each potentially hazardous chemical, physical, and biological agent in the workplace should be identified. For each agent, information describing its use, physical properties, routes of exposure, potential health effects, and pertinent OELs should be gathered.

A site’s inventory of hazardous materials and associated safety data sheets (SDS’s) can be a good foundation for identifying environmental agents. The SDS inventory should cover the majority of chemical agents in the workplace, including raw materials, products, additives, solvents, refractories, insulations, lubricants, coatings, resins, welding rods, and compressed gases.

Establishing Similar Exposure Groups
In most workplaces, it is difficult to measure the exposures of every individual worker. Even if these assessments were practical, daily measurements of each worker are seldom possible except in very specific circumstances, such as through the use of dosimeters to measure each worker’s daily exposure to ionizing radiation.

One strategy for meeting these challenges and attaining the goal of completing comprehensive exposure assessments for all workers is to assemble workers believed
to have similar exposures into a group. This stratification of workers into “similar exposure groups” allows limited resources to be allocated well so that all of the exposures present in a particular workplace can be characterized and managed effectively and efficiently.

A Similar Exposure Group (SEG) is defined as “A group of workers having the same general exposure profile for an agent because of the similarity and frequency of the tasks they perform, the similarity of the materials and processes with which they work, and the similarity of the way that they perform the tasks.” The SEG concept looks at the agents and tasks in an operation and seeks to group workers based on the similarity of their general exposure profile to these agents.

The methodology for establishing the SEGs and the determinants describing the SEGs may differ depending upon the exposure assessment goals (e.g. baseline assessment goals verses epidemiological study goals).

Two general methodologies are used to define SEGs: the observational (or qualitative) approach and the sampling (or quantitative) approach. In the traditional observational approach, workers are assigned to SEGs based on an examination of the activities they perform and a judgment on the expected similarity of their exposures. Exposure monitoring data are not needed. In the sampling approach, the exposures of many workers are measured, and the individual workers are assigned to SEGs based on a statistical analysis of the exposure data.

**Establishing Similar Exposure Groups by Observation**

In the observational approach, workers are subdivided into groups based upon the industrial hygienist’s qualitative review of the workplace. That review begins with the data gathered during the basic characterization. The industrial hygienist reviews these data and uses his or her training and experience to identify a group of workers who perform similar work and receive similar exposures.

The basic characterization should provide relevant descriptive information on the significant tasks being performed in the workplace, including some measure of task duration and frequency (e.g., days per year). This information may prove useful for prioritizing exposure groups for further information gathering and health hazard control.

In one application of the observational approach, the workplace is first subdivided into processes. Then each process is subdivided into jobs and/or tasks, and finally the workers associated with each of the jobs or tasks are identified thereby creating similar exposure groups. Environmental agents are linked with the SEGs via the process and task. Workers may be affiliated with more than one SEG.

In the sampling approach, the exposures of many workers are measured, and individual workers are assigned to SEGs based on a statistical analysis of the monitoring data.
This approach can be more accurate than the observational approach but an extreme amount of monitoring data is required.

A combination of both the observational and the sampling strategies is recommended to accrue the economies of the observational approach while minimizing the risk posed by misclassification of workers into SEGs by focusing the monitoring approach on "Critical SEGs". "Critical SEGs" are those SEGs for which there is a significant risk of inadvertently grouping some workers who incur unacceptable exposures to an environmental agent with workers judged to have acceptable exposures to the same environmental agent. As the organization's exposure assessment program matures, the industrial hygienist will be able to identify those "Critical SEGs." Critical SEGs can be targeted for more extensive exposure monitoring. Statistical analysis of the monitoring data can then be used to check the homogeneity of the SEGs formed by observation, and if necessary, individuals can be reassigned to an appropriate SEG.

**Exposure Profile**

An exposure profile is a summary “picture” of the exposures experienced by an SEG. This would include an understanding of the central tendency of the exposures (such as the mean exposure), an understanding of the variability of the exposures (such as the geometric standard deviation), and, most importantly, an understanding of the upper tail of the exposure relative to the OEL (such as the upper 95th percentile or the frequency with which exposures exceed the OEL).

Exposure profiles need to be defined well enough to ensure that the appropriate exposure management rating can be identified with confidence, instead of defining exposure profiles with a minimum uncertainty. Ensuring the appropriate exposure management rating is one of the keys to an exposure risk assessment and management program that is both effective (ensures acceptable exposure risk for all people on all days) and efficient (understands and manages the risk in a manner that is cost effective as possible).

**Exposure Acceptability Judgments**

The AIHA EASC established three judgments that can be made about acceptability of an SEG’s exposure profile:

1. It is acceptable (below the OEL)
2. It is unacceptable (above the OEL)
3. It is uncertain if there is not enough information available to make a judgment (e.g., the exposure profile has not been adequately characterized or there is limited toxicity data on the agent).

