Guide to Data Gathering Systems for Risk Assessment of Metals and Metal Compounds

Final Version
(October 1999)
Foreword
Any risk associated with the production and use of metals must be acceptable from the health, safety and environmental perspectives. To that end, scientific knowledge gathered partly through epidemiological studies is used to assess and manage the risks associated with metals and/or their compounds. However, many of the current regulations do not take into account the fact that separate metal species have unique properties, risks and benefits. I.e., metal speciation is generally ignored. There may be good reason for this, as knowledge of the differing effects of different metal species has not been well documented. It is therefore crucial that this knowledge gap be closed if accurate risk assessments and appropriate and effective regulations are to be developed and implemented.

ICME has developed the present guide in an effort to help close this gap. The purpose of the guide is to provide ICME members and others in industry with a tool to develop and implement systems in occupational settings that collect data related to speciated metal compounds. Data thus collected will not only help clarify the relationship between exposure to metal species and occupational health effects, but will also allow for more accurate risk assessments by providing necessary information for epidemiological studies.

ICME recognizes that the implementation of an effective data gathering system will take some time, as will the generation of sufficient data to permit a credible risk assessment.
less, it is hoped that the approach reflected in this guide is a step in the right direction.

Gary Nash
Secretary General
ICME
INTRODUCTION TO THE GUIDE

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Introduction to the Guide
Introduction to the Guide

The information contained in this guide is designed and presented for a non-specialized reader. No particular expertise or background is required to be able to use and apply the information in a practical setting.

An Assessment Survey is presented in Appendix F. This survey can be used by the company as a framework to assess the current status of its data gathering system. It can also be used as a valuable tool for conducting ongoing audits of its program.

The outer part of each page is reserved for brief comments that act as an overview of the contents of the page. Ample space is provided for readers to add their own notes and supplementary information appropriate to their companies and circumstances.

An outline of the guide in slide presentation format (PowerPoint) is contained on a floppy disk included in this binder (Appendix G). The presentation may be used by in-house instructors and/or printed in booklet form and used for note-taking by in-house participants. Please note that this presentation was prepared by a health and hygiene team from Noranda Inc., and some of the examples are specific to their sites.

This guide is based on the 1996 ICME publication *Infrastructure and Systems for Risk Assessment of Metal*
Section 1: Reasons to Develop an Infrastructure

Metals and Health

Speciation

Epidemiology and Risk Assessment

Consistent Data Collection and Storage
Section 1: Reasons to Develop an Infrastructure

Metals and Health

Metals and Health

All substances are poisons: there is none which is not a poison. The right dose differentiates a poison and a remedy.

This quote, attributed to the sixteenth-century physician Paracelsus, applies to metals as well as non-metallic substances. In fact, metals play key roles in the routine activity of many of the physiological systems of humans and other living organisms. Too little of some of these metals can be as damaging to human health as too much.

FIGURE 1
Percent of Population Subjected to Deficiency and Toxicity Effects According to Exposure of Intake of the Essential Trace Element.

METALS HAVE A COMPLEX RELATIONSHIP WITH LIVING ORGANISMS.
## Metals and Health

For example, the human body needs:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>calcium</td>
<td>copper</td>
</tr>
<tr>
<td>iron</td>
<td>molybdenum</td>
</tr>
<tr>
<td>sodium</td>
<td>chromium</td>
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<td>potassium</td>
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<td>zinc</td>
<td>cobalt</td>
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<td>germanium</td>
<td>nickel</td>
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<tr>
<td>rubidium</td>
<td>silicon</td>
</tr>
<tr>
<td>vanadium</td>
<td></td>
</tr>
</tbody>
</table>

Apart from the biological significance of certain metals as essential elements, the possibility that metals can have adverse effects on human health is a concern held by members of the metal industry, scientists, and regulatory bodies. Some relationships are known. For example, cumulative exposure to cadmium is associated with emphysema and kidney disease, an understanding that resulted from years of collection of cadmium exposure information. However, there is still a great deal that is unknown about the relation between metals and disease.

### NOTES
Section 1: Reasons to Develop an Infrastructure
Section 1: Reasons to Develop an Infrastructure

Speciation

Metals appear in many different forms—as elements as well as different species or compounds. Cadmium occurs as a number of distinct inorganic chemical compounds, each with different properties. Some of the cadmium species are known to present different degrees of hazard to human health.

Cadmium Species

- cadmium oxide
- cadmium cyanide
- cadmium fluoride
- cadmium chloride
- cadmium sulphide
- cadmium formate
- cadmium fluorosilicate
- cadmium iodide
- cadmium sulphate

Speciation—attention to species of metals—has become a significant issue among members of the metals industry, scientists, and regulatory bodies. Every metal, as well as any of its species or compounds containing that metal, must be considered individually.
Section 1: Reasons to Develop an Infrastructure
Section 1: Reasons to Develop an Infrastructure

Speciation

This position is supported by considerable evidence suggesting that the various species of metals can differ significantly with respect to their effects on human health. The degree of these effects is partly determined by toxicity. Toxicity is the ability of a material to produce unwanted effects when the substance has reached a sufficient concentration at a specific site in the body (Ottobani, 1991 as cited in Verma et al., 1996). The toxicity of many metals is profoundly affected by their chemical form.

The combination of metals and other chemicals that we are exposed to complicates the picture further. For example, the pyrometallurgical smelting of zinc is associated with exposures to zinc, lead, cadmium, arsenic, sulphur dioxide and dust (Gaunt, 1997). In the past, there was also exposure to asbestos and crystalline silica from the handling of refractory products and to fumes from coke ovens. Again, with exposure to all of these substances simultaneously (or concomitantly), it becomes difficult to determine which substance is having a negative effect.

Table 1 suggests there are thousands of substances to which the public may be exposed (Report of the International Workshop on Risk Assessment of Metals and Their Inorganic Compounds, 1997). The fact that there are so many substances also makes it difficult to establish which substance is having a negative effect.

THERE IS EVIDENCE THAT SOME SPECIES OF SOME METALS MAY BE HEALTH HAZARDS.
Section 1: Reasons to Develop an Infrastructure

Speciation

**ESTIMATED NUMBERS OF CHEMICALS**
(EPA estimations, 1995)

- Number of Chemicals: 5,000,000
- Chemicals in Commerce: 80,000
- Industrial Chemicals: 72,000 (millions of products)
- New Chemicals: 2,000/year (1,000 in US)
- Pesticides: 600 (21,000 products)
- Food Additives: 8,700
- Cosmetic Ingredients: 7,500 (40,000 products)
- Human Pharmaceuticals: 3,300

**Table 1**

Studies related to chromium also illustrate the importance of speciation (Gray, Jeffery and Marchant, 1997). Studies had shown excess risk for lung cancer in workers in the chromate production industry. However, because workers were exposed to a variety of forms of chromium, including chromium [VI] and [III] compounds, it was difficult to attribute the risk to a particular type of chromium. When researchers looked in greater depth at workers in the chromium plating industry, who are exposed primarily by inhalation to soluble chromium [VI] compounds (and who also have an excess of lung cancer), and ferro-chromium workers who are primarily exposed to chromium [III] compounds and to metallic chromium (and who do not show an increase in lung cancer), they were able to determine that inhaled chromium [VI] compounds are carcinogenic, but

THERE ARE THOUSANDS OF CHEMICAL SUBSTANCES TO WHICH WE MAY BE EXPOSED.
Section 1: Reasons to Develop an Infrastructure

there was not enough evidence to say that chromium [III] compounds or chromium metal are carcinogenic.

The following list of metal elements indicates some species that have been implicated as health hazards:
Speciation

nickel:
metallic nickel, oxidic nickel,
soluble nickel, sulphidic nickel

chromium:
chromium III, chromium VI

cadmium:
cadmium oxide, cadmium chloride,
cadmium sulphate

lead:
lead oxide, lead stearate, organic lead

mercury:
organic mercury, inorganic mercury

arsenic:
inorganic arsenic, arsenic trioxide

Some of the species of the mineral forms of metals also differ with respect to their effect on human health:

silica:
a-quartz, cristobalite, trydimite

asbestos:
chrysotile, amosite, crocidolite

Nickel is a naturally occurring element that exists in nature mainly in the form of sulfide, oxide, and silicate minerals. Because it is ubiquitous, humans are constantly exposed to nickel in various amounts. “Zero exposure” to nickel is neither possible nor desirable. The nickel ion has been shown to be an essential element in certain micro-organisms,
animals and plants. The generally held view is that ionic nickel is probably an essential element for humans as well.
Nickel is an important metal in a number of manufacturing industries (e.g. stainless steel production, electroplating, battery manufacturing, electronics, etc.) and consequently, workers in nickel refineries have been the subjects in numerous epidemiological studies. These studies have demonstrated that the primary toxicities of concern from occupational exposure to nickel compounds are respiratory and dermal. Consequently, the major routes of toxicological relevance in the workplace are inhalation and skin contact. In most work environments, the potential chronic toxicity of various nickel species is likely to be of more concern than acute effects (nickel carbonyl being the exception). Long-term exposures to high concentrations (> 10 mg/m^3) of sulfidic and oxidic nickel compounds have been associated with excess lung and nasal sinus cancers. Conversely, metallic nickel has not been shown to cause cancer, while the role of water-soluble nickel compounds in causing respiratory cancer is under debate.

The only source of evidence for the association of exposure to soluble nickel compounds with cancer comes from epidemiological studies of nickel refinery workers. In fact, eleven animal studies have not demonstrated a carcinogenic effect from inhalation or oral exposure to soluble nickel compounds. The epidemiologic studies that have demonstrated increased respiratory cancer involved nickel refinery workers who were exposed to a variety of potentially carcinogenic substances, including arsenic compounds, polycyclic aromatic hydrocarbons (PAHs), and sulfuric acid mists. These concurrent exposures make a direct cause-and-effect interpretation of the data difficult or impossible. The only conclusion that can be drawn from these studies is that the specific industrial processes at the plants included in those studies created an environment that caused an increase in cancer incidence.
Speciation

Variation in the distribution of metal compounds across and within industry sectors has made it difficult to quantify the effect that individual metal compounds have on the workers in each industry sector. This is compounded by generally poor historical exposure records that are “incident-based” as opposed to “screening-based.” Historically, measurements of nickel compound exposure were taken when there was a reason to suspect that a problem existed. These “incident-based” measures tend to inflate the estimates of historical exposure. Clearly, regular static and personal sampling in the workplace will produce an exposure record that is truly representative of day-to-day working conditions (i.e., “screening-based” measures).

A major area for improvement in understanding the relationship between metals and effects on human health is the collection of data for individual metal compounds or species. It is generally agreed that health risks depend not only on a specific metal, but also on its particular species, its bioavailability—which is the extent to which a substance can be absorbed by an organism—and the rate at which this occurs, and the characteristic size and shape of particles. In line with this observation, the metals industry promotes the need for regulatory and standard-setting bodies to classify metals hazards and risks according to specific metal species designations.

"...current criteria for hazard identification of...substances based simply on elemental composition are not scientifically tenable." John Duffus, Edinburgh Centre for Toxicology

WE NEED DATA
ABOUT INDIVIDUAL METAL COMPOUNDS OR SPECIES.
The need for speciated exposure data has been articulated by numerous observers, human health specialists, and representatives of the metals industry. The metals industry has also been promoting the need to classify health risks based on specific metal species rather than the more general category of metals and their compounds. While regulatory bodies are interested in supporting such classifications, they require the data which would allow them to make decisions on this basis.
Epidemiology and Risk Assessment

Epidemiology and Risk Assessment

Epidemiology is the study of the distribution and determinants of diseases and injuries in human populations. The presence of disease is compared between people exposed and not exposed to the agent under study. Because epidemiology evaluates human rather than animal data, it can be very helpful in identifying human hazards.

Occupational epidemiology is a branch of epidemiology and is particularly useful because it applies epidemiologic methods to describe the patterns of disease occurrence among workers and to identify causative factors in the workplace environment. However, an epidemiological conclusion about what caused a certain disease will only be as good as the data and records that are available.

Risk assessment is the determination of the relationship between the predicted exposure/concentration and adverse effects in four major steps: hazard identification, dose–response assessment, exposure assessment and risk characterization. A general framework for the risk assessment process has been provided by the National Research Council, the research arm of the US National Academy of Sciences, in their Technical Guidance Document (TGD). The European Union (EU) uses a similar framework.

SCIENTIFIC APPROACHES TO UNDERSTANDING THE CAUSES OF HUMAN DISEASE CAN BE VALUABLE TO THE METALS INDUSTRIES.
The four steps of risk assessment are:
1) hazard identification; 2) dose–response evaluation;
3) exposure assessment; and 4) risk characterization.

1) **Hazard identification** is the identification of the adverse effects which a substance has an inherent capacity to cause.

2) **Dose–response evaluation** is the determination of the relationship between the magnitude of an administered, applied or internal dose and a specific biological response.

3) **Exposure assessment** is the process of measuring or estimating concentrations (or intensity), duration and frequency of exposures to a chemical present in the environment.

4) **Risk characterization** is the estimation of the incidence and severity of the adverse effects likely to occur in an environmental compartment due to an actual or predicted exposure to a substance (i.e., integration of hazard identification, dose–response evaluation and exposure assessment).

Appendix A contains more details on the steps of risk assessment.
Section 1: Reasons to Develop an Infrastructure
Epidemiology and Risk Assessment

Problems with Risk Assessment

John Duffus of the Edinburgh Centre for Toxicology (Science Progress: 1996) has expressed the concern that exists about risk assessment. In his discussion of the difficulties encountered in assessing human carcinogenicity from epidemiological studies, he identifies the following problems:

- limited database;
- poorly defined exposure data;
- inadequately recorded job history data;
- inability to distinguish individual compounds or processes as causative agents; and
- problems of confounding exposures.

These findings are among of many indications that improvements are needed in the collection of data in relation to the workplace, the worker, the exposures, and the health effects.

We need to improve our data collection methods.
Consistent Data Collection and Storage

Developing infrastructure and systems to collect speciated data can help ease some of these problems; however, the value of epidemiology for risk assessment depends heavily on the quality, accuracy and availability of sound occupational exposure information. Unfortunately, a consistent and systematic occupational exposure data collection process does not exist in most industries.

“There is a growing recognition that reliable exposure data are needed for assessing and managing health risks to workers, and that such data are too often lacking or inaccessible.” (Lippmann, M. 1995. Exposure data needs in risk assessment and risk management: Database information needs. Appl. Occup. Environ. Hyg. 10: 244-250.)

There is agreement in the metals industry that consistent procedures are needed to help clarify the relationship between exposure to metal compounds and work-related diseases. Information collected for some other purpose, such as payroll or compliance testing, may be inadequate for epidemiological investigations or risk assessment. In addition, there must be a well-maintained historical record of people and events such as the date when a new process was commissioned or when the feed stock was changed. Appropriate information must be gathered for epidemiological studies so that industry can provide risk
estimates for separate species of chemical compounds if and when the need arises in the future. Furthermore, the information collected must be stored or archived properly.
Consistent Data Collection and Storage

“Workplace exposures of employees are assessed by… industrial hygienists for a variety of purposes, most often for compliance with regulations or with consensus or corporate exposure guidelines. With adequate documentation and means for linking results with groups of workers, the results of most exposure assessment efforts may be useful in future epidemiologic studies. It is vital that exposure assessment data be archived in such a way that they can be identified and retrieved.” Harris, R.L. 1995. Guideline for collection of industrial hygiene exposure assessment data for epidemiologic use. Appl. Occup. Environ. Hyg. 10: 311-316.

