Chapter 10: Industrial pollution and chemical safety

10.1. Problem-solving exercise: occupational exposure to inorganic lead
10.2. Discussion starter on occupational hazards
10.3. Lecture/demonstration on personal protective equipment and methods for atmospheric monitoring
10.1. Problem-solving exercise: occupational exposure to inorganic lead
Prepared by Evert Nieboer*

**Time:** Two 1-2 hour sessions, with independent study.

**Objectives:**
At the end of the exercise, students will be able to:

1. Define and explain hazard identification, dose-response relationships, exposure assessment, risk characterization, NOAELs and LOAELs, risk management, environmental controls, threshold limit values (TLVs), and the principles of occupational health surveillance/monitoring.

2. Understand the need for a preventive approach to protect workers' rights to a clean working environment and for workers' participation in planning environmental control or health surveillance programmes.

3. Appreciate the long-term social and economic benefits of a clean working environment.

4. Promote worker education and training in health and safety and the promulgation of air and related exposure regulations.

**Procedures:**

1. Introduce the exercise and review its objectives. Divide participants into small groups (4-6 persons). Instruct participants to identify a chairperson and a recorder.

2. Distribute the exercise and review the participants' tasks.

3. Brainstorm a list of the key issues raised in the case study with the entire group. Alternatively this can be done in small groups. This helps to establish the existing knowledge among members of the group and to identify resource persons.

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4. Following small group work, reconvene the groups and invite a response from one group to the first question. Ask whether other groups have any different responses. Summarize, and if necessary, expand on the participants' responses and proceed to Question 2. Allow a different group to initiate the discussion and continue in this way until all questions have been answered. Possible answers to the questions are provided below. These answers are not all-inclusive. Instructors are encouraged to develop alternative responses and intervention strategies that are appropriate to the local situation.

5. Summarize the results, emphasizing key messages.

Materials:

Problem-solving exercise (Annex 23), flip chart, coloured markers.

Case scenario

To assess lead exposure in the Jamaican lead-acid battery manufacturing industry, three separate plants were surveyed. Of the 42 personal breathing-zone air samples collected, 38 exceeded the OHSA (US Occupational Health and Safety Administration) regulated permissible exposure level (PEL) of 50 µg/m³ (range 30-5300 µg/m³) and nine samples exceeded 500 µg/m³. The air samples were collected on mixed cellulose-ester filters using a flow rate of 2 L/min for the duration of the work-shift. Twenty-eight percent of the workers had blood levels exceeding 2.90 µmol/L (60 µg/dL). More specifically, in Plant B, the geometric mean of the air lead levels was 233 µg/m³, with 60% in the range 50 to 200 µg/m³ and the remaining 40% exceeding 500 µg/m³. The distribution of the measured blood-lead levels in the same plant was: 9% < 1.93 µmol/L (<40 µg/dL), 17% between 1.93 to 2.85 µmol/L (40-59 µg/dL), 57% in the range 2.90-3.81 µmol/L (60-79 µg/dL), and 17% above 3.86 µmol/L (80 µg/dL).

In a recent critical assessment of the literature, IPCS (1995) suggests the following NOAEL blood-lead levels for biochemical or health effects of lead exposure in adults: 1.20 µmol/L (25 µg/dL, men) and 0.96 µmol/L (20 µg/dL, women) for haem synthesis depression measured by zinc protoporphyrin (ZPP), also referred to as erythrocyte protoporphyrin (EP); 2.16 µmol/L (45 µg/dL) in men and 1.68 µmol/L (35 µg/dL) in women for urinary excretion of ALA (aminolaevulinic acid); ≤ 0.48 µmol/L (10 µg/dL) for learning and behavioural effects in children; 2.40 µmol/L (50 µg/dL) for anaemia; 1.44 µmol/L (30 µg/dL) for reduction in peripheral nerve conduction velocity; 1.92 µmol/L (40 µg/dL) for sensory motor function impairment; 1.68 µmol/L (35 µg/dL) for alterations in the autonomic nervous system function; and 2.88 µmol/L (60 µg/dL) for risk of nephropathy. The blood-lead/air-lead relationship in occupational settings is curvilinear, having slopes between 0.00096 and 0.0038 µmol/L (0.02 and 0.08 µg/dL) per µg/m³ air. WHO (1980) recommends that air levels should not exceed 30-60 µg/m³; in most other jurisdictions, threshold limit value-time-weighted average (TLV-TWA) values of 100 to 150 µg/m³ are recommended (Saryan and Zenz, 1994).
Review questions