Judgment and consideration of other factors such as material toxicity, confidence in the OEL, and process characteristics must also be used to determine the difference
between statistical and practical significance. It may be possible to determine that the upper 95th percentile exposure to chemical “X” (OEL = 100 ppm) was 95 ppm with a statistical 95% upper tolerance limit of 98 ppm. The industrial hygienist would then be 95% sure that the average exposure was below the 100 ppm OEL. However, from a practical standpoint the risk might be found unacceptable because of concerns about the lack of an adequate safety factor in the exposure limit or the possibility of small changes in the operation leading to an elevated exposure profile 95th percentile.

Software tools for exposure decision making are now widely available – several of them as freeware. IHSTAT macro and macro-free version.

In determining compliance with regulatory and authoritative OELs that exist today, a focus on the upper tail would be most appropriate.

**Example: Examining the Upper Tail of the SEG Exposure Profile**

The following examples are provided here as initial illustrations of statistical techniques for examining the upper tail of an SEG’s exposure profile.

Six 8-hour TWA samples were taken to evaluate 2-butoxyethanol exposures for the Coil Coating Feed Operator SEG with the following results:

<table>
<thead>
<tr>
<th>Date</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 14</td>
<td>4</td>
</tr>
<tr>
<td>June 3</td>
<td>8</td>
</tr>
<tr>
<td>June 6</td>
<td>11</td>
</tr>
<tr>
<td>June 28</td>
<td>2</td>
</tr>
<tr>
<td>July 2</td>
<td>14</td>
</tr>
<tr>
<td>July 9</td>
<td>1</td>
</tr>
</tbody>
</table>

The monitoring data were used to estimate the 95th percentile of the SEG exposure profile and calculate a 95%, 95% upper tolerance limit for comparison to the 2-butoxyethanol OEL of 25 ppm.
LOGNORMAL PARAMETRIC STATISTICS

95th percentile 25.4 ppm

UTL95%,95% 214 ppm

The 95th percentile estimate is 25.4 ppm – just above the OEL and indicative of a Category 4 exposure. Because the UTL95%,95% of 214 ppm is far above 25 ppm, the industrial hygienist is not 95% confident that the true 95th percentile is less than the OEL. This exposure would probably be rated as “unacceptable.”

Exposure Ratings:

Category 0 – 95th percentile < 1% OEL
Category 1 – 1% OEL < 95th percentile < 10% OEL
Category 2 – 10% OEL < 95th percentile < 50% OEL
Category 3 – 50% OEL < 95th percentile < 100% OEL
Category 4 – 95th percentile > 100% OEL

For an example using the IHSTAT spreadsheet, see the annotated presentation on entering data into the AIHA IHSTAT spreadsheet. This example walks you through each step of entering data from a FEMA formaldehyde study.

Summary: Steps for Analyzing Monitoring Data

Review the exposure assessment decision criteria for acceptability. An appropriate objective might be to ensure that we are 95% confident that less than 5% of the exposures in the SEG exceed the OEL. The following steps would then be applied to baseline exposure assessments:

1. Design the sampling strategy.
   a. Consider the SEG and time interval being evaluated.
   b. Plan to gather at least six to 10 measurements to start.
   c. Randomize the measurements as much as possible.
   d. Try to avoid clustering of measurements into a single monitoring campaign covering successive periods.

2. Collect the measurements.
   a. Collect random samples as often as possible.
   b. Take care to record relevant information about the measurement and the process.
   c. If there is an unusual occurrence (e.g., spill, process shutdown) make note of it.
   d. This information will help with data interpretation; however, be wary of excluding data – just because it is not “typical” does mean it does not
contribute to naturally occurring variability.

3. Plot the data in a time series as a subjective test for population stability.
   a. Trends in the data, as opposed to random variability, might indicate that the exposure distribution from which you are sampling is systematically changing over time.
   b. If systematic change is apparent, be extremely careful when pooling or omitting data for statistical analysis.

4. Calculate simple descriptive statistics (i.e., sample size, mean, median, minimum, maximum, standard deviation, GM, GSD, percent of actual data above OEL).

5. Plot the exposure data on log probability scales.
   a. If the plot approximates a straight line there is reason to believe the data are adequately described by a lognormal distribution.
   b. If the data do not approximate a straight line then consider that the SEG was improperly defined.
   c. If the data fit a straight line on lognormal paper then a Filibens test, W-test, or other objective test can be used to quantitatively test the hypothesis that the data are parametric.

6. Use the eyeballed best-fit straight line through the points on the log probability paper to estimate GM (50% point) and the GSD (85% point divided by the 50% point).
   a. Examine the plot to determine the 95th percentile to begin getting a picture of the upper extremes of the exposure profile.

7. Estimate the 95th percentile and its upper confidence limit (tolerance limit) for the percentile.

8. Review the available data, information, and statistical results for the SEG.
   a. Determine whether misclassification of individuals in the SEG is critical.
   b. If so, prioritize the SEG for further information gathering to better refine the SEG.
   c. If ANOVA will be used, randomly choose several employees from the SEG and monitor their exposures several times.

Judge the exposure to be acceptable or unacceptable in view of the exposure assessment objectives.