Developing infrastructure and systems that support consistent data collection and storage requires effort, careful planning and commitment of resources. Senior management is encouraged to recognize the importance of supporting such systems within their companies. While it requires an allocation of time and money today, for which rewards may only be reaped in a number of years, it is important to realize that, in terms of health, those rewards will be well worth the investment.
Section 1: Reasons to Develop an Infrastructure
Consistent Data Collection and Storage

The need for information is clear. The desire to assemble the information is strong. The Nickel Producers Environmental Research Association is an example of the kind of effort being made. The Association is developing equipment and procedures for collecting exposure information that is both species-specific and sensitive to low doses. This initiative could be of value to the entire metals industry and could act to stimulate other developments in measuring exposure to the different species of metals.

The Advantages of a Consistent Methodology in the Metals Industry

Verma, Julian and Muir recommend that companies in the metals industry attempt to use a consistent methodology for sampling and analysis of the results of sampling. They point out that if data on occupational exposure were collected in a consistent manner within the industry, the data could be combined for risk assessment and epidemiological purposes. Such a wealth of data would produce strong advances in the understanding of the relations between metals and human health. Everyone would benefit—employers, employees, consumers, regulatory agencies, manufacturers, etc.
Consistent Data Collection and Storage

Conclusions of Section 1

1. We need a better understanding of the relation between occupational health effects and metals and their species so that more accurate risk assessment can take place.

2. This improved understanding requires consistent data collection and analysis procedures that take into account metals and their species.

3. Records of all data must be properly stored and maintained so that they can be used for risk assessment and epidemiologic purposes.

4. The development of effective data gathering systems requires effort, careful planning and the commitment of management.
Introduction to the Guide

and Metal Compounds on Human Health by D.K. Verma, J.A. Julian, and D.C.F. Muir.

The Guide Is Divided Into Four Sections

Section 1: Reasons to Develop an Infrastructure provides background information designed to increase awareness of the importance of developing a data gathering system. It includes information on health research, health protection, speciation, epidemiological aspects, regulatory factors and data consistency.

Section 2: Strategies to Develop an Infrastructure provides suggestions for specific approaches. These include methods and procedures that can be recruited as potential elements in the development and implementation of an infrastructure and systems for risk assessment of metals and their compounds.

Section 3: Internal Benchmarking contains a summary of the elements of the process of benchmarking. Chapters in the section offer a systematic method of organizing and implementing a benchmarking approach for refining and improving risk assessment activities.

Section 4: Reference consists of information that clarifies and elaborates the subject matter of metals, their compounds, and human health.
Section 2: Strategies to Develop an Infrastructure

Six Steps to Setting Up a Data Collection System:

1. Determining the Population at Risk
2. Identifying the Hazards and Assessing the Exposures
3. Defining the Worker–Workplace Interface
4. Assessing the Health Outcomes
5. Developing the Data Collection and Management System
6. Training the In-House Staff
Section 2: Strategies to Develop an Infrastructure
Six Steps to Setting Up a Data Collection System

When setting occupational exposure standards for specific contaminants, governmental and regulatory agencies use quantitative risk assessment (QRA) methodology based on information collected in both animal studies and epidemiological investigations of exposed human populations.

The six basic steps to setting up a data collection system for quantitative risk assessment system are:

**Step 1:**
Determining the Population at Risk

**Step 2:**
Identifying the Hazards and Assessing the Exposures

**Step 3:**
Defining the Worker-Workplace Interface

**Step 4:**
Assessing the Health Outcomes

**Step 5:**
Developing the Data Collection and Management System

**Step 6:**
Training the In-House Staff
Section 2: Strategies to Develop an Infrastructure

Six Steps to Setting Up a Data Collection System

This publication proposes a set of guidelines for a data collection system that is based on these six steps. Individual companies may need to adapt some of the guidelines to fit their particular situation.

It is also important to note that these six components in the data collection system contain information that may change over time. For example, if a company acquires a new piece of equipment, it could affect the hazard and exposure level of a substance. Therefore, it is important to regularly update the data collection system when any changes occur in feed, equipment and processes.

Finally, although this system could be used to collect information on other types of hazards, this publication is designed to provide guidelines for developing a simple data collection system for exposure to metals and metal compounds.

NOTES

EACH COMPANY IN THE INDUSTRY CAN ADAPT THE STRATEGIES OUTLINED TO ITS OWN SITUATION.
Determining the Population at Risk

Step 1: Determining the Population at Risk

Who is “At Risk”?
A worker is “at risk” if he or she has a greater chance of developing disease than a similar, but non-exposed worker (Verma, 1996). Therefore, data should be collected for most employees including plant, mine workers and supervisory staff workers. Even personnel such as office workers who may not be working directly with a metal species may be exposed in some way and should be included. If possible, data should also be collected on past employees such as those who have left employment, are on pension, or are deceased.

Unique Identification of Personnel

It is critical to identify uniquely each individual worker so that exposure can be assessed correctly and followed through time. Therefore, it is important to be able to identify each individual worker without confusion or error. Companies should have a system for the unique identification of workers—a record-keeping system that builds in zero possibility of mistaking one worker’s information for that of another.

There are many advantages to having a complete and error-free profile of individuals. Additional information can be entered into a record at any time, with certainty and confidence. Complete records can play a major role in resolving problems that might arise. However, a major reason for having unique identification of workers is that such information can become solid data for any epidemiological studies that might be conducted in the future.
Determining the Population at Risk

Unique Identifiers

Ideally, each individual should be given a “unique identifier” that is associated with the specific plant or company. What are the possibilities for unique identifiers?

A name is not unique—there might be other people with exactly the same name, so that an error might be made. For example, there could be six employees named John Smith in the same company. A birth date is also not unique, since other personnel may share the same birth date.

Human resources departments in some companies may have already assigned unique identifiers to their employees, for example for payroll purposes. If not, then unique identifiers will have to be created.

One possibility is to give each worker a number taken from a list of numbers that are assigned sequentially as each individual is hired. Or a system could be devised in which a number could code certain distinctive information within it—information like the birth date, the job, etc. Another possibility would be to combine, for example, the first three letters of a name with several digits (again sequentially assigned). This method decreases the chance of error and helps ensure that the identifier will remain unique. The important thing about the unique identifier is that any number assigned to an individual should belong to that individual and only to that individual. Any particular number should never be used again. Once assigned to a worker, a number should always refer to that individual.
Determining the Population at Risk

Information That Should Be Recorded

- full name (e.g., first name, middle name, surname)
- birth date—year, month, day
- other official numbers that have been assigned to the individual (social insurance number, miner’s number, etc.)
- gender
- parents’ names, especially for female personnel
- place of birth
- ethnic origin if possible, because some disease rates are higher among certain groups of people
- dates of contracting serious diseases like cancer
- date of departure from company (quitting, retirement, etc.)
- date of death during employment or after employment

Records should be updated regularly in order to keep all information current. Furthermore, records should continue to be updated after employees leave, to include information about diseases that might arise after the person has retired or left employment. Such complete information is essential to the success of any future epidemiological studies.

Table 2 summarizes the personal identifying information that should be collected if the files are to be of use to epidemiological researchers.
### Section 2: Strategies to Develop an Infrastructure

#### Determining the Population at Risk

| List of Basic Personal Information Needed for Epidemiological Research |
|---|---|
| **Identifiers** | |
| Employee Number | Company assigned unique identifier |
| Social Insurance Number | Government assigned unique identifier |
| Medical Insurance Number | Public or Private health insurance identifier |
| Retirement Number | Public or private retirement identifier |
| **NAMES** | |
| Surname | |
| Forename(s) | Use at least 3 separate fields |
| Father’s Forename(s) | |
| Mother’s Name(s) | Pre-marriage surname, forename(s) |
| Spouse’s Name(s) | Pre-marriage surname, forename(s) |
| **DATES** | |
| Birth Date | See date format* |
| First Hire Date | See date format* |
| Last Work Date | See date format* (quit, pension, death, or current date) |
| Last Follow-Up Date | See date format* (date of last contact with employer) |
| **DEATH INFORMATION** | |
| Death Date | See date format* |
| Place of Death | Country, state/province/region, city/town |
| Cause of Death | Description of underlying and contributing causes |
| **OTHER INFORMATION** | |
| Gender | |
| Place of Birth | Country, state/province/region, city/town |
| Marital Status | Single, married, widowed, divorced |
| Vital Status | Alive, quit, pension, dead |

*RECOMMENDED DATE FORMAT: CCYYMMDD= 4 digit year, 3-letter month, (e.g. JAN, FEB, DEC), 2-digit day*
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

Step 2: Identifying the Hazards and Assessing the Exposures

Hazards Identification and Exposure Assessment

Not all companies have the trained occupational health personnel or the resources to set up a comprehensive exposure measurement program. However, all workplaces are capable of setting up the following “first step” program, which is composed of three basic elements:

1) health hazard identification
2) measurement of exposure; and
3) creation/use of occupational exposure databases.

1) Health Hazard Identification

A hazard can be defined as the set of inherent properties of a substance that makes it capable of causing adverse effects to organisms or the environment.

When identifying health hazards in the workplace, start with a complete inventory of all the raw materials used, the materials produced and the by-products, contaminants or emissions that are associated with the workplace operations. In addition, a record should be made of all procedures and equipment that are essential parts of the process in the plant.
## Section 2: Strategies to Develop an Infrastructure

### Identifying the Hazards and Assessing the Exposures

Questions to guide the development of the inventory and process description:

- what raw materials are used?
- what is being produced?
- what intermediate products are generated?
- what emissions are generated?
- what is the process flow?
- what equipment is used?
- what type of Personal Protection Equipment (PPE) is used?
- what control measures are in place?

Important information about both raw materials and processed products is available in many developed countries in documents called Material Safety Data Sheets (MSDSs). An MSDS provides extensive information in a number of significant areas, including health hazards, physical and chemical properties, fire and reactivity data, spill and disposal procedures, first aid recommendations, guidelines for personal protection, and storage and handling recommendations. MSDS documents can be acquired in many ways, including through the Internet. For example, the Canadian Centre for Occupational Health and Safety (CCOHS) maintains an electronic database of MSDSs. See the following web sites for more information.

- [http://siri.org/msds/index.html](http://siri.org/msds/index.html)
- [http://msds.pdc.cornell.edu/issearch/msdssrch.htm](http://msds.pdc.cornell.edu/issearch/msdssrch.htm)
Section 2: Strategies to Develop an Infrastructure

- http://www.esd.uga.edu/
- http://www.chemfinder.com/
- http://gilligan.mc.duke.edu/oem/index2.htm
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

HCP
(Hazard Communication Program)

To promote and strengthen occupational health, countries like Australia, Canada, Japan, the USA and members of the European Union require that companies have HCPs (Hazard Communication Programs) that deal with the handling and use of chemicals. MSDSs are key to organizations’ HCPs, which also generally include labelling and worker training.

As previously mentioned, it is known that different species of nickel, for example, have different effects on human health. The same is true of the different species of cadmium as well as other metals. Thus the health risks of some species of each of these metals may be very low, while the health risks of other species of each of these metals may be very high. These findings, along with the other data presented in this chapter, reinforce the idea that metals and their various chemical and physical forms and species may have very different toxicological properties. When assessing hazards, therefore, it is critical that different metal compounds are considered on a compound-by-compound basis rather than being combined and considered together with the elemental form.

Plant layout and process description

Use a floor plan of the workplace to identify all equipment and all plant processes. Indicate both potentially hazardous operations as well as other facilities like non-production areas.
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

Plant operations should be described, perhaps by means of a flow chart that shows each step of the process in sequence. The flow chart should include every part of the plant process: arrival, transportation and transformation of all raw products; the equipment used to process the raw materials; and all by-products that are consequences of processing. Figures 2 and 3 respectively show the floor plan and process description of a paint manufacturing plant.

MAKE A FLOOR PLAN OF THE PLANT LAYOUT.
FIGURE 2
Floor Plan of a Paint Manufacturing Plant
Section 2: Strategies to Develop an Infrastructure

**Process Description**

1. Raw materials on skids are moved by fork truck. Three hundred skids with 40 bags each are received per week. Each bag weighs 22 kilograms. Spillage occurs when some bags break.

2. Coarse raw materials are moved to grinding area by fork truck.

3. 20 bags of pigment are dumped by hand into the grinder. Dust generated is collected by an exhaust hood and vented into atmosphere. Coarse pigment powder is ground into powder (2 to 4 hours per batch).

4. Empty bags are carried by hand ten metres to the waste compactor where they are compacted. They are then wrapped in plastic and disposed of in an approved landfill by a certified waste hauler.

5. Pigment powder is dumped into small bins and transported by fork truck to weighing area. Bins do not have lids.

6. All materials are carefully weighed. Dust generated is exhausted.

7. Bins carrying approximately 500 kilograms of powdered materials are moved by fork truck to the mixing room. Bins do not have lids.

8. Bin contents are dumped into large mixing tanks by opening a valve at the bottom of the cone-shaped bin. Ten bins are needed for one batch. Dust generated by dumping is exhausted. Solvents are added to the mixing tank via a closed system from outdoor storage tanks. Mechanical agitation is used.

9. Paint is transferred via a closed system of pipes to the dispensing area.

10. Paint is dispensed via an assembly line into 4.5 litre cans.

11. Sealed cans of paint are labelled and placed two in a carton on skids which are moved by fork truck to the storage area.

12. Skids are stored at floor level until shipped.

13. Trucks are loaded with skids of the product using the fork truck.

14. Shipping occurs by truck transport.
Identifying the Hazards and Assessing the Exposures

The potential of a metal or metal species to be a risk depends on a number of factors:

1. the toxicity of the substance;
2. the intensity of the exposure to the substance;
3. the duration of the exposure to the substance;
4. the route of entry of the substance;
5. engineering measures used to control exposure to the substance; and
6. metal species.

Toxicity of the substance is its ability to produce unwanted effects when it has reached a particular concentration at a specific site in the body. Intensity, or concentration, refers to the degree to which a person is exposed to the substance, while the duration of exposure describes the length of time a person is exposed to the substance (for example, the number of hours per day and number of days per year). The route of entry of the substance refers to the manner in which the substance gets inside the human body. The route of entry may be inhalation (breathing), absorption (through skin or eyes), or ingestion (swallowing liquids or solids).

Engineering measures used to control exposure to the substance, including enclosing work processes, general and local ventilation systems, may affect the degree of the hazard. Other measures may include personal protective clothing, equipment and/or administrative controls. Finally,
the differing toxicities of various species of metals may present different degrees of hazard.
Identifying the Hazards and Assessing the Exposures

Toxicology is the scientific discipline that identifies poisonous or toxic properties of a substance using controlled studies in organisms, isolated tissues, cells or cellular components. Toxicology uses a variety of techniques to determine concentration levels that are safe or harmful. An important concept in toxicology is that of the threshold. A threshold is the concentration level below which it is believed that there will be no adverse effect on nearly all exposed individuals, a level usually referred to as the NOAEL (no observed adverse effect level). The lowest concentration level at which an adverse effect is produced is referred to as the LOAEL (lowest observed adverse effect level).

Routes of Entry

**Inhalation** is the main route of entry in the workplace. Airborne chemicals in the form of mists, vapours, gases, fumes, or solids can be inhaled and distributed by the blood system to any of the body organs.

**Ingestion** is usually a less important route of entry for metals and metal species. It may be of significance in some cases of exposure to toxic metals like lead or arsenic.

**Skin and Eye Absorption** are also important routes of entry in the workplace. Chemicals that come into contact with the skin or eyes can have local effects, but they can also enter the bloodstream and reach any of the body organs.