Chapter 3 Questions

1. In terms of hazard identification, succinctly state what we know about the adverse health effects of lead.

   The exposure in the case scenario is to inorganic lead. This grouping includes lead metal fumes, lead binary compounds such as oxides or sulphides, ternary compounds such as sulphates and phosphates, water-soluble lead salts (e.g. chloride, nitrate, acetate). The majority of the lead compounds have lead in the +2 oxidation state. Organometallic lead compounds (organic lead) are characterized by the lead-carbon bond. The prime example is the gasoline additive tetraethyllead [\(\text{Pb}(\text{CH}_2\text{CH}_3)_4\)]. In alkyl lead compounds, lead is in the +4 oxidation state. By contrast to inorganic lead compounds, organometallic lead compounds are soluble in organic solvents and biologically speaking are lipid (fat) soluble.

   Inorganic lead compounds are systemic poisons (IPCS, 1995). Acute effects include abdominal pain (colic), encephalopathy (degenerative brain disease), haemolysis and acute renal failure. Chronic effects are manifested as fatigue, weakness, muscle and joint pain, anaemia, peripheral nervous system disturbances (neuropathy), central nervous system (CNS) effects (including neurobehavioural disturbances), gout and kidney alterations. Reproductive and developmental effects have also been documented. Lead is readily transferred across the placenta. Of great concern are the learning and behavioural deficits observed in young children, even for low-level exposures. Contaminated soils or lead-containing paints are frequent sources of inorganic lead for children. The symptomatology associated with exposure to alkyl lead compounds is somewhat different than for inorganic lead intoxication. Symptoms comprise fatigue and lassitude, headache, nausea and vomiting, neuropsychiatric complaints (memory loss, difficulty in concentrating) and, if severe, delirium seizures and coma.

   Perhaps short student presentations would be an effective way to summarize the health effects of lead.

2. Based on the biological exposure indices or NOAELs provided in the case scenario, what are the likely shapes of the dose-response curves (i.e. effect versus lead in blood)?

   A “threshold response” such as that depicted in Figure 3.12 is predicted.
3. **Are the threshold values in agreement with those indicated in Figure 3.10?** Give reasons for any discrepancies.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Scenario</th>
<th>Threshold (µg Pb/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>haem synthesis (ZPP)</td>
<td>200 (females), 250 (men)</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>urinary ALA</td>
<td>350 (females), 450 (men)</td>
<td>-----</td>
</tr>
<tr>
<td>anaemia</td>
<td>500</td>
<td>750</td>
</tr>
<tr>
<td>peripheral nerve conduction</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>sensory motor function</td>
<td>400</td>
<td>-----</td>
</tr>
<tr>
<td>autonomic nervous system</td>
<td>350</td>
<td>-----</td>
</tr>
<tr>
<td>nephropathy</td>
<td>600</td>
<td>-----</td>
</tr>
<tr>
<td>cognitive and behavioural</td>
<td>≤100</td>
<td>≤100</td>
</tr>
<tr>
<td>effects in children</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The differences in these threshold evaluations probably reflect the number of published studies reviewed to obtain the data depicted in the figure. The lead value of <50 µg/L for increases in ZPP probably refers to children. IPCS (1995) suggests that 0.72 µmol/L (150 µg/L) is the NOAEL for excess ZPP formation in children. In spite of these discrepancies, it is clear that lead is a very potent systemic poison.