**Recordkeeping & Reporting**

Communications are the vital link between the industrial hygienist’s efforts and employee health protection. Workers and management must understand the health risk
present in the workplace since their support and participation is vital to implementation of health hazard controls. Industrial hygiene communications must be timely and effective. Exposure assessment findings must be shared with all similarly exposed workers and those in the organizations who support employee health protection. Exposure assessment findings may be communicated through both written reports and oral presentations. Graphical tools and statistical parameters can be used to enhance communication of exposure assessment findings and health risks.

Note: your professor or PDC instructor may provide you with a specific report format to follow. Also, some graduate programs will require you to follow a specific style guide or APA format!
Section 2 – Specific Iron Foundry Project Information

The following is a description of the sections and processes that appear in the Foundry tour video. The description is intended to provide you with some additional information for developing completing your assignment.

The foundry produces steel castings. It operates as a job shop, making parts based on orders that they receive. The foundry basically is a batch processor; the type of parts that are made can change from day to day.

The foundry uses an induction furnace to melt scrap iron and steel, unused steel returned from previous pours, and alloying metal powders which are used to adjust the chemistry of the steel to meet the specifications of the parts that they are making. There are two workers, a furnace operator and a helper, who add the scrap steel and metal powders (called charging) and turn on the furnace. When the steel reaches the proper temperature and consistency, samples will be taken by the helper and tested in the foundry’s chemistry lab to determine the steel's makeup. The furnace operator will add steel, iron, and alloying metals until the steel meets the required specifications. When the steel meets specifications, it is poured from the furnace into a transfer ladle. Then more steel/iron and alloying metal powders are added to begin the second batch.

The molten metal in the transport ladle is moved over to the pouring floor which is shown as “Cope and Drag” on the plant layout. The ladles hang from overhead tracks and the ladle operator pushes them from one area to another. There are about six workers involved in the pouring; usually there will be a ladle operator and a helper for each ladle. The molten metal from the transfer ladle is poured into two smaller ladles which are then used to pour the molten metal into the molds. There are two types of molds shown in the video: one is an open top mold which is used to make the manhole covers; the other is a two-part (covered) mold which is used to make more complicated parts such as the diesel engine mounts. For the single part open molds, the ladle operator simply pours the molten metal into the cavity on the top like pouring water into a tank. For the closed two-part mold, the molten metal is poured into an opening in the top of the mold (call the spur) until molten metal comes up through one or more smaller holes called raisers. When the molten metal is added to the molds, the binders and sealers in the mold will begin to decay and release some decomposition produces, some of which are flammable and will begin to burn when they come into the air (in most cases the ladle operators will ensure that the flammable materials do burn off by lighting themselves).
See the foundry basic Characterization pdf file for process information from each area.

Virtual video tour:

Virtual Tour Route → →

Start: ★

End: ★
Instructions for completing your research project or virtual case study

Step 1 - Basic Characterization:

☐ Identify the hazards recognized in the shell core foundry video clip
☐ Identify the worker roles, and whether those roles and exposures are distinct

1. Review the shell core video, facility map, MSDSs, etc.
2. Complete Basic Characterization Blank Form for the shell core operation
3. Qualitatively consider/judge exposure profiles, complete initial exposure rating for the shell core operation

Step 2 - Establishing similar exposure groups (SEG):

☐ Identify the hazards recognized in the foundry video clip
☐ Identify the worker roles, and whether those roles and exposures are distinct enough to generate numerous SEGs
☐ Propose those SEGs

1. Review the walk-through video, facility map, foundry description, MSDSs, etc.
2. Complete Form 1 SEG Blank Form
3. Prioritize the SEGs

Thought Questions to consider as you evaluate the Foundry Videos and Data:

1. What common roles or tasks do you observe?
2. Do these tasks link clearly to hazards? Why or why not?
3. What SEGs have you created? List them.
4. What was the basis of determining the need for further evaluation?
5. Which Operations or Environmental Agents should be prioritized for additional investigation and/or exposure monitoring further? Why?
Isopleth Map of PM 10

PM-10 in mg/m³ collected with a TSI handheld dust monitor
Isopleth Map of PM 2.5

PM-2.5 in mg/m³ collected with a TSI handheld dust monitor
Isopleth Map of Carbon Monoxide

CO data in ppm collected with an Industrial Scientific TMX412
Isopleth Maps

Velocity data in m/s collected with TSI Velocicalc
Area noise data collected with a Quest Sound Level Meter:

- Vibration table back end of Shaker
  - 100 dBA running
  - 93 dBA background noise
- Bench Grinders
  - #1 97 dBA
  - #2 100 dBA
  - #3 97 dBA
- Grinders Wheels # 1 & 2
  - 92 – 95 dBA
- Shell Core Machines
  - 82 – 85 dBA

Personal noise data collected with a Quest Noise Dosimeter:

- Back End Shakeout
  - 96.5 dBA
- Bench Grinder
  - 98.4
- Grinding Wheel
  - 97.0 dBA
- Shell Core
  - 83.3 dBA

Utilize the information provided above to tailor your project / case study presentation, then show the students.