THE CONCEPT OF THRESHOLD HELPS US CONTROL EXPOSURE TO HAZARDS.
Identifying the Hazards and Assessing the Exposures

Determining how your chemicals of interest are regulated will determine the type of sample you need to collect. There are three categories of exposure limits:

- TLV-TWAs: 8-hour time-weighted averages
- TLV-STELs: Short-term exposure limits
- TLV-Cs: Ceiling values

For workplace situations, the concept of the Threshold Limit Value (TLV) was introduced by the American Conference of Governmental Industrial Hygienists (ACGIH). TLVs are guidance values that refer to airborne concentrations of substances and represent conditions to which nearly all workers may be exposed day after day without adverse health effects. TLVs are expressed in terms of milligrams of substance per cubic metre of air (mg/m³) and are based on the best available information from three sources—industrial experience, experimental human studies and experimental animal studies. The three categories of TLVs are as follows:

a) Threshold Limit Value–Time–Weighted Average (TLV-TWA)—the time-weighted average concentration for a conventional 8-hour workday and 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.
Identifying the Hazards and Assessing the Exposures

b) Threshold Limit Value–Short-Term Exposure Limit (TLV-STEL)—the concentration to which it is believed workers can be exposed continuously for a short period of time, provided that the daily TLV-TWA is not exceeded, without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency. It is not a separate independent exposure limit; rather, it supplements the time-weighted (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only when toxic effects have been reported from short-term exposures in either humans or animals.

A STEL is defined as a 15-minute TWA exposure which should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA.

c) Threshold Limit Value–Ceiling (TLV-C) is the concentration that should not be exceeded during any part of the working exposure.
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

In 1969, the International Agency for Research on Cancer (IARC) initiated a program on the evaluation of the carcinogenic risk of chemicals to humans involving the production of critically evaluated monographs on individual chemicals. In 1980 and 1986, the program was expanded to include the evaluation of the carcinogenic risk associated with exposures to complex mixtures and other agents. The term “carcinogenic risk” in the IARC Monograph series is taken to mean the probability that exposure to an agent will lead to cancer in humans. IARC has developed a five-point system to classify chemicals in terms of their carcinogenicity (their likelihood of causing cancer).

IARC Classification System

1: The agent (mixture) is carcinogenic to humans.
2A: The agent (mixture) is probably carcinogenic to humans.
2B: The agent (mixture) is possibly carcinogenic to humans.
3: The agent (mixture or exposure circumstance) is not classifiable as to its carcinogenicity to humans.
4: The agent (mixture) is probably not carcinogenic to humans.
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

Metals, metal species and non-metal substances that could be present in a typical metal/mining facility are listed below, with their corresponding 1998 TLV–TWAs, TLV–STELs, and 1995 IARC classifications.

<table>
<thead>
<tr>
<th>Substance</th>
<th>ACGIH TLV–TWA</th>
<th>ACGIH TLV–STEL</th>
<th>IARC Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminum dust</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aluminum oxide</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ammonia</td>
<td>17</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>antimony</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>arsenic</td>
<td>0.01</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>arsenic trioxide</td>
<td>0.01</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>bismuth telluride</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cadmium</td>
<td>0.01</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>calcium carbonate</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>carbon black</td>
<td>3.5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>chromite</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coal dust–bituminous</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coal dust–anthracite</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cobalt</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>copper dust and mist</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fluorine</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>germanium tetrahydride</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>indium</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iron dust and fume</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lead</td>
<td>0.05</td>
<td>2B</td>
<td></td>
</tr>
<tr>
<td>magnesium oxide fume</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>manganese</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mercury</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section 2: Strategies to Develop an Infrastructure

<table>
<thead>
<tr>
<th>Compound</th>
<th>TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>mica</td>
<td>3</td>
</tr>
<tr>
<td>molybdenum, soluble</td>
<td>5</td>
</tr>
<tr>
<td>nickel–elemental/metal</td>
<td>1.5 (f) A5</td>
</tr>
<tr>
<td>nickel–soluble compounds</td>
<td>0.1 (f) A4</td>
</tr>
<tr>
<td>nickel–insoluble compounds</td>
<td>0.2 (f) A1</td>
</tr>
<tr>
<td>nickel carbonyl</td>
<td>0.12</td>
</tr>
<tr>
<td>nickel subsulfide</td>
<td>0.1 (f) A1</td>
</tr>
<tr>
<td>rhodium</td>
<td>1</td>
</tr>
<tr>
<td>selenium</td>
<td>0.2</td>
</tr>
<tr>
<td>silica crystalline—cristobalite</td>
<td>0.05</td>
</tr>
<tr>
<td>quartz</td>
<td>0.1</td>
</tr>
<tr>
<td>tridymite</td>
<td>0.05</td>
</tr>
<tr>
<td>tripoli</td>
<td>0.1</td>
</tr>
<tr>
<td>silver</td>
<td>0.1</td>
</tr>
<tr>
<td>sulphur dioxide</td>
<td>5.2</td>
</tr>
<tr>
<td>sulphuric acid*</td>
<td>1</td>
</tr>
<tr>
<td>tantalum</td>
<td>5</td>
</tr>
<tr>
<td>tellurium</td>
<td>0.1</td>
</tr>
<tr>
<td>tin</td>
<td>2</td>
</tr>
<tr>
<td>titanium dioxide</td>
<td>10</td>
</tr>
<tr>
<td>uranium</td>
<td>0.2</td>
</tr>
<tr>
<td>zirconium</td>
<td>5</td>
</tr>
</tbody>
</table>

(f) These TLVs are for the inhalable fraction of particulate matter for the substance listed. The concentration of inhalable particulate for the application of this TLV is to be determined from the fraction passing a size-selector with the characteristics defined in the “A” paragraph of Appendix D in the TLV Booklet.

* There is sufficient evidence that occupational exposure to strong-inorganic-acid mists containing sulfuric acid is carcinogenic (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, 1992).
ACGIH has also developed a set of biological reference values for health hazard assessment in the workplace—Biological Exposure Indices (BEIs). BEIs identify warning levels of undesirable substances in workers’ urine, blood, or exhaled air. As with TLV–TWAs, BEIs are based on exposures for eight hours a day, five days a week. Generally, biological monitoring and the use of BEIs are complementary to air monitoring, and conducted only when there is an advantage over the use of air monitoring alone. For example, if there is the possibility of a chemical entering a human’s body by absorption through the skin or by swallowing, biological monitoring may be appropriate.
Identifying the Hazards and Assessing the Exposures

2) Measurement of Exposure

Once workplace hazards have been identified, the next logical step is to measure worker exposure to the hazards. The measurement process requires appropriate methods of measurement, relevant equipment and meaningful analytical procedures.

Applications of Air Sampling

Air sampling is an essential tool in the development and implementation of data gathering systems for risk assessment of metals and metal compounds. However, its techniques can be applied to other situations:

• to ensure compliance with regulatory standards;
• to choose the proper personal protective equipment;
• to evaluate the effectiveness of engineering controls;
• to perform epidemiology studies as needed.

Questions to Ask and Answer
When Developing an Air Sampling Strategy

• Are there common generic exposures to metals, minerals and other contaminants that should be included for measurement?

• Can a list of priority substances for exposure measurement be produced?
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

• Have the toxicological and other relevant considerations of species and compounds of metals and minerals been included in this strategy?

• How should the measurement of selected exposures be carried out?

• Should air sampling or biological monitoring or both be part of the strategy?

• Should the air sampling include personal or area samples or both?

• Should the air sampling strategy be based on long-term sampling or short-term sampling or both?

• What exposure level should trigger the implementation of control procedures?

• Who should be sampled?

• How many samples should be taken?

• How often and when should samples be taken?

• Should samples be taken on the basis of job, occupational group, or similar exposure group?

• Should a common methodology for sampling and analysis for the metal industry be part of the strategy?

• Who should design and carry out exposure measurements?

GUIDELINES FOR DEVELOPING AN AIR SAMPLING STRATEGY.
Identifying the Hazards and Assessing the Exposures

Several texts and references may be consulted for guidance in developing an air sampling strategy: (Grosjean, 1994; Hawkins, et al., 1991; NIOSH, 1977).

Common Methodology of Sampling and Analysis

When determining which methods of sampling and analysis your company will use, it is important to remember that the data gathered must be collected in such a manner that it can be usefully compared to other data. Only in this way will the data be useful for risk assessment and epidemiological studies. Standard methods of sampling and analysis such as those described by the US government agencies—the National Institute for Occupational Health and Safety (NIOSH, 1994) and the Occupational Safety and Health Administration (OSHA, 1991)—and other occupational health organizations, e.g. British or European, should be evaluated. If there are regulated methods in your jurisdiction, they must be used. If not, then the most appropriate and convenient approved approaches should be adopted. The American Conference of Governmental Industrial Hygienists (ACGIH) has a very useful publication titled Air Sampling Instruments for Evaluation of Atmospheric Contaminants that discusses current air sampling instruments. (ACCG, 1995b).
ASSESSING THE HEALTH RISKS OF METAL SPECIES INVOLVES:

1. MEASUREMENT OF INDIVIDUAL METAL SPECIES
Measurement of the total amount of a metal present, without identifying and measuring the different species that may be present, is incomplete. Risk assessment requires that different metal compounds not be combined or otherwise confused so that hazard identification can be made on a compound-by-compound basis.

2. APPROPRIATE SAMPLING AND ANALYSIS OF METAL SPECIES
Different sampling methods, sampling equipment and analytical protocols may be required for the different metal species. For example, the various species of nickel metals are assessed using the same sampling and analytical methods, but Chromium III and Chromium VI are sampled and analysed differently. The main analytical chemistry techniques for the detection of various species are gas chromatography coupled with microwave-induced plasma atomic emission spectroscopy (GC-MIP-AES) and atomic absorption spectrometry (GC-AAS).

3. CONSIDERATION OF ROUTE OF EXPOSURE
Adverse effects of metal species appear to be route-specific. That is, a metal compound may be dangerous by inhalation but pose no threat when ingested. As a result, risk assessment should give the greatest weight to data for relevant routes of exposure. Exposure involving the respiratory system can use a classification of three progressively finer, particle size-selective fractions: inhalable (the part that enters the nose and/or mouth during
Section 2: Strategies to Develop an Infrastructure

breathing); thoracic (the part that penetrates into the respiratory tract below the larynx); and respirable (the part that penetrates down to the alveolar region of the lung).
Identifying the Hazards and Assessing the Exposures

There is a broad range of techniques and equipment available for exposure measurement (see Appendices at the back of this manual for illustrations of equipment). Choice of methodology and apparatus depends on the industrial process and the nature of the hazards identified. Physical agents like noise, heat and radiation can be measured with a number of sampling techniques. Measurement of exposure may include sampling and analysis of airborne chemical contaminants, sampling and analysis of contaminants on workplace surfaces, or collection and analysis of chemicals in body tissues or fluids.

Sampling of airborne hazards may involve a variety of specialized equipment like colorimetric devices, adsorption tubes, impingers, dosimeters, filters, cyclones and impactors. Samples of blood, urine, sputum, hair or finger nails may be used for biological indications of the presence of hazardous substances. Common techniques for the chemical analysis of samples include specialized procedures like spectral or atomic absorption, gas chromatography, or x-ray diffraction. Information about industrial hygiene measurement techniques is readily available through a number of agencies like the National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA).

METHODS AND EQUIPMENT USED DEPEND ON PLANT AND HAZARD CIRCUMSTANCES.
Identifying the Hazards and Assessing the Exposures

This Publication provides guidelines for developing data gathering systems by using the methods of air sampling.

Measuring airborne concentration of inhalation hazards is the most widely used method for assessing occupational exposure in the metals industry. For lead, as well as some other metals, a biological monitoring program involving the sampling of urine or blood can be an important addition. Although an air sampling program does not, by definition, measure dermal exposure or ingestion hazards, air sampling is generally considered appropriate for the metals industry.

Air Sampling Methods

There are two general types of sampling techniques—active and passive:

- In active sampling, an air sampling pump draws airborne substances onto an appropriate sampling medium.

- In passive sampling, airborne gases and vapours are collected through a static air layer or by permeation through a membrane; an air sampling pump is not involved.
Identifying the Hazards and Assessing the Exposures

**KEY ELEMENTS OF ACTIVE SAMPLING**

A sampling pump pulls air through the sampling media; a calibrator measures the flow rate—how much air has been pushed or pulled—in ml/min or l/min. Best practice involves calibrating the sampling pump before and after every sample is taken. The sampling medium for active sampling of particulate hazards is a filter—a porous substance typically 25 or 37 mm in diameter, used for sampling airborne chemical hazards in particulate form. The filter diameter, type and pore size will vary depending on the chemical being sampled. Following collection, the contents of the filter are subjected to an analytic procedure like atomic absorption/ICP for the determination of specific compounds. AIHA can provide a list of laboratories they have accredited.

**Other sampling media** include:

- **sorbent tube**—small glass tube containing solid sorbent material like activated charcoal or silica gel, used for sampling gases and vapours.

- **grab sample**—special bag which becomes filled with gas or vapour, used to measure peak airborne concentrations of gases and vapours.

- **impinger**—glass bottle filled with a particular liquid, used for sampling gases and vapours.
Measurement of airborne dust should include the collection of airborne samples of total dust, inhalable dust and respirable dust. Analysis of various metals can often be made on any of the total, inhalable or respirable dusts, including analysis of important toxic metals and species identified in the process of hazard identification. Respirable dust is dust so small in size that it can reach deeply into the gas-exchange region of the lungs. Respirable dust is collected on a filter of a type and pore size appropriate for the particulate being sampled. Preceding the filter is a particle size-selective device, typically a cyclone, that will separate the respirable fraction from the non-respirable fraction. Table 3 on the following page outlines methods and apparatus for measuring a number of substances (NIOSH Manual of Analytical Methods, 1994).

**Inhalable and Respirable Dust**

- **inhalable particulate mass:** materials that are hazardous when deposited anywhere in the respiratory tract, including the nose and mouth, typically collected using an IOM sampler (developed at Scotland’s Institute of Occupational Medicine).