4. **Comment on the exposures experienced by the workers.**

As indicated in the case scenario, TLV-TWA values vary between 30 and 150 µg/m³. The American Conference of Governmental and Industrial Hygienists (ACGIH) in its 1995-1996 TLV-TWA listing has set it at 50 µg/m³ for elemental and inorganic lead compounds; the previous value was 150 µg/m³. The reason for this change is that lead compounds have been designated as animal carcinogens. Clearly, some of the workers in the scenario are exposed to air-lead levels that are too high by most international standards.

5. **In your opinion, are the workers at risk? Justify your answer. Can you characterize this risk?**

Taking Plant B as the example, it is clear that the air levels of lead exceeded all international standards. A similar picture emerges by comparing the blood-lead values with the NOAEL values. In terms of risk characterization, up to 90% of the workers may be expected to have enhanced risk for measurable biochemical, haematological or neurological changes; about 60% of the workers may be considered at risk for kidney damage.
6. **Do you believe the workers are subjected to a risk high enough to warrant work refusal?**

Certainly the workers with blood-lead levels exceeding 3.86 µmol/L (80 µg/dL) would be removed from work in most jurisdictions. For example, this is warranted in the USA if three blood samples exceed 2.90 µmol/L (60 µg/dL); in the Province of Ontario, Canada, removal is required for levels ≥ 3.38 (70 µg/dL) in the case of male workers and 1.90 µmol/L (40 µg/dL) for females of childbearing age.

7. **Clearly lead is a systemic poison. Explain why the total (inhalable) lead levels are measured rather than the respirable fraction?**

Total inhalable lead levels are relevant for a systemic poison like lead. Some absorption can take place directly through the tissues of both the upper and lower respiratory tract. In addition, the upper respiratory tract is cleared by ciliary action (including the nasal passages and bronchial epithelium), which results in swallowing or rejection by coughing/spitting. Of course, the amount swallowed will contribute significantly to the total amount absorbed.

**Chapters 4 and 10 Questions**

1. **Would you recommend that the workers in the case scenario should be issued personal protection equipment? If so, what would you recommend?**

Personal protective equipment should be issued to some workers since their exposure is at levels above the TLV-TWA of many jurisdictions; personal protection is usually mandated for occasional brief exposures above the TLV-TWA or for emergencies. For example, in the USA, NIOSH prescribes the following respirators: (i) half-mask, air-purifying respirator equipped with high-efficiency filters for air-lead levels not exceeding 500 µg/m³ which corresponds to 10 x PEL; (ii) full facepiece, air-purifying respirator with high-efficiency filters for air-lead levels not exceeding 2500 µg/m³ (50 x PEL); (iii) for levels not in excess of 50,000 µg/m³ (1000 x PEL), any powered, air-purifying respirator with high-efficiency filters or half-mask supplied-air respirator operated in positive-pressure mode. It is further specified that full facepiece protection is required if the lead aerosols cause eye or skin irritation at the use concentrations and that a high efficiency particulate filter means it is 99.97% efficient against 0.3 µm size particles (Saryan and Zenz, 1994). It should be emphasized that personal protective equipment is for use when the engineering control measures fail to provide a safe working environment. Respirators are not to be substituted for technical control measures and are not to be regarded as the primary method of protection.
2. **What additional information do you need to know about the plant and workers before an environmental control programme can be considered?**

Before an environmental control programme can be implemented, more needs to be known about the physical characteristics and dimensions of the plant (including workroom ventilation), the manufacturing process, and the operational details (number of employees, job classifications, daily production, number of shifts etc.).

To make the discussion more realistic, a number of the students might consult the references that deal with exposures of lead-acid battery workers (i.e. Awad El Karim et al., 1986; Matte et al., 1989; and especially Caplan et al., 1979). Briefly, a lead matrix or grid is cast and a paste, primarily composed of lead, lead oxide, sulphuric acid, water and expanders, is pressed into and onto the grids at the pasting machine. The pasted grids or plates pass through an oven to dry the surface to prevent sticking. Curing follows, with the plates stacked on racks. Subsequently, plates are parted as they are produced in pairs. Parted plates are arranged to form elements (alternating negative or positive plates with an inert separator between them) by hand or machine and are then welded to form groups. A common feature of battery plants is the transfer of grids, plates, elements or groups between steps of the process, on racks or pallets (i.e. platforms). Often the employees transfer the plates by hand between the racks and work stations. Lead dust is the most significant health exposure (Caplan et al., 1979).