- **respirable particulate mass:** materials that are hazardous when deposited in the gas-exchange region of the lungs.
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

### Measurement Methods for a Basic Industrial Hygiene Program

<table>
<thead>
<tr>
<th>Substance</th>
<th>Apparatus, Method for Sampling and Analysis</th>
<th>Reference*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dust</td>
<td>• Personal sampling pump&lt;br&gt;• 25 or 37 mm mixed cellulose ester MCE or polyvinyl chloride (PVC) filters in cassettes&lt;br&gt;• Air sampling flow rate at 2Lpm&lt;br&gt;• Weigh on microbalance</td>
<td>NIOSH method #0500</td>
</tr>
<tr>
<td>Inhalable Dust</td>
<td>• Personal sampling pump&lt;br&gt;• IOM inhalable aerosol sampler&lt;br&gt;• 25mm diameter MCE/PVC filter&lt;br&gt;• Air sampling flow rate at 2Lpm&lt;br&gt;• Weigh on microbalance</td>
<td>Vincent et al. (1955)&lt;br&gt;Tse et al. (1996)</td>
</tr>
<tr>
<td>Respirable Dust</td>
<td>• Personal sampling pump&lt;br&gt;• 10 mm nylon cyclone&lt;br&gt;• 25mm or 37mm diameter MCE/PVC filter&lt;br&gt;• Air sampling flow rate at 1.7Lpm&lt;br&gt;• Weigh on microbalance</td>
<td>NIOSH method #0600</td>
</tr>
<tr>
<td>Respirable Silica (crystalline quartz)</td>
<td>• Personal sampling pump&lt;br&gt;• 10 mm nylon cyclone&lt;br&gt;• 25mm or 37mm diameter MCE/PVC filter&lt;br&gt;• Air sampling flow rate at 1.7Lpm&lt;br&gt;• Weigh on microbalance&lt;br&gt;• Analysis&lt;br&gt;• infrared spectrophotometer (IR)&lt;br&gt;• X-ray diffraction (XRD)&lt;br&gt;• colorimetric metals</td>
<td>NIOSH method #7500 (XRD)&lt;br&gt;NIOSH method #7601 (UV-VIS)&lt;br&gt;NIOSH method #7602 (IR)&lt;br&gt;NIOSH method #7603 (IR)</td>
</tr>
<tr>
<td>Metals (lead, cadmium, zinc, nickel, etc.)</td>
<td>Same as total dust or inhalable dust&lt;br&gt;Use only MCE filters (No PVC filters)&lt;br&gt;Analysis&lt;br&gt;• atomic absorption spectrophotometer (AA)&lt;br&gt;• inductively coupled plasma spectrophotometer (ICP)</td>
<td>NIOSH method #7300 (ICP)&lt;br&gt;NIOSH methods for general metals (P &amp; CAM #7300)&lt;br&gt;Specific Methods for other metals</td>
</tr>
</tbody>
</table>

* NIOSH Manual of Analytical Methods (NIOSH, 1994)

Table 3
Section 2: Strategies to Develop an Infrastructure
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

NOTES
Identifying the Hazards and Assessing the Exposures

Companies such as SKC Inc. publish two-page application guides, designed to accompany their equipment, which describe sampling and calibration methods. These guides are written with clear, easy-to-follow directions and include illustrations. They explain how to use equipment such as:

- air sample bags
- filters
- sorbent tubes
- pre-filter and tube
- long-duration detector tubes
- two tubes in series
- calibrating a pump with an electronic calibrator
- calibrating a pump with a film flowmeter
- air sampling in cold weather conditions

These guides briefly describe equipment and methodology. They then list required and optional equipment for the particular sampling process; explain the steps of preparation, setting up, calibration and sampling; and finally, explain the follow-through process. An example of a guide can be found in Appendix E. Although this particular guide is one that is used for sampling gases and vapours, SKC also provides guides for the metals industry.
A baseline assessment of metals that can be done by most companies involves taking a sample using a standard technique, and analysing the sample using an ICP spectrophotometer. Using the ICP, a number of metal elements can be easily quantified for the same sample. For example, using NIOSH (1994) Method 7300: Elements (ICP), up to 28 elements can be analysed simultaneously on a single filter, including the metals aluminum, arsenic, beryllium, cadmium, cobalt, iron, lead, manganese, nickel, vanadium and zinc. This at least provides an estimate of metal exposure. However, the ICP is unable to measure the amount of each metal species. Also, different sampling and analytical protocols may be required for the different species of metals. For example, the various species of nickel metals are assessed using the same sampling and analytical methods, while Chromium III and Chromium VI are sampled and analysed differently. SKC Inc. offers Chemical Fact Files which explain how to sample for individual chemicals according to specific methods.

Examples of suppliers of exposure measurement equipment and apparatus can be found in Appendix D.
Section 2: Strategies to Develop an Infrastructure

Identifying the Hazards and Assessing the Exposures

The Homogeneous Exposure Group

Wherever possible, an exposure assessment strategy should be based on the following five principles:

1) Define a manageable number of similarly exposed workers within each operation. These worker clusters are known as Homogeneous Exposure Groups (HEGs). They should be put together under the guidance of an industrial hygienist and with the advice of the workers involved. It is advisable to review the jobs included within the group after the exposure data have been collected.

An HEG is the core idea in making detailed workplace exposure assessments. An HEG can be defined as a group of workers with exactly the same likelihood of exposure to a single environmental agent. The group is homogeneous in the sense that the probability distribution of exposures is the same for all members of the group. The term homogeneous does not mean that all members have identical exposures any single day. Since this definition of an HEG has certain statistical importance, it means that a small number of randomly selected samples can be used to define exposure distributions and trends within the HEG. Thus use of the HEG has great practical value in terms of time spent collecting data. The concept of an HEG is that it is unique for each exposure agent. In practice, it is likely that membership in an HEG will be the same for several agents, particularly if the agents are involved in similar ways in the process or operation.
Identifying the Hazards and Assessing the Exposures

2) Use full-shift (for example, 8 hour) personal sampling as much as possible. If partial-shift sampling is employed, at least 75% of the shift should be covered, including highest exposure times. If there are extended workshifts of 10 or 12 hours, the full extended shift should be sampled. If this is not possible, then at least 75% of the full shift should be sampled.

3) Within an HEG, the person, the day and the shift must be randomly sampled. Random sampling is essential for statistical purposes.

4) Reliability is a statistical concept of repeatability. It involves knowing how confident you can be that a finding is real, and not the result of chance. To be reliable, a sufficient number of samples should be collected.

A general rule of thumb is to collect at least 10 samples from each HEG, with each worker sampled on at least two occasions. The actual number of samples for a particular operation depends heavily on the day-to-day, shift-to-shift and worker-to-worker variability of the workplace exposure concentrations. Variability of the concentrations is determined by reference to the GSD (geometric standard deviation) of the measurements. A GSD greater than 4 indicates that the workplace concentrations are highly variable, and that substantially more samples are required for statistical precision. A GSD between 2 and 4 indicates intermediate variability, requiring a moderately greater number of samples. A GSD of less than 2 indicates low variability of the workplace concentrations, so that 10 samples should be satisfactory.

5) Put together a statistical summary of HEG concentrations. This involves calculating the arithmetic mean
(AM) and standard deviation (SD) of the measured exposures. In general, exposure data distributions tend to show many more extreme results on the high side of the concentration scale than on the low end (a phenomenon known as “skewed to the right”). As a result, statistical summaries should be put together after the measured exposures have been transformed into logarithms, with
Identifying the Hazards and Assessing the Exposures

references to the geometric mean (GM) and geometric standard deviation (GSD). No sample results should be rejected unless there is strong documented evidence of equipment malfunction, the use of improper procedures, or sample tampering.

An Addendum on Statistics

As a further note on the use of appropriate statistics, conclusions to be drawn from a data collection system cannot be reliably ascertained by simple direct inspection of the data. Classification, summary description and rules of evidence for drawing valid inferences are required. Statistics provide the methodology whereby this can be done.

A simple statistical analysis of data can involve answering four basic questions. The first question is, what is the general pattern of the data? This is answered by preparing a frequency distribution as illustrated below:

<table>
<thead>
<tr>
<th>Score interval</th>
<th>Tallies</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34-36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31-33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28-30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19-21</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Frequency Distribution
Section 2: Strategies to Develop an Infrastructure

The rules for preparing a frequency distribution, as well as for the other statistical procedures discussed below, can be found in any basic statistics textbook.
Data from the frequency distributions can be represented graphically in a histogram as seen below.

The next question has to do with what the scores are like on average. Information gained from looking at the frequency distribution helps in determining the next step in the statistical analysis, namely choosing the most appropriate measure of **central tendency**. The three measures of central tendency are the **mode** (the score that occurs most frequently), the **median** (the score that separates the top half of the group from the bottom half), and the arithmetic **mean** (the sum of a series of measurements divided by the number of measures). If the frequency distribution is perfectly symmetrical, all three measure of central tendency will be the same, as illustrated below.

However, if the distribution is not symmetrical, that is, if it is skewed, as is usually the case, the measures of central tendency will differ, as seen below.
Generally, the mode, although very easy to calculate, is the least useful because it can be greatly affected by one or two small differences in measurements. The mean should not be used by itself if the measurements contain some extreme scores. The median typically best represents the average or central tendency of the measurements.

The next question is about the extent to which the scores or measures spread out away from the average value, and thus, the third step in statistically analysing the data is to establish the variability of the measurements. Frequency distributions representing variability are shown below.

The statistic most frequently used to calculate variability is the **standard deviation**. The standard deviation is a statistic that characterizes a distribution of scores, and the size of the standard deviation increases in direct proportion as the scores spread out more widely. The larger the standard
deviation, the wider the spread of scores. Typically, two-thirds of the measures will fall within one standard deviation from the mean, and thus, if the measurement from an individual is two or three standard deviations from the mean it is increasingly at variance. Standard deviation scores above the mean are represented by a plus sign and below the mean, by a minus sign. The percentage of the group falling below selected standard deviation values for a normal curve are as follows:

<table>
<thead>
<tr>
<th>Standard Deviation</th>
<th>Percentage With Scores Below This Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3.0</td>
<td>99.9</td>
</tr>
<tr>
<td>+2.0</td>
<td>97.7</td>
</tr>
<tr>
<td>+1.0</td>
<td>84.1</td>
</tr>
<tr>
<td>0</td>
<td>50.0</td>
</tr>
<tr>
<td>-1.0</td>
<td>15.9</td>
</tr>
<tr>
<td>-2.0</td>
<td>2.3</td>
</tr>
<tr>
<td>-3.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The fourth question to be addressed through the statistical analysis has to do with assessing the relationship between a first and second set of measurements. Is there, for example, a relationship between length of exposure and measures obtained from a particular piece of exposure measurement equipment? As an index of this degree of relationship, a statistic known as the **correlation coefficient** can be computed. Correlations range from +1 to -1. A high positive correlation, for example +.95, indicates that an individual who had the highest score on one measure had among the highest score on the other, while a minus correlation indicates that the scores go in exactly the reverse direction. A zero correlation represents a complete lack of relationship between the variables. The correlation statistic can be used to describe the precision or reliability of a
Section 2: Strategies to Develop an Infrastructure

measurement device as well as allowing prediction from one set of measurements to another.
Identifying the Hazards and Assessing the Exposures

Who Should Design and Carry Out the Industrial Hygiene Program?

Determining who should design and carry out the industrial hygiene program is probably the most important part of the occupational exposure assessment strategy. The initial hazard and exposure assessment should be conducted by a trained and experienced industrial hygienist as much as possible. A person who is a holder of the CIH (Certified Industrial Hygienist) should design the occupational exposure assessment.
Industrial Hygienist) of the American Board of Industrial Hygienists, the ROH of the Canadian Registration Board of Occupational Hygienists, the Diploma of the British Examining Board in Occupational Hygiene or an equivalent qualification, such as those awarded in Italy and the Netherlands (Verma et al., 1994; Burdorf and Kortsha, 1995), would normally possess the skills required to carry out the workplace assessment and provide guidance.

*Industrial hygienists are trained specifically in the science and art of anticipating, recognizing, evaluating and controlling health hazards in the workplace.*

### Identifying the Hazards and Assessing the Exposures

**Industrial Hygienists:**
Section 2: Strategies to Develop an Infrastructure

- understand the methods, processes and materials used to produce the product in the workplace;
- examine exposure levels of contaminants in the workplace;
- are familiar with the technical aspects of sampling and analysis of agents that are potential health hazards;
- analyse the worker and the job tasks;
- record exposures to occupational contaminants, identifying the duration and concentration of exposure as well as the exposure routes;
- analyse the occupational exposure data and how they fit with current occupational exposure standards and regulatory requirements;
- estimate the risk of work-related disease associated with occupational exposure;
- advise on control methods to eliminate or minimize exposure of workers; control methods may involve engineering, ventilation, administrative actions and personal protective equipment.
3) The Occupational Exposure Database

Occupational exposure databases containing complete and reliable data are needed for testing compliance against a standard, for occupational medicine assessments, for occupational epidemiological studies, and finally, for quantitative risk assessments.

Checkoway et al. (1987) and Harris (1995) have provided guidelines for the collection of industrial hygiene exposure assessment data for epidemiological use. The plan developed by Harris for the Chemical Manufacturers Association proposed three levels of sophistication in the data collection process. The “basic level” program is a minimal effort that will permit a reasonable level of retrieval and epidemiological interpretation of industrial hygiene exposure data that are routinely collected. Companies should adopt at least the “basic level” program in its entirety, or with some modifications, for its operations. The sample documentation component of the basic level suggested by Harris and adapted for the metal industry is given in Table 4. Time-dependent operation and process data should be collected as well to supplement the sampling results. An industrial hygiene record system suggested by Checkoway et al. (1987) is presented in Table 5.
Identifying the Hazards and Assessing the Exposures
## SAMPLE DOCUMENTATION CHECKLIST

<table>
<thead>
<tr>
<th></th>
<th>COMPANY NAME</th>
<th>FACILITY</th>
<th>DEPARTMENT OR UNIT</th>
<th>DATE OF SAMPLE</th>
<th>SAMPLE NUMBER</th>
<th>SAMPLE TYPE</th>
<th>EXPOSURE TYPE</th>
<th>OPERATION TYPE</th>
<th>WORK ACTIVITY</th>
<th>PERSONAL PROTECTIVE EQUIPMENT</th>
<th>EMPLOYEE SAMPLED</th>
<th>EMPLOYEE TYPE</th>
<th>JOB CLASSIFICATION</th>
<th>EXPOSURE GROUP</th>
<th>REPRESENTATIVENESS</th>
<th>MATERIAL(S) SAMPLED</th>
<th>SAMPLING/ANALYTICAL METHOD</th>
<th>SAMPLING RESULTS</th>
<th>SAMPLE DURATION</th>
<th>SHIFT AND WORK WEEK DURATION</th>
<th>EXPOSURE VARIABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>name of plant, mine or other facility</td>
<td>name and classification code</td>
<td>year - month - day</td>
<td>unique sample identifier</td>
<td>personal, area, or other</td>
<td>compliance (worst case)</td>
<td>random (exposure typical for worker or work group), other</td>
<td>typical daily operation (specify)</td>
<td>intermittent operation (specify with frequency)</td>
<td>specific task (specify with frequency)</td>
<td>location, press, equipment, materials handled</td>
<td>list any abnormal condition</td>
<td>for each type, list if required or optional; if worn during measurement, the nominal protection factor</td>
<td>name and unique identification number</td>
<td>company employee or contract worker</td>
<td>job title or job code for employee samples</td>
<td>homogeneous exposure group (HEG), or other worker tracking system group of which the employee sampled is a member</td>
<td>does sample represent exposure group (yes/no)</td>
<td>common chemical name(s), CAS number(s), species of metals</td>
<td>specify</td>
</tr>
</tbody>
</table>

### Table 4
## Type of Data for Inclusion in Industrial Hygiene Record System

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Process, descriptions, flow charts and plant layouts</td>
</tr>
<tr>
<td>02</td>
<td>Job and task descriptions</td>
</tr>
<tr>
<td>03</td>
<td>Raw materials and intermediates, by industrial process</td>
</tr>
<tr>
<td>04</td>
<td>Plant production records</td>
</tr>
<tr>
<td>05</td>
<td>Engineering control records</td>
</tr>
<tr>
<td>06</td>
<td>Industrial hygiene sampling records</td>
</tr>
<tr>
<td>07</td>
<td>Physical and biological agent measurements</td>
</tr>
<tr>
<td>08</td>
<td>Personal protective equipment availability and use</td>
</tr>
<tr>
<td>09</td>
<td>Inspection and accident reports</td>
</tr>
<tr>
<td>10</td>
<td>Biological monitoring results</td>
</tr>
<tr>
<td>11</td>
<td>Environmental discharge and incident reports</td>
</tr>
</tbody>
</table>


Table 5
Defining the Worker-Workplace Interface

**Step 3:**
*Defining the Worker–Workplace Interface*

To understand the relation between exposure to metals and metal species on human health, it is necessary to be able to estimate cumulative exposure for each employee. To estimate cumulative exposure to potential hazards, employees’ personnel records should contain two sets of basic information:

1) clear job descriptions; and
2) job durations.

1) Clear Job Descriptions
Each employee’s personal information should include reference to each job performed by that employee. This means that a company should have a classification system in place, one that contains a list of all jobs. It is important that this classification system really describe and identify the job. Job titles are usually unsatisfactory for this purpose because they do not contain enough information about the actual job activities, and they mean different things to different companies.

An existing classification system may be satisfactory. If there is room for improvement in an existing system, or if a new approach is needed, a “hierarchical numerical” classification system should be considered. The system should be appropriate for each particular company.
Defining the Worker–Workplace Interface

The hierarchy of classification can be as simple as departments and occupations within a department. A third level may be necessary to define the specific plant, mine or process. In such a system, a number or set of numbers and letters is distinctive, and refers to only one job activity in one location, involving one process.

For consistency within an industry, similar companies might consider developing and adopting a classification system appropriate to their operations and processes.

2) Job Durations
Each employee’s time spent on a particular job should be part of his/her record, with jobs identified according to the classification system the company uses. This is important because the length of time a worker spent on a job is necessary information for determining his/her exposure to a particular hazard.

Recording the length of time an employee spent on a job does not mean recording daily work schedules or other normal breaks in the work schedule (regular holidays, vacation time, etc.). All that is needed is a record of the start and end date for each job.

However, because most risks are related to long-term average exposures, a record should be made of the “standard” work
patterns of the company. In many cases, this is an 8-hour day over a 40-hour week.

Defining the Worker–Workplace Interface

Cumulative Exposure Estimates

By referring to job identification and duration information in an employee’s record, and adding the data from exposure measurement for that job, you can produce exposure estimates for an individual employee in a particular job.

For employees who have performed different jobs over the course of their work in a company, cumulative exposure to a particular potential hazard would be estimated by computing the exposure information for each job and combining all of the job/duration/exposure information. Data of this type form the basis of epidemiological studies that try to understand the influence of metals and their species on human health.

NOTES
Assessing the Health Outcomes

Step 4: Assessing the Health Outcomes

Medical information is an essential part of personnel records. In many countries the health evaluation must be risk-related. A “complete medical” may be offered as part of a wellness approach. The medical evaluation is a key tool to ensuring that an employee is fit to work at a particular occupation without risk to himself/herself or others. The type of information typically collected during a medical evaluation is summarized in Table 6.
### Table 6

**Type of Information Typically Collected During a Medical Evaluation**

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Employee Number</td>
</tr>
<tr>
<td>02</td>
<td>Date of Examination</td>
</tr>
<tr>
<td>03</td>
<td>Name and Signature of Health Professional</td>
</tr>
<tr>
<td>04</td>
<td>Full Name (surname and given names)</td>
</tr>
<tr>
<td>05</td>
<td>Date of Birth</td>
</tr>
<tr>
<td>06</td>
<td>Height and Weight</td>
</tr>
<tr>
<td>07</td>
<td>Previous Occupations and Exposures</td>
</tr>
<tr>
<td>08</td>
<td>Family Medical History</td>
</tr>
<tr>
<td>09</td>
<td>Past Personal Medical History (illnesses, accidents, injuries, operations)</td>
</tr>
<tr>
<td>10</td>
<td>Current Medical Concerns (symptoms and medications)</td>
</tr>
</tbody>
</table>
| 11  | Smoking (age started, number per day, age stopped), express as pack/years*
  *average # of packs per day X years smoked, 1 pack = 20 cigarettes |
| 12  | Alcohol Consumption (number of drinks per day - current and past), and controlled substances |
| 13  | Examination (note all abnormal findings)
  - respiratory systems (clubbing, lymph glands, breath sounds)
  - cardiovascular system (include blood pressure)
  - gastrointestinal system (check mouth, abdomen, hernial orifices)
  - nervous system (check reflexes, coordination, gait)
  - musculoskeletal system (joints, spine, posture)
  - eyes (vision)
  - ears (hearing)
  - skin (record signs, type of dermatitis) |
| 14  | Professional Summary |
Assessing the Health Outcomes

Types of Tests
Certain job requirements may mean that specific tests should be added to those that would make up a general physical examination. This may include tests for mobility, exercise tolerance, or tests of fitness to wear personal protective equipment like a respirator if there are specific occupational hazards and risks.

In the metals and minerals industries, it may be advisable to include a chest radiograph (x-ray) as well as respiratory questionnaires (for example, the American Thoracic Society), spirometry and audiometry to evaluate lung condition and pulmonary function.

Because personnel records of workers in the metals industries are likely to be part of future epidemiological studies, it is recommended that medical practitioners use the same methods and equipment in collecting medical data.

Information About Tobacco and Alcohol Use
Tobacco use is known to be a powerful predictor of illness in later years. Similarly, alcohol intake is related to certain types of cancer. For these reasons, it is essential to collect accurate data about tobacco and alcohol use—information like age when smoking began, the number of cigarettes smoked every day, and the amount of alcohol consumed weekly. Since smoking patterns may change over time, it is important to update medical information on a regular basis.

MEDICAL TESTS
SHOULD BE TAILORED
TO THE SPECIFIC
CIRCUMSTANCES
OF THE PLANT
OPERATION.
Assessing the Health Outcomes

Information About Previous Occupational Exposure
As it may take years, sometimes decades, for health effects of prior exposures to appear, it is important to include information about previous employment. This involves collecting a detailed history of jobs and occupations before current employment. Wherever possible, it is advisable to get specific information about employers, work activities, starting and ending dates, and exposure to hazards.

Confidentiality
Since all of the medical information in personnel records is of a confidential nature, there must be systems, safeguards and assurances that confidentiality will be respected and maintained. Care must be taken, when keeping medical records, to respect company policies and/or the country’s statutory requirements.

Health Surveillance Programs
Health surveillance programs are an important way to monitor worker’s health on an ongoing basis. In addition, they can provide useful information for studying effects of exposure to speciated metals. In addition to the physical examinations conducted to determine a worker’s fitness for a particular job, regular physical examinations may be conducted as part of a health surveillance program. Health surveillance programs should include all activities related to risk exposures or job requirements, including history, questionnaires, physical examinations, screening tests, investigation tests, biological monitoring, follow-up, results communication to employee, and trends analysis.
A health surveillance program should be designed and administered by an occupational health physician. The program should be set up to monitor the worker’s health on a regular basis so that potential health problems are detected as soon as possible. In order to collect information from physical examinations that will be useful for studying the effects of exposure to speciated metals, the examining physician must know what questions to ask. To determine what these questions might be, you must identify the potential health problems of your particular plant.

To identify the potential health problems, begin with a review of the industrial process in your plant. List the compounds in the ore, the changes in concentration or composition that result from refining, and any external substances that are introduced. Then, have a toxicologist or occupational health physician evaluate the list to identify potential health problems. Use these potential problems to create a list of relevant questions that can then be used in a medical evaluation. Consulting with industrial hygienists in your plant is also worthwhile since they may already have put this information together.

If there is no occupational health physician within the health personnel of your company, it may be possible to locate one at an independent occupational health clinic. If a decision is made to use such a facility, it is important that the program be clearly outlined and the importance of confidentiality...
stressed. It is also important that management be kept informed of problem areas, and that quality of testing procedures and record storage be regularly monitored.
Biological monitoring is an important part of health surveillance programs. Biological monitoring results are used to keep track of employees’ exposure to harmful substances and to deal with its consequences. By measuring levels of toxic substances in the blood or urine of exposed workers, and detecting other changes in the blood and urine which may be caused by heavy metals, early intervention and prevention can help protect workers’ health. Information from biological monitoring also helps in the evaluation of the work environment and work practices, and in the promotion of engineering changes to decrease exposures.

A regular biological monitoring program should include components such as:

- categories of employees according to exposure time;
- frequency of biological monitoring according to exposure time;

For example:

<table>
<thead>
<tr>
<th>Categories</th>
<th>Frequency of monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I (minimal exposure)</td>
<td>Pre-placement</td>
</tr>
<tr>
<td>Category II (less than 20% of time)</td>
<td>Pre-placement and depending on exposure</td>
</tr>
<tr>
<td>Category III (more than 20% of time)</td>
<td>Pre-placement and as per specific hazardous substance</td>
</tr>
</tbody>
</table>
Assessing the Health Outcomes

- types of health assessment according to employee status;

For example:

<table>
<thead>
<tr>
<th>Employee status</th>
<th>Health Assessment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>New employees</td>
<td>Pre-placement health assessments and biological monitoring baseline</td>
</tr>
<tr>
<td>Regular employees</td>
<td>Periodic exams and biological monitoring</td>
</tr>
<tr>
<td>Exiting employees Category III</td>
<td>Biological monitoring if not done in the previous month</td>
</tr>
</tbody>
</table>

- definitions for levels of exposure;
  ⇒ normal level: average level found in population;

  ⇒ action level: a level that is safe, but serves as an indication of potentially significant exposure. It is the level at which prevention activities are carried out by occupational health and industrial hygiene professionals;

  ⇒ relocation level: a level at which there is concern about an employee’s level of exposure and he or she is relocated temporarily or permanently to a location where exposure levels are non-existent or low;
Assessing the Health Outcomes

- lists of substances and hazards that are biologically monitored regularly;

- lists of substances and hazards for specialized monitoring;

- due process, that is:
  - right person
  - schedule
  - tests done
  - results received
  - results reviewed
  - communicate to employee;

- a process to review the results of monitoring, including trends analysis, problem identification, and recommendations;

- a process to make necessary changes.

Each hazardous substance should have a list of guidelines for carrying out biological monitoring. Guidelines could include:

- route of entry;
- biological tests done;
Section 2: Strategies to Develop an Infrastructure

- frequency of testing;
- normal values;
- action levels;
- relocation level and/or criteria when applicable;
- “return to regular duties” level when applicable; and
- permanent relocation criteria and other relevant actions.

Assessing the Health Outcomes

Update health screening programs

Health screening programs, whether within the company or conducted through a nearby facility, should be reviewed regularly to ensure that they incorporate factors identified by the latest medical research as well as any changes to the plant’s industrial process.

Ongoing Health Surveillance

Effects of exposure to metals and their species may occur after a worker has left the company. A worker may no longer work for a company because of illness, death, retirement, or because of employment elsewhere. Ideally it is important to maintain health status records for these employees since the effects or non-effects of metals may be seen long after the worker departs from your company.
Although keeping track of former employees’ health may be somewhat difficult, it is important to gather this information for future epidemiological studies. If you know that an employee has plans to leave, you could schedule an “exit” interview to obtain information such as a forwarding address. It is also sometimes possible to trace former employees through labour unions since they keep member records. Often a worker who leaves one company to work for another remains in the same labour union.
Assess the Health Outcomes

With the increasing use of computers for information storage, it is likely that in future, more information links will exist between government and company records. Therefore, it is critical that when designing your program, you use as many quality personal identifiers as possible so that the records you create today will have an increased chance of being useful as links in future. For example, it would be useful to keep track of occupational disease claims for outside expertise or referrals. It would also be valuable for possible decisions from Workers’ Compensation Boards (WCB).
Section 2: Strategies to Develop an Infrastructure

Assessing the Health Outcomes
Step 5: Developing the Data Collection and Management System

A useful way to manage your collected data is by using database management system (DBMS) computer software. One such program, produced by Microsoft, is called Access.

The key to developing an effective database is in its initial design. A well-designed database is flexible and provides useful and accurate information.

The concepts of tables, fields and relationships are useful in understanding database design. Tables are made up of fields of related information. Databases are typically made up of a variety of different tables that are treated as a single unit.

For example, your database could have one table called “Employees.” In this table, you could have one field of information for an employment start date, with another field for employee names. A second table could be called “Health Assessments.” In this table, you could have one field of information for medical examination dates, with another field for health status.

Creating a common field that is shared by both tables—for example, a field for employee number—creates a relationship between the two tables. This relationship thus allows you to tie information together from the Employee and Health Assessment tables.
Developing the Data Collection and Management System

Table: Employees

<table>
<thead>
<tr>
<th>Name</th>
<th>Start Date</th>
<th>Employee Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booth, Ian</td>
<td>1985, JUN, 05</td>
<td>10951</td>
</tr>
<tr>
<td>Winter, Ann</td>
<td>1997, NOV, 22</td>
<td>21355</td>
</tr>
</tbody>
</table>

Table: Health Assessments

<table>
<thead>
<tr>
<th>Employee Number</th>
<th>Date of Last Medical Examination</th>
<th>Health Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>10951</td>
<td>1975, MAY, 05</td>
<td>Good</td>
</tr>
<tr>
<td>21355</td>
<td>1998, JAN, 08</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Once a database has been created, it is possible to retrieve information from it by using query language. Query language is a set of commands that you use to find and manipulate data within your database. For example, you can create a query requesting all records for employees who started working for your company after a certain date. DBMS programs are also capable of displaying information, retrieved through queries, on forms and reports.
The following steps can be used as guidelines in designing a database.

1. Understand the purpose of creating your database.

2. Identify the tables for which you wish to collect data.
3. Identify the fields needed for each table.

4. Establish a unique identifier for each table, for example, an employee number. If every employee has his or her own employee number, it reduces the chance of errors in your database.

5. Identify a common field between tables. The employee number would be a logical choice if it were included in all tables.

6. Avoid data redundancy—that is, with the exception of a common field used to link tables, do not put the same information into more than one table. Data redundancy takes up space and can make your database unnecessarily cumbersome.

7. Construct queries, forms and reports.

8. Test your design, and redesign as required.

In larger companies, departments such as human resources (payroll and benefits), computer systems, medical, and industrial hygiene/environmental control may already have large collections of data. Developing a data collection and management system requires that these departments work together by linking their respective collections.
Section 2: Strategies to Develop an Infrastructure
Developing the Data Collection and Management System

Designing An In-House System For Data Collection Involves The Following Principles:

- compatibility of departmental computer databases;
- the use of a unique identifier as the key field for all employee-based files;
- development of a central worker database summarizing and linking the departmental information;
- quality assurance programs to check data quality and integrity;
- the smooth flow of information between departments;
- built-in mechanisms (e.g., multiple level passwords, keeping documents in locked cabinets) for protecting the confidentiality of employees’ personal information;
- fail-safe operations (e.g., database replication) to prevent the loss of information.
Training the In-House Staff

Step 6: Training the In-House Staff

Although the expertise of the professional industrial hygienist, toxicologist, epidemiologist and physician is required to design a proper data collection system, non-expert staff can collect much of the data once a well-designed system is in place. These workers could be trained to collect data “on the job” or through short-term educational courses. What is most important is that these workers be given the time and the tools to learn how the data collection system works.

This training should include basic instruction in critical appraisal, epidemiology and biostatistics, quantitative industrial hygiene, toxicology and health effects. A typical course outline would include: population sampling measurement and rates: association, bias, confounding and causation; probability concepts; methodology used in the conduct of epidemiological studies; and critical appraisal. Such a course should also include laboratory exercises and field visits (e.g. paint producing company, pulp and paper mill or steel producing company) to encourage experiential learning.

Topics covered in such a course could include: dust, cancer, solvents, ventilation, accidents, biological hazards, asbestosis, asthma, chronic obstructive lung disease, exposure to hazards, silicosis, chemicals, sampling strategies and regulatory requirements.
Section 2: Strategies to Develop an Infrastructure
Training the In-House Staff

In addition to courses designed to provide training on data collection, there are also short-term courses available that can provide experience in industrial hygiene air sampling techniques. One such course is offered through the Johns Hopkins University School of Hygiene and Public Health. This course includes four half-day laboratory sessions devoted to each of the following topics:

- flow calibration and volume determinations;
- gas and vapour sampling and analysis;
- particulate sampling and analysis; and
- the use and limitations of direct reading instruments.

There are also more intensive programs of study that could be considered for staff who might be overseeing an infrastructure for data gathering. One such program has been established by the USA’s Centre for Disease Control (CDC) in conjunction with four universities (University of Washington, the Johns Hopkins University School of Public Health, Tulane University, and Emory University). The focus of the CDC Graduate Certificate Program is to use “innovative learning resources and distance education methodology to deliver a sound public health curriculum to meet the needs of the working health professional.” The curriculum offers basic core competencies such as:

- communication skills;
- teaching skills;
- epidemiology; and
- general comprehensive knowledge of health care systems.
Section 2: Strategies to Develop an Infrastructure
Training the In-House Staff

These core areas of study are coupled with speciality academic tracks. One such track is the Health Information Management Track. Its areas of concentration are:

- development, implementation, and evaluation of information systems;
- collection and use of epidemiological and surveillance data; and
- clinical design and evaluation of health services.