3. **Discuss the control options that might be considered or implemented to decrease workers’ exposure?**

As mentioned in answer to Question 1, it is important to stress that personal protection is not an acceptable substitute for proper ventilation and containment. Personal protection is only an interim measure. The control options are administrative controls (change procedures, establish work rules) and engineering controls (e.g. install a suitable ventilation system, limit lead exposures). Ventilation by diluting contaminated air with uncontaminated air is not as satisfactory for health hazard control as local exhaust ventilation, in which contaminants and process emissions are captured prior to their escape into the workplace environment.

4. **What is a TLV-TWA? Would the promulgation of such an inorganic air-lead standard help? What about BEIs?**

The TLV-TWA used in western countries is the time-weighted average concentration for a normal 8-hour workday and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. BEIs, biological exposure indices, are reference values intended as safety guidelines in biological monitoring to evaluate the existence of potential health hazards in the practice of industrial hygiene. Biological monitoring consists of an assessment of overall exposure to
chemicals by measuring the appropriate parameter in biological specimens collected from the worker at specified times. Blood and urine are the usual body fluids collected. The concentration of the contaminant in these fluids is often a suitable indicator of exposure. The measurement of metabolites that reflect biochemical changes or tissue injury are also possible, such as ZPP in blood or ALA or enzymes in urine.

There is no doubt that the implementation of a suitable TLV-TWA would protect the worker.

5. **Design a risk management package that includes air monitoring, biological monitoring and medical surveillance for use after the appropriate control measures have been put into place.**

In the short term, routine and rather frequent personal air measurements should help to identify the exposure associated with various components of the plant operations or specific jobs. Collection should be over an entire shift and, if possible, on two to three consecutive days for individual workers. Adjustments to the engineering controls may be necessary to keep exposures within accepted ranges. The frequency of air measurements can probably be reduced when designing a long-term monitoring programme. Of all the biochemical parameters that can be measured, blood-lead concentration appears to be the most effective index of exposure. Consequently, periodic (e.g. twice per year) assessment of blood-lead levels is warranted. The frequency of such measurements should be increased in cases where the levels give an indication of unwanted lead exposure (e.g. > 1.93 µmol/L or > 40 µg/dL), and increased to monthly assessments during medical removal from exposure (e.g. for levels > 2.90 µmol/L or > 60 µg/dL). Medical examination might be done when any blood-lead level exceeds 1.93 µmol/L (40 µg/dL), prior to assignment in an area where lead levels are around the TLV-TWA, or as soon as possible if a worker develops any signs or symptoms of lead intoxication. Worker personal hygiene also needs to be optimized.

6. **Does the risk management package suggested adhere to the principles of occupational health surveillance stated in Table 10.5?**

The workers must be involved in the planning and acceptance of the monitoring programme. Appropriate worker training sessions should be implemented to explain the programme objectives and the health implications associated with exposure to lead. Baseline levels of blood-lead should be obtained. Each worker should be informed of his or her individual result; only group test results, without personal identifiers, should be posted or reported to ensure workers’ confidentiality.
7. **Debate workers' rights and responsibilities using the present scenario as a basis for discussion.**

In the planned debate, the following workers' rights might be considered: (i) the right to participate or be part of identifying and resolving workplace health and safety concerns; (ii) the right to know about potential hazards; (iii) the right to refuse work that is believed to be dangerous, without penalty or discrimination; (iv) the right of certified “safety and health” personnel to stop the work. No doubt the acceptance or manner of implementation of such rights will vary between jurisdictions. Responsibilities are usually not identified formally. Nevertheless, they should be part of your debate/ deliberations.

**Selected references**


10.2. Discussion starter on occupational hazards

Prepared by Merri Weinger

✍️ Time: 1 hour

✔ Objectives:

At the end of the exercise, students will be able to:

1. Identify how occupational hazards affect women in particular ways.
2. Use gender as a critical category to analyse and propose potential solutions for occupational health hazards.