Following is a list of contacts for training discussed in this section.

Johns Hopkins School of Public Health  
Department of Biostatistics  
Rm. E3132  
615 N. Wolfe Street  
Baltimore, MD 21205-2179  
USA  
Phone: +1 (410) 223-1830 or +1 (888) 548-6741  
Fax: +1 (410) 223-1832  
http://distance.jhsph.edu

Tulane University  
CDC Program Co-ordinator  
Community Health Sciences  
1501 Canal Street, Room 908  
New Orleans, LA 70112  
USA  
Phone: +1 (504) 988-7778  
Fax: +1 (504) 584-3540
Section 2: Strategies to Develop an Infrastructure

http://www.tulane.edu/

Training the In-House Staff

Northwest Center for Public Health Practice
Box 354809
University Building
1107 Northeast 45th Street, Suite 427
Seattle, WA 98195
USA
Phone: +1 (206) 616-9460
Fax: +1 (206) 616-9415
http://healthlinks.washington.edu/

Centers for Disease Control and Prevention
1600 Clifton Rd., MS-E-07
Atlanta, GA 30333
USA
Phone: +1 (404) 639-8025
Fax: +1 (404) 639-8629
http://www.cdc.gov/

McMaster University
Gilmour Hall, Room 108
1280 Main Street West
Hamilton, ON L8S 4L8
CANADA
Phone: +1 (905) 525-4600
Fax: +1 (905) 527-1105
http://www.mcmaster.ca/
Section 2: Strategies to Develop an Infrastructure

US National Institute
for Occupational Safety and Health (NIOSH)
Hubert H. Humphrey Bldg.
200 Independence Ave., SW
Room 715H
Washington, DC 20201
USA
Phone: +1 (202) 401-6995
Fax: +1 (202) 260-4464
http://www.cdc.gov/niosh/homepage.html

Institut de recherche en Santé et en Sécurité du Travail du
Québec (IRSST)
505, boul. de Maisonneuve Ouest
Montréal (Québec) H3A 3C2
CANADA
Phone: +1 (514) 288-1551
Fax: +1 (514) 288-7636
http://www.irsst.qc.ca/

Canadian Centre for Occupational Health and Safety
(CCOHS)
250 Main Street East
Hamilton, ON L8N 1H6
CANADA
Phone: +1 (800) 263-8466 (Canada only)
Phone: +1 (905) 572-4400
Fax: +1 (905) 572-4500
http://www.ccohs.ca/
Section 3: Internal Benchmarking

Four Steps to Internal Benchmarking:

1. Define Your Data Gathering Systems
2. Assess Strengths and Weaknesses of Your Systems
3. Decide and Plan Improvements
4. Implement Changes
Section 3: Internal Benchmarking

Four Steps to Benchmarking

Internal Benchmarking

Benchmarking is a standard or reference point used to measure or evaluate how well your systems are working. It also provides a way to monitor and improve the efficiency of your already established systems.

This section of the guide describes an internal benchmarking process that you can use to help determine whether your data gathering systems are effective.

As mentioned previously, a data gathering system is not a static system. Improved technology, altered plant processes and new staff are examples of changes that must be included in your system if it is to result in useful data. Benchmarking provides a means to integrate such changes.

There are no hard and fast rules for benchmarking. What is best for a big company might not be best for a smaller one. Also, you may have already established methods or practices in your company that you can use either instead of, or in addition to, those listed on the following pages to help determine the efficiency of your data gathering system. What is important is that you use some process to evaluate and maintain your system.
Section 3: Internal Benchmarking
Four Steps to Benchmarking

**STEPS OF INTERNAL BENCHMARKING**

An internal benchmarking program involves a series of actions or steps:

1. Define Your Data Gathering Systems.
3. Decide and Plan Improvements.
4. Implement Changes.
Define Your Data Gathering Systems

Step 1: Define Your Data Gathering Systems

Define the data gathering systems or infrastructure that you have developed within your company. If you have followed the steps outlined in Section 2 of this guide, answering the following questions should help to provide you with a clear definition.

- Describe your population at risk.
- Describe your hazards and level of exposures.
- Describe your worker–workplace interface.
- What employee information are you gathering?
- What health outcome information do you gather, and how do you gather it?
- How are you managing your gathered data, and how is it linked together?
- Are your in-house staff trained to collect data, and if so, how? Are they working together as a team?
Section 3: Internal Benchmarking
Assess Your Data Gathering Systems

Step 2: Assess Strengths and Weaknesses of Your Systems

Assess the strengths and weaknesses of the data gathering systems or infrastructure that you have developed by considering the following points.

- Did you experience difficulties in the development or implementation of any part of your data gathering systems? If so, identify these difficulties. For example, one company may have found it difficult to come up with the financial resources to purchase monitoring equipment used to gather data, while another company may not have had the necessary personnel to adequately manage a data gathering system.

- Identify differences or gaps between your systems and the systems outlined in Section 2 of this manual.

- Identify the parts of your systems that are working smoothly as well as the parts that are problematic.

- Use a team approach and include workers from different parts of your company when making the above-mentioned identifications.
Assess Strengths and Weaknesses of Your Systems

- Look for reasons for gaps: factors might include procedures, equipment and technology, employee skills, or essential differences in company focus.

- Compare functioning of the different parts of your data gathering systems. Do some parts of the systems seem to function more effectively than others and, if so, why? Using the knowledge gained from the effective functioning of one aspect of a system can increase the efficiency of other aspects and result in better overall systems.

- Assess changes in your plant or company that need to be incorporated into your data gathering systems. For example, plant processes, your worker–workplace interface or your Homogeneous Exposure Group may have changed, or you may be using new or different equipment. Any such change may affect either how your data are gathered or the type of data that you need to gather.

- Assess how the various parts of your systems are working together. For example, if you are gathering useful data when collecting medical information, but your air sampling techniques are faulty, the medical data collected cannot be connected with exposure levels.

A TEAM APPROACH
RESULTS IN MORE
INFORMATION AND
A MORE ACCURATE
ASSESSMENT OF THE
STRENGTHS AND
WEAKNESSES OF
YOUR
DATA GATHERING
SYSTEMS.
Section 3: Internal Benchmarking

Decide and Plan Improvements

Step 3: Decide and Plan Improvements

Decide what changes you are going to make to improve your data gathering systems and plan to make them. Some of the guidelines for implementing systems that were provided in Section 2 of this guide may have been particularly helpful, while others may have been difficult to implement. Using the knowledge you have gained from the assessment step of the benchmarking process may help you resolve problems encountered in your initial systems development.

- Be realistic about your benchmarking goals. It is generally recommended that the goals not be too ambitious.

- Perhaps you have determined that the in-house staff requires more or different training, that you need to bring additional staff on board, or that you require a trained professional to determine the hazard potential of a new process. Once you have determined what parts of your systems need revision or improvement, determine how you can best make the necessary revisions.
Section 3: Internal Benchmarking
Decide and Plan Improvements

- Determining which revisions you wish to make also requires assessing their feasibility. You will need to consider such things as financial resources, staff resources, and support of management.

- Prepare a draft of the benchmarking report, containing all of the findings and suggestions completed in Step 2 of the benchmarking process.

- Ask for feedback about the draft report from team members as well as from other representatives of your organization, and then prepare a final report, building in revisions.

- Create an action plan to reduce or eliminate the identified gaps. Include a cost and benefit review in the action plan.
Implement Changes

Step 4: Implement Changes

It’s all well and good to get data. But without implementation and support, the information doesn’t mean anything.

Implement the changes that you have determined are necessary and feasible.

- Arrange for appropriate people or a project management team to implement the action plan.

- Establish a process to monitor the changes and improvements that you make.

Although it may not be possible to implement every change, it is important to implement what you can.
Final Notes on Benchmarking

The benchmarking process described in this section of the guide can be thought of as a cycle. That is, the steps can be followed over again whenever you decide to benchmark your systems.

Deciding when to benchmark is something that may differ from one company to the next. You may want to set up a regular time that you benchmark (for example, every year), or you may decide to benchmark if your plant develops a new process or acquires new technology.

Regardless of how and when you decide to benchmark, such an evaluation provides opportunities for improving and updating systems. These improved and updated data gathering systems will result in more accurate and useful data for risk assessment.

BENCHMARKING HAS MANY APPLICATIONS. IT SUPPORTS:

- IMPROVING PROCEDURES
- SOLVING SPECIFIC PROBLEMS
- REDESIGNING PROCEDURES
- INVOLVING EMPLOYEES
- STIMULATING NEW IDEAS
- COMPARING PERFORMANCE
- DEVELOPING STRATEGY
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Guide to Data Gathering Systems for Risk Assessment of Metals and Metal Compounds

Appendix F: Assessment Survey

Appendix G: Slide Presentation of Guide (PowerPoint file on disk)
Bibliography
Bibliography

American Conference of Governmental Industrial Hygienists. 1997. *1997 TLVs® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents; Biological Exposure Indices.* ACGIH: Cincinnati, Ohio, USA.


Section 4: Reference

occupational exposure to chemical agents.
Analyst. 119: 9-12.

Bibliography


Section 4: Reference


Organizations
Organizations

ACGIH: American Conference of Governmental Industrial Hygienists
   Web site: http://www.acgih.org

ACOEM: American College of Occupational and Environmental Medicine

AIHA: American Industrial Hygiene Association
   Web site: http://www.aiha.org

American Board of Industrial Hygiene

ATS: American Thoracic Society
   Web site: http://www.thoracic.org

CCOHS: Canadian Centre for Occupational Health and Safety
   Web site: http://www.ccohs.ca

Canadian Registration Board of Occupational Hygienists
   Web site: http://www.crboh.ca/

IARC: International Agency for Research on Cancer

ILO: International Labour Organization
   Web site: http://www.ilo.org

MSHA: Mine Safety and Health Administration
   Web site: http://www.msha.gov

NIOSH: National Institute for Occupational Safety and Health
   Web site: http://www.cdc.gov/niosh/homepage.html

OEM: Occupational & Environmental Medicine
   Web site: http://gilligan.mc.duke.edu/oem/index2.htm
Section Four: Reference

**OSHA:** Occupational Safety and Health Administration
   Web site: http://www.osha.gov/

**WHO:** World Health Organization
   Web site: http://www.who.org
Glossary
Glossary

**AA spectrophotometer**: Atomic absorption spectrophotometer.

**AM**: Arithmetic mean.

**BEI**: Biological Exposure Index.

**Benchmarking**: A standard or reference point used to measure or evaluate how well a system is working.

**Bioavailability**: The extent to which a substance can be absorbed by an organism and the rate at which this occurs.

**Biomarkers**: Biological and genetic changes in cells, body fluids and tissues.

**CIH**: Certified industrial hygienist.

**DBMS**: Database management system.

**Epidemiology**: The study of the distribution and determinants of diseases and injuries in human populations. The presence of disease is compared between people exposed and people not exposed to the agent under study.

**GM**: Geometric mean.

**GSD**: Geometric standard deviation.

**HCP**: Hazard Communication Program.

**HEG**: Homogeneous Exposure Group.

**ICP spectrophotometer**: Inductively coupled plasma spectrophotometer.
**IHWS**: Industrial hygiene walk-through survey.

**Glossary**

**Infrastructure**: The underlying foundation or basic framework of a system or organization.

**IR spectrophotometer**: Infrared spectrophotometer.

**LO AEL**: Lowest observed adverse effect level.

**MCE**: Mixed cellulose ester.

**MSDS**: Material Safety Data Sheet.

**NOAEL**: No observed adverse effect level.

**Occupational Epidemiology**: The branch of epidemiology that applies epidemiologic methods to describe the patterns of disease occurrence among workers and to identify potential causative factors in the workplace environment.

**PPE**: Personal Protection Equipment.

**PVC**: Polyvinyl chloride.

**QRA**: Quantitative Risk Assessment.

**Reliability**: A predefined level of statistical precision and repeatability.

**Risk Assessment**: The determination of the relationship between the predicted exposure/
Section 4: Reference

concentration and adverse effects in four major steps: hazard identification, dose–response assessment, exposure assessment and risk characterization.

**ROH:** Registered occupational hygienist.

**SD:** Standard deviation.

**Speciation:** The process by which the different chemical forms or *species* of an element are determined.

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**Glossary**

**TGD:** Technical Guidance Document.

**TLV:** Threshold Limit Value.

**TLV-C:** Threshold Limit Value–Ceiling.

**TLV-STEL:** Threshold Limit Value–Short-Term Exposure Limit.

**TLV-TWA:** Threshold Limit Value–Time Weighted Average.

**Toxicity:** The ability of a material to produce unwanted effects when the substance has reached a sufficient concentration at a specific site in the body.

**Toxicology:** The scientific discipline that identifies poisonous or toxic properties of a substance using controlled studies in organisms, isolated tissues, cells or cellular components.

**XRD:** X-ray diffraction.
Appendix A:

ICME
EnvironMetal Q&A
Information Sheet
WHAT ARE THE KEY STEPS IN THE HEALTH AND ECOLOGICAL RISK ASSESSMENT OF CHEMICALS (INCLUDING METALS AND METAL COMPOUNDS)?

A key to effective risk management is to accurately assess the risks associated with a chemical in a product in particular application and through other stages of the product life-cycle.

Risk assessment is the determination of the relationship between predicted exposure and adverse effects through the following four major steps:

STEP 1 HAZARD IDENTIFICATION
STEP 2 DOSE-RESPONSE EVALUATION
STEP 3 EXPOSURE ASSESSMENT
STEP 4 RISK CHARACTERIZATION

This general approach to risk assessment has been endorsed by a number of national governments and, international organizations such as: The International Programme on Chemical Safety (IPCS), the OECD, the US-EPA, the European Union, among others.

STEP 1 HAZARD IDENTIFICATION

Hazard identification is defined as the identification of the adverse effects which a chemical has an inherent capacity or potential to cause.

Examples of physical hazards include: combustion, explosivity, flammability, corrosivity.
Section 4: Reference

Examples of health hazards include: acute (e.g., skin and eye irritation, lethal effects, asphyxiant), chronic (e.g., carcinogenicity, effect on reproductive system, effects on nervous system, effects on organs, sensitizers). Examples of ecological hazards include mortality (acute) or reduced growth and reproduction (chronic) to representatives species. Hazard identification is only the first step in risk assessment. It is not an appropriate basis upon which to make a risk management decision. However, hazard identification

Toxicity: the inherent potential or capacity of a chemical (generally established from a dose–response relationship) to cause adverse effects on a living organism that seriously damages its structure or function or results in death. Usually toxicity testing (for humans: toxicity and for the environment: ecotoxicity) is performed through controlled studies on living organisms, isolated tissues, cells or cellular components.

Toxicity is generally influenced by the unique physico-chemical properties of the chemical. Examples of Toxicity tests that are pertinent to human health hazards relate to: skin and eye irritation, sensitization, carcinogenicity, reproduction toxicity. Examples of Ecotoxicity tests that are pertinent to ecological hazards relate to: acute and chronic toxicity to fish and algae.
Section 4: Reference

The term “toxic” is generally used in the regulatory context to categorize chemicals based on certain criteria and test results. Consequently, a chemical that may have a low level of toxicity (e.g., NaCl: table salt) may not be classified as toxic for regulatory purposes. In this context, all chemicals have a level of toxicity (i.e., inherent ability to cause some adverse effect under certain controlled conditions) but are not necessarily classified as toxic.

**Epidemiology** is the study of the distribution and likely determinants of diseases and injuries in human populations. The incidence of disease is compared between people exposed and people not exposed to the agent under study. Because epidemiology, as opposed to toxicology, evaluates human rather than animal and cellular data, it has the potential to be particularly informative for human hazard identification.

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“Q&A risk assessment/ toxicity: Document # 8573” April 14, 1998, draft 6

A-2

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**STEP 2 DOSE–RESPONSE EVALUATION**

Dose–response evaluation is the determination of the relationship between the magnitude of an administered, applied or internal dose and a specific biological response. The dose is the total amount of a substance administered to, taken or absorbed by an organism under standardized laboratory conditions used for toxicology testing. The response can be expressed as the measured or observed incidence, the percent response in groups of subjects (or population), or the probability of occurrence of a response in a population.
Section 4: Reference

“All substances are poisons; there is none which is not a poison. The right dose differentiates a poison from a remedy” Paracelsus, 1493-1541

STEP 3 EXPOSURE ASSESSMENT

**Exposure Assessment** is the process of measuring or estimating concentrations (or intensity), duration and frequency of exposures to a chemical present in the environment (either workplace or “outside environment”). Common routes of exposure are ingestion, injection (less likely), skin absorption and inhalation. Generally, estimates of exposure are obtained by determining the emissions, pathways and rates of movement of a chemical in the workplace or the general environment. There are a number of methods/techniques available to estimate or measure level of exposure. Ecological Risk Assessment represents an extra challenge in the number of potential receptors/species that may need to be considered when assessing risk.

STEP 4 RISK CHARACTERIZATION

**Risk** is the probability that an adverse outcome will occur in a person, a group of persons or an ecological system that is exposed to a particular dose or concentration of a chemical.

“Q&A risk assessment/ toxicity: Document # 8573” April 14, 1998, draft 6

ICME ENVIRONMENTAL Q&A

It is expressed as a probability in values ranging from zero (certainty that an effect will not occur) to one (100% certainty that an effect will occur).

**Risk characterization** is the final stage of risk assessment. It summarizes the
Section 4: Reference

information from **hazard identification, dose–response evaluation** and **exposure assessment** into an overall conclusion on risk. The result of a risk characterization is a qualitative and/or quantitative description under specific exposure conditions. Risk characterization is highly context-specific and cannot be automatically applied from one context or location to another. This is because risk should be determined for a chemical in a product in particular applications and through other stages of the product life-cycle. Risk characterization should allow for the identification of the strengths and weaknesses of the tests used, the uncertainties in the data base and the assumptions made within the methodology used to reach the overall conclusions.

Complete **characterization of risk** is very important to good **risk management** and risk communication. Full characterization can help distinguish between exposures that are likely to be associated with significant or socially unacceptable risks and those that are not.

“Q&A risk assessment/ toxicity: Document # 8573” April 14, 1998, draft 6
Appendix C:

Examples of Forms Associated with Exposure Measurement
Section 4: Reference

Appendix C: Examples of Forms

FIGURE 20
OSHA Air Sampling Form
FIGURE 21

OSHA Air Sampling Form (continued)
# FIGURE 22
Request for Laboratory Analysis

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>CLIENT'S SAMPLE ID/DESCRIPTION</th>
<th>ANALYSIS REQUIRED</th>
<th>AIR VOLUME (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
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<td>7</td>
<td></td>
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<td>8</td>
<td></td>
<td></td>
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<td>9</td>
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<td>10</td>
<td></td>
<td></td>
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<td>11</td>
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<td></td>
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<td>12</td>
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<td></td>
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<td>13</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**COMMENTS:**

I authorize all analytical work as listed in the above Request for Analysis.

Signature: ___________________________  Date: ___________

(Please note: client's signature must appear on form for work to proceed.)

Please See Reverse For All Terms And Conditions

White: Lab  Yellow: Admin.  Pink: Client
LABORATORY REPORT

July 18, 1996

Mr. John Smith
Smith Mining & Smelting
P.O. Box 10
Hamilton, Ontario A1B 2C3

Dear Mr. Smith:

I enclose the laboratory report for the samples you submitted for analysis.

The samples were received in the laboratory on July 3, 1996. They consisted of two filters plus one blank for analysis of total dust, lead, iron oxide, copper, arsenic, cadmium, manganese and zinc oxide. The blank values have been subtracted from the reported results.

Please note that any unused portions of the samples which are feasible to preserve will be kept for a period of 30 days from the date on this report and then discarded, unless you have requested otherwise.

If you require any additional information, please feel free to contact the laboratory. Thank you for the opportunity to provide you with our services.

Yours sincerely,

Ph.D., P.Eng., CIH, ROH

Laboratory Director

FIGURE 23
Sample Cover Letter from Analytical Laboratory
The samples were received in the laboratory on July 3, 1996. They consisted of two filters plus one blank for analysis of total dust, lead, iron oxide, copper, arsenic, cadmium, manganese and zinc oxide. The blank values have been subtracted from the reported results.

<table>
<thead>
<tr>
<th>Laboratory Sample No.</th>
<th>Your Sample Identification</th>
<th>Air Volume (l)</th>
<th>Analyte</th>
<th>Concentration</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>96070081</td>
<td>GA12</td>
<td>973.5</td>
<td>Total dust</td>
<td>3.39000</td>
<td>3.48000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lead</td>
<td>0.00920</td>
<td>0.00945</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iron oxide*</td>
<td>1.55271</td>
<td>1.59498</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Copper</td>
<td>0.02490</td>
<td>0.02558</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arsenic</td>
<td>0.00072</td>
<td>0.00074</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cadmium</td>
<td>0.00040</td>
<td>0.00041</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manganese</td>
<td>0.16790</td>
<td>0.17247</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zinc oxide*</td>
<td>0.03087</td>
<td>0.03171</td>
</tr>
<tr>
<td>96070084</td>
<td>GA52</td>
<td>966.7</td>
<td>Total dust</td>
<td>0.92000</td>
<td>0.95000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lead</td>
<td>0.00640</td>
<td>0.00662</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iron oxide*</td>
<td>0.49755</td>
<td>0.51469</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Copper</td>
<td>0.00580</td>
<td>0.00600</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arsenic</td>
<td>0.00055</td>
<td>0.00057</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cadmium</td>
<td>&lt;0.00010</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manganese</td>
<td>0.01610</td>
<td>0.01665</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zinc oxide*</td>
<td>0.01842</td>
<td>0.01906</td>
</tr>
</tbody>
</table>

* This assumes that all of the iron and zinc present is in the form of iron oxide and zinc oxide respectively.

**Method Summary:**
- Total Dust: Weighing on a Cahn 25 Electrobalance, NIOSH Method 0500 (with modifications)
- Lead: Flame Atomic Absorption Spectrophotometry, NIOSH Method 7082 (with modifications)
- Iron Oxide: Flame Atomic Absorption Spectrophotometry, NIOSH Method P&CAM 173
- Copper: Flame Atomic Absorption Spectrophotometry, NIOSH Method 7029 (with modifications)
- Arsenic: Flameless Atomic Absorption Spectrophotometry, Ontario Ministry of Labour Method as per Arsenic Regulations, 1987
- Cadmium: Flame Atomic Absorption Spectrophotometry, NIOSH Method 7048 (with modifications)
- Manganese: Flame Atomic Absorption Spectrophotometry, NIOSH Method P&CAM 173
- Zinc Oxide: Flame Atomic Absorption Spectrophotometry, NIOSH Method 7030 (with modifications)

FIGURE 24
Sample Report from Analytical Laboratory
FIGURE 25
Sample Report from Analytical Laboratory (continued)
Sample Summary Report from Analytical Laboratory
Appendix D: Suppliers of Exposure Measurement Equipment and Apparatus
Appendix D: Suppliers

Suppliers of Exposure Measurement Equipment and Apparatus

Integra Environmental Inc.  
(supplier of SKC products)  
5035 North Service Road, Unit C  
Burlington, Ontario L7L 5V2  
Canada  
Telephone: +1 (905) 336-2096

SKC Ltd.  
Unit 11, Sunrise Park  
Higher Shaftesbury Road  
Blandford Forum  
Dorset DT11 8ST  
United Kingdom  
Telephone: +44 (1258) 480188

SKC Inc.  
863 Valley View Road  
Eighty Four  
Pennsylvania 15330  
USA  
Telephone: +1 (724) 941-9701  
SKC Gulf Coast: +1 (28) 859-8050  
SKC: South: +1 (804) 352-7149  
SKC West: +1 (714) 992-2780

MSA International  
P.O. Box 426  
Pittsburgh  
Pennsylvania 15230  
USA  
Telephone: +1 (412) 967-3000  
Facsimile: +1 (412) 967-3451

MSA Toronto  
North York, Ontario  
Canada  
Telephone: +1 (416) 667-9400

MSA Montreal  
Ville Lasalle, Quebec  
Canada  
Telephone: +1 (514) 595-6565
Appendix E:

Example of an SKC Application Guide
Appendix E: Example of an SKC Application Guide

**Application Guide**

**Sampling Train—Air Sample Bags**

SKC Publication #1167—Rev 9705

**Air sample bags** are a convenient and accurate means of sampling gases and vapors when the concentration is higher than the detection limits of common analytical instruments. Air sampling using bags is usually done for short periods of time to give an indication of peak airborne concentrations. In areas where the chemical levels remain constant, several samples can be used to determine TWA exposures. SKC sample bags are made from Tedlar® film, a material which is inert to a wide range of chemicals. Tedlar has been shown to have the lowest sample loss in storage and a low memory of the previous sample. This Application Guide demonstrates how to set up a Sampling Train using Air Sample Bags.

**Required Equipment**

1. An air sampling pump capable of sampling at the recommended flow rate with the sampling medium in line, such as:
   - SKC 224-XR Universal Series Sampler, or
   - SKC 222 Series Low Flow Sampler, or
   - any other appropriate sampler
2. An air flow calibrator such as:
   - SKC Electronic Calibrator Cat No. 709, or
   - SKC Film Flowmeter Cat No. 303, or
   - SKC 320 Series Rotameter
3. SKC 231, 232 or 233 Series Tedlar Bags
4. The appropriate Septum
5. Teflon® tubing

**Optional Equipment**

1. Gas Flushing Kit Cat. No. 231-9-06

**Introduction**

The illustrations in this guide show sampling trains using SKC 224-XR Series Universal Samplers. The sampler used for bag sampling must be both a suction and pressure sampler; i.e., the sampler must be able to pull air as well as push air into the sampling bag. To determine the correct flow rate for the chemical being sampled, refer to the appropriate analytical method. Refer to the operating instructions for the sampler to ensure that it is both a suction and pressure sampler and that it is capable of sampling at the correct flow rate.

If taking a simple grab sample, the flow rate is not important, as long as the bag is not overfilled. Never fill a bag more than about 80% of its maximum volume. If taking a bag sample according to a specific analytical method which specifies a flow rate, it will be necessary to calibrate the flow rate using a film flowmeter.

1. **Calibrating the Flow Rate**

If using an SKC Universal Sampling Pump for ordinary grab samples, ensure that the pump is in the high flow mode. Access the outlet port of the 224-XR Series Universal Sampling Pump by removing the discharge air cap screw on top of the pump. Fit the pressure port fitting into the outlet port hole. If using the 222 Series sampler, the outlet port is located on the top of the pump next to the inlet port, and no special fitting is needed. To calibrate the flow, use flexible tubing to connect the pump's outlet port to the lower inlet port of an external flowmeter.

Calibrate the flow rate specified in the analytical method for the chemical being sampled. Please see your pump and flowmeter operating instructions for calibrating the flow rate.
Appendix E: Example of an SKC Application Guide

Sampling Train—Air Sample Bags

2. Preparing the Bag
The 231 Series sample bags are supplied with dual stainless steel fittings—a hose/valve fitting and a replaceable septum fitting. The hose/valve fitting is used to flush and to fill the bag, and to seal off the bag after sample collection. The septum fitting is used to remove samples for analysis. The 232 Series utilize a patented single fitting made of inert polypropylene that combines the hose/valve and septum fitting into one unit. The 233 Series utilizes a single stainless steel fitting combining hose/valve and septum. A special Teflon coated septum is used with all bags; the septum should be replaced after each use.

4. Sampling
To begin sampling, open the valve on the bag. (Refer to the operating instructions for each bag.) Turn the sampler on, and note the start time and any other pertinent information. Avoid filling a bag more than 80% of its maximum volume.

5. After Sampling
At the end of the sampling period, turn the pump off and close the valve on the bag, ensuring the fitting and valve are securely sealed. (Refer to the operating instructions for each bag.) Note the ending time. Remove the bag from the pump and record any pertinent sampling information.

6. Shipping Bag Samples
Sample bags sent out for analysis should be packed loosely and padded to minimize the danger of being punctured during shipment. Bag samples should not be shipped by air unless the cargo cabin is pressurized. A significant decrease in barometric pressure may cause sample bags to burst.

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3. Setting Up the Sampling Train—See Figures 1 & 2
Attach a piece of Teflon tubing to the hose/valve fitting of the bag. Connect the other end of the tubing to the outlet fitting of the pump. For bag sampling, use only Teflon tubing, never rubber or Tygon tubing.
Appendix F:
Assessment Survey
Appendix F: Assessment Survey

Answer the following questions by checking either “Yes” or “No.” If you answer “No,” rate your priority for accomplishing this in future by checking either “High,” “Medium” or “Low.”

For easy reference, related sections in the manual are listed on the left side of the page.