🎉 Procedures:

1. As mentioned in the review of selected teaching methods in Part I, the discussion starter can take a variety of forms such as role-play, case study, picture, or video. This exercise demonstrates a scripted role-play of a conversation among workers at a fish factory. Ask for three volunteers and invite them to come to the front of the room to read their lines.

Role-play

Maria: Did you hear about Catherine? She's still off work with those pains in her wrist. She may lose her job.

William: It didn't sound that serious to me. I think she just wanted some time off.

Maria: It is serious. She's been to the doctor several times, but he's not sure what it is.

William: That's because it's all in her head.

Anna: Why doesn't she just change jobs?

Maria: What else could she do? All the better jobs around here are done by men.

William: She'd better figure it out soon. She can't stay off work forever.

2. Facilitate a discussion on the scenario portrayed in the role-play using the following guidelines. Your leading questions to participants follow the acronym SHOWEd described on page 8. Some potential responses are listed below each question.

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See: What do you see here? What are the issues being raised?
Some ideas might be the expression of different attitudes about the illness of a co-worker, the problems faced by a woman worker, her lack of options, and a lack of compassion for her problems.

Happening: What’s really happening here? How do each of the characters feel? What about William?
Cynical, lacking in compassion, skeptical about the illness of his colleague, reflecting "traditional" attitudes about women and work, representing the views of management.

What about Maria?
Compassionate, concerned about her friend, conscious of the problems and the apparent lack of options available to her co-worker.

What about Anna?
Perhaps a bit naïve, unaware of her own lack of mobility and that of her co-worker, and looking for an easy solution to a complicated problem. She may not acknowledge the health problem of her co-worker.

Our: Does this situation seem familiar? How is it similar? How is it different?
Encourage participants to share similar or different experiences.

Why: Why is .............. such a problem?
Name the problem identified during the discussion. For example, it may be discrimination against women, lack of options for women, occupational hazards and their effect on women, or lack of understanding about certain occupational health problems. Discuss the causes of the problem (e.g. social, political, cultural, institutional, etc.).

Do: What can you do about it?
Discuss short-term and long-term action strategies. Some could be adopted immediately; others would require long-term institutional changes.

3. Conclude the discussion. Review the issues that have been raised about occupational hazards and their effects on women. Acknowledge the important role of values and attitudes in determining outcomes and action (e.g. the pervasive attitude that women workers are complainers, unequal to the task, hysterical, and so on).
10.3. Lecture/demonstration on personal protective equipment and methods for atmospheric monitoring

含まれที่: 1 hour

✓ Objectives:
At the end of the exercise, students will be able to:
1. List the main types of personal protective equipment used to prevent exposure to occupational hazards, as well as their advantages and disadvantages.
2. List the main methods for atmospheric monitoring, plus their advantages and disadvantages.

✍ Procedures:
1. Bring to the classroom samples of protective work clothing and equipment for a particular work environment and display them in front of the class. (For example, for agricultural workers with exposure to pesticides, bring several types of respirator, gloves, hat, overalls, boots.) Display samples of both adequate and inadequate equipment to provide more of a challenge to students.

2. Introduce the following scenario.
“You are a farmworker who will be manually applying pesticides using a backpack sprayer. You need to get dressed for work. The temperature today is 90°F.”
Invite a volunteer to select from the equipment displayed and dress for work. Ask for comments from the class and the volunteer.

3. Follow with a discussion of appropriate protective clothing and equipment, attitudes toward utilizing equipment, level of personal comfort and compliance, and implications for development of control strategies.

4. Demonstrate equipment for air monitoring (e.g. monitor carbon dioxide in the classroom), noise monitoring, etc. Utilize the demonstration to initiate discussion of the different atmospheric monitoring techniques and their advantages and disadvantages.
Alternatively, ask for students to volunteer to track down and bring in equipment to demonstrate and discuss.
Materials:
Sample protective clothing and equipment, sample monitoring equipment.