Step One: Determining the Population at Risk

• Have you determined your population at risk? 
  Yes □ No □
  Priority: High □ Medium □ Low

• Are these workers uniquely identified? 
  Yes □ No □
  Priority: High □ Medium □ Low

• Do you have basic personal information recorded on each of these workers? 
  Yes □ No □
  Priority: High □ Medium □ Low

Step Two: Identifying the Hazards and Assessing the Exposures

1) Health Hazard Identification

• Do you have lists of the following:
  • raw materials that your company uses? 
    Yes □ No □
    Priority: High □ Medium □ Low
Appendix F: Assessment Survey

• materials that your company produces?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐

• by-products generated in your workplace?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐

• contaminants associated with your workplace operations?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐

• emissions associated with your workplace operations?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐

• the equipment that is used in your workplace?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐

• the type of Personal Protection Equipment (PPE) that is used?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐
Appendix F: Assessment Survey

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Priority: High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>• the type of PPE that <strong>should</strong> be used?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• control measures that are in place?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-10 • Do you have a floor plan of your workplace?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Does your floor plan identify all equipment?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Does your floor plan identify all relevant plant processes?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Does your floor plan identify potentially hazardous operations?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Does your floor plan identify other facilities like non-production areas?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix F: Assessment Survey

• Do you have a flow chart that shows each step (in sequence) of the process that is followed in your workplace?  
  Yes ☐  No ☐  
  Priority: High ☐  Medium ☐  Low ☐

• Does your flow chart include every part of the plant process such as:
  - arrival of raw materials  
    Yes ☐  No ☐  
    Priority: High ☐  Medium ☐  Low ☐
  - transportation of raw materials  
    Yes ☐  No ☐  
    Priority: High ☐  Medium ☐  Low ☐
  - transformation of all raw products  
    Yes ☐  No ☐  
    Priority: High ☐  Medium ☐  Low ☐
  - the equipment used to process the raw materials  
    Yes ☐  No ☐  
    Priority: High ☐  Medium ☐  Low ☐
  - all by-products that are consequences of processing  
    Yes ☐  No ☐  
    Priority: High ☐  Medium ☐  Low ☐
Appendix F: Assessment Survey

2) Measurement of Exposure

• Do you currently have an air sampling strategy that you are using? Yes ☐ No ☐
  Priority: High [ ] Medium [ ] Low [ ]

• Do you have a defined Homogeneous Exposure Group (HEG), that is, a manageable number of exposed workers with exactly the same likelihood of exposure to a single environmental agent? Yes ☐ No ☐
  Priority: High [ ] Medium [ ] Low [ ]

3) The Occupational Exposure Database

• Do you have an occupational exposure database in place? Yes ☐ No ☐
  Priority: High [ ] Medium [ ] Low [ ]

Step Three: Defining the Worker-Workplace Interface

• Do your employees’ personnel records contain clear job descriptions? Yes ☐ No ☐
  Priority: High [ ] Medium [ ] Low [ ]

• Do your employees’ personnel records contain clear job durations? Yes ☐ No ☐
  Priority: High [ ] Medium [ ] Low [ ]

Step Four: Assessing the Health Outcomes
### Appendix F: Assessment Survey

- **Do your personnel records include medical information?**  
  - Yes [ ]  No [ ]  
  - Priority: High [ ]  Medium [ ]  Low [ ]

- **Do your medical records contain results of formal and standardized medical history/evaluations?**  
  - Yes [ ]  No [ ]  
  - Priority: High [ ]  Medium [ ]  Low [ ]

- **Is there a link from the medical outcomes to human resources management?**  
  - Yes [ ]  No [ ]  
  - Priority: High [ ]  Medium [ ]  Low [ ]

- **Do you update this information regularly?**  
  - Yes [ ]  No [ ]  
  - Priority: High [ ]  Medium [ ]  Low [ ]

- **Do your medical records include information about previous occupational exposure?**  
  - Yes [ ]  No [ ]  
  - Priority: High [ ]  Medium [ ]  Low [ ]

- **Do you have a health surveillance program related to the workplace exposure?**  
  - Yes [ ]  No [ ]  
  - Priority: High [ ]  Medium [ ]  Low [ ]
## Appendix F: Assessment Survey

- Has your health surveillance program been designed by an occupational health physician?  
  - Yes ☐  No ☐  
  - Priority: High ☐  Medium ☐  Low ☐

- Is your health surveillance program administered by an occupational health physician?  
  - Yes ☐  No ☐  
  - Priority: High ☐  Medium ☐  Low ☐

- Have you identified the potential health problems of your particular plant by reviewing the industrial processes in your plant and listing:
  - compounds in the ore  
    - Yes ☐  No ☐  
    - Priority: High ☐  Medium ☐  Low ☐
  - changes in concentration or composition which result from refining  
    - Yes ☐  No ☐  
    - Priority: High ☐  Medium ☐  Low ☐
  - any external substances which have been introduced  
    - Yes ☐  No ☐  
    - Priority: High ☐  Medium ☐  Low ☐
Appendix F: Assessment Survey

- Have you had a toxicologist or occupational health physician evaluate the list to identify potential health problems?  
  Yes ☐ No ☐
  
  Priority: High ☐ Medium ☐ Low ☐

- Have you consulted with the industrial hygienists in your plant since they may have already put this information together?  
  Yes ☐ No ☐
  
  Priority: High ☐ Medium ☐ Low ☐

- If there is no occupational health physician within your company, have you tried locating one at an independent occupational health clinic?  
  Yes ☐ No ☐
  
  Priority: High ☐ Medium ☐ Low ☐

- Does the occupational health physician and/or hygienist routinely tour the site to see that the current program remains adequate?  
  Yes ☐ No ☐
  
  Priority: High ☐ Medium ☐ Low ☐

- Does your health surveillance program include a regular biological monitoring program?  
  Yes ☐ No ☐
  
  Priority: High ☐ Medium ☐ Low ☐

- Do you have a list of guidelines for carrying out biological monitoring on all hazardous substances in your workplace?  
  Yes ☐ No ☐
  
  Priority: High ☐ Medium ☐ Low ☐
Appendix F: Assessment Survey

Step Five: Developing the Data Collection and Management System

• Do you have a computerized database management system to manage your collected material?
  Yes ☐ No ☐

  Priority: High ☐ Medium ☐ Low ☐

  ☐

• Have you identified parameters that allow you to measure improvements?
  Yes ☐ No ☐

  Priority: High ☐ Medium ☐ Low ☐

  ☐
Step Six: Training the In-House Staff

- Do you have a staff training program in place for those workers who are responsible for collecting data? 
  Yes ☐ No ☐
  Priority: High ☐ Medium ☐ Low ☐

- Are there outside educational courses available to workers who are responsible for collecting data? 
  Yes ☐ No ☐
  Priority: High ☐ Medium ☐ Low ☐

- Are workers who are responsible for collecting the data given adequate time to learn how the data collection system works? 
  Yes ☐ No ☐
  Priority: High ☐ Medium ☐ Low ☐
Appendix G:

Slide Presentation of Guide
Guide to Data Gathering Systems for Risk Assessment of Metals and Metal Compounds
Introduction and Background
Section 1

Reasons to Develop an Infrastructure
The human body needs some metals:

- calcium
- iron
- sodium
- potassium
- magnesium
- zinc
- vanadium
- copper
- molybdenum
- chromium
- selenium
- cobalt
- nickel
- silicon
Some metals play key roles as beneficial in human physiology

- too little can be dangerous
- too much can be just as dangerous
- RDI (Recommended Dietary Intake) has been established for most metals and minerals (and vitamins)
- ideal is to maintain acceptable intake for normal homeostasis
All substances are poisons: there is none which is not a poison
Some may have both beneficial and adverse effects
All substances can have a lethal concentration

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\text{LD}_{50}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Cyanide</td>
<td>10</td>
</tr>
<tr>
<td>Tetraethyl lead</td>
<td>35</td>
</tr>
<tr>
<td>Lead</td>
<td>100</td>
</tr>
<tr>
<td>DDT</td>
<td>150</td>
</tr>
<tr>
<td>Phenobarbital</td>
<td>660</td>
</tr>
<tr>
<td>Aspirin</td>
<td>1500</td>
</tr>
<tr>
<td>Table Salt</td>
<td>3000</td>
</tr>
</tbody>
</table>
Deficiencies of Using LD$_{50}$ for Assessing Risk

- LD$_{50}$ relates only to short-term exposure with drastic consequences.
- Chronic toxicities are not necessarily related to acute toxicities.
- It is possible for some compounds (e.g., asbestos) to have only a moderate LD$_{50}$ but work in insidious ways over a long period and cause serious damage to health.
### Speciation

**Metals appear in different forms, and different metal species have different risks**

<table>
<thead>
<tr>
<th>Metal Species</th>
<th>Metal Species</th>
<th>Metal Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium oxide</td>
<td>Arsenic bromide</td>
<td>Lead oxide</td>
</tr>
<tr>
<td>Cadmium cyanide</td>
<td>Arsenic chloride</td>
<td>Lead dioxide</td>
</tr>
<tr>
<td>Cadmium fluoride</td>
<td>Arsenic pentoxide</td>
<td>Lead sulphate</td>
</tr>
<tr>
<td>Cadmium chloride</td>
<td>Arsenic sulphide</td>
<td>Lead sulphide</td>
</tr>
<tr>
<td>Cadmium sulphide</td>
<td>Arsenic trioxide</td>
<td>Lead arsenate</td>
</tr>
<tr>
<td>Cadmium sulphate</td>
<td>Iron arsenate</td>
<td>Lead acetate</td>
</tr>
</tbody>
</table>
Speciation

- various metal species can have different effects
- the toxicity of many metals is affected by their chemical form
- the combination of metals may also further complicate the assessment
## Speciation Example
Chromium sometimes appeared to cause cancer

<table>
<thead>
<tr>
<th>Plating Industry</th>
<th>Ferro-chromium Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>● exposure to soluble Chromium [VI]</td>
<td>● exposure to less soluble Chromium [III] and metallic Chromium</td>
</tr>
<tr>
<td>● incidence of lung cancer</td>
<td>● no incidence of lung cancer</td>
</tr>
</tbody>
</table>
**Speciation Example**

Nickel is an essential element

<table>
<thead>
<tr>
<th>Nickel Refineries</th>
<th>Metallic Nickel</th>
</tr>
</thead>
<tbody>
<tr>
<td>• exposure to soluble forms of Nickel</td>
<td>• exposure to insoluble form of Nickel</td>
</tr>
<tr>
<td>• also exposure to Arsenic, PAH, Acid Mist</td>
<td>• no exposures to other carcinogens</td>
</tr>
<tr>
<td>• increased incidence of lung and nasal sinus cancer</td>
<td>• no incidence of cancer</td>
</tr>
</tbody>
</table>
## Speciation Example

**Mine and smelter exposures to lead**

<table>
<thead>
<tr>
<th>Lead Sulphide (Galena)</th>
<th>Lead oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Sulphide minerals considered less soluble</td>
<td>- various lead species are soluble to very soluble</td>
</tr>
<tr>
<td>- literature shows residents in close proximity to mines have low risk due to sulphide form of lead</td>
<td>- literature shows risk to residents living in proximity of some lead smelters</td>
</tr>
</tbody>
</table>
If there are concurrent exposures, the direct cause-and-effect interpretation of the data is difficult or impossible.
Understanding the Relationship Between Metals and Effects on Human Health

- individual metal compounds
- individual metal species
- bioavailability
- size and shape of particles
## Characterizing Contaminants

<table>
<thead>
<tr>
<th></th>
<th>Dust</th>
<th>Smoke</th>
<th>Fume</th>
<th>Mist</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin</strong></td>
<td>Crushing</td>
<td>Burning</td>
<td>Burning</td>
<td>Liquid</td>
<td>Chemical</td>
</tr>
<tr>
<td></td>
<td>Grinding</td>
<td>organic</td>
<td>Metals</td>
<td>Aerosol</td>
<td>Reaction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(wood, paper)</td>
<td></td>
<td>Spray</td>
<td></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>1-100</td>
<td>0.1-5</td>
<td>1-10</td>
<td>10-100</td>
<td>Formless</td>
</tr>
<tr>
<td>(microns)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fluid</td>
</tr>
<tr>
<td><strong>Shape</strong></td>
<td>amorphous</td>
<td>amorphous</td>
<td>amorphous</td>
<td>spherical</td>
<td>no shape</td>
</tr>
<tr>
<td><strong>Settling</strong></td>
<td>Medium - Fast</td>
<td>Slow</td>
<td>Slow</td>
<td>Medium - Fast</td>
<td>Depends upon Density</td>
</tr>
<tr>
<td><strong>Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Most metallic contaminants in the workplace may be dust or fume.

Some may be in vapour state immediately over the heated process. Mercury may be present as either a dust or a vapour in the general work environment.
Epidemiology and Risk Assessment
Epidemiology

- study of the distribution and determinants of diseases and injuries in human populations
- the presence of disease is compared between people exposed and not exposed to the agent
- an epidemiological conclusion about what caused a certain disease or effect depends on the data and records
Risk Assessment

determining the relationship between predicted exposure/concentration and adverse effects in 4 major steps:

1. Hazard Identification
2. Dose-Response Assessment
3. Exposure Assessment
4. Risk Characterization
Risk Assessment

- Hazard Identification
- Exposure and Dose-Response Assessment
- Risk Characterization

Risk Management

- Develop and Screen Alternatives
- Remedy Selection, Design and Implement
- Monitoring and Review
Typical Problems with Risk Assessment

- limited database
- poorly defined exposure data
- inadequately recorded job history data
- inability to distinguish individual compounds or processes
- problems of confounding exposures
Improvements may be needed in the Collection of Data in Relation to:

- workplace
- worker
- exposures
- health effects
Requirement for Consistent Data Collection and Storage

- consistent procedures are required to help clarify the relationship between exposures and work-related diseases
- there must be a well-maintained historical record of people and events
Developing an Infrastructure and System for Risk Assessment of Metals and Metal Compounds

- Developing infrastructure and systems that support consistent data collection and storage requires effort, careful planning and commitment of resources.
Section 2

Strategies to Develop an Infrastructure
The Need for Human Data

When setting exposure standards, regulatory agencies use quantitative risk assessment (QRA) based on information collected in animal studies and epidemiological investigation of human populations.
The Need for Human Data

- Safe levels derived from animal experiments do not necessarily take into account biological differences in humans.
- Safe levels derived from human data are relatively scarce.
- Epidemiology must be based on a strong and rigorous exposure database.
Steps for setting up a data collection system for Quantitative Risk Assessment

- six basic steps to setting up a data collection system for QRA

- basic concepts and terms that must be understood before outlining the different steps
Background information

- what is toxicity/hazard/risk?
- what is QRA?
- what is a threshold?
Toxicity

- the inherent capacity of a substance to produce deleterious effects

- a measure of the degree of harm caused by a specific exposure of a living organism to a substance
Toxicity

- there are no harmless substances — there are only harmless ways to use substances

- the dose makes the poison
  - duration
  - concentration
  - route
  - frequency
  - ...

Hazard

- the set of inherent properties of a substance that makes it capable of causing adverse effects on organisms or the environment

- often considered equivalent to toxicity
A hazard is a potential source of risk that does not necessarily produce risk. A hazard produces risk only if an exposure pathway exists and if the exposure creates the opportunity for adverse consequences.
Risk

- a characteristic of a situation or action where a number of outcomes are possible:
  - the particular one that will occur is uncertain and at least one of the possibilities is undesirable

- involves:
  - the possibility of an adverse outcome and uncertainty over the occurrence, timing, or magnitude of the adverse outcome
Risk

- the probability that a toxic effect will occur
  - depends on the conditions under which a substance is used

- whether or not something is a risk depends on a number of factors:
  - toxicity of the substance
  - intensity of the exposure
  - route of entry
  - controls in place
Quantitative Risk Assessment

- a systematic process for quantifying and describing the risk associated with a substance, situation or action:
  - equivalent to risk characterization
  - a process of attributing probability with the associated uncertainties
  - considers the concepts of threshold
Concept of threshold

- A threshold is the concentration level below which it is believed that there will be no adverse effects on nearly all exposed individuals.

- A threshold level is often derived from a NOAEL (no observed adverse effect level) established in animal experiments or human studies.
Six Steps to Setting Up a Data Collection System

1) determining the population at risk
2) identifying the hazards and assessing the exposures
3) defining the worker-workplace interface
4) assessing the health outcomes
5) developing the data collection and management system
6) training the in-house staff
Step 1

Determining the Population At Risk
Population At Risk

• of whom should we keep a record?
• what type of record?
• information needed?
Records of Whom?

- a worker is at risk if he or she has a greater chance of developing disease than a similar, but non-exposed worker
- for recording purposes, each worker should be included in the data collection system and have a distinct/unique identification
Type of Record?

- record-keeping system that builds in zero possibility of mistaking one worker’s information with that of another
- complete records can play a major role in resolving problems and become solid data for epidemiology
Information Needed on Records

- Employee records should be accurate and up-to-date with:
  - Full name (first, middle and surname)
  - Birthdate (year, month, day)
  - Official numbers (SIN, miner’s, ...)
  - Gender
  - Parents’ names
  - Place of birth
  - Ethnic origin if possible (disease rate/origin)
  - Date serious diseases (cancer) contracted
  - Date of departure from company
  - Date of death (during employment or after)
Information Needed on Records

- example of basic personal information needed for epidemiologic research
Step 2

Identifying the Hazards and Assessing the Exposures
Assessing the Hazards and Exposures

The first steps of Hazard Identification and Exposure Assessment include:

1. Health Hazard Identification
2. Measurement of Exposure
3. Creation/Use of Occupational Exposure Database
1. Health Hazard Identification

- inventory of raw materials used
- materials produced
- byproducts, contaminants and emissions
- procedures used
- equipment
- PPE used
- control measures in place
Hazard Communications

- WHMIS has lead the way in Canada to provide information to those who work with hazardous chemicals.
- MSDS has a wealth of information to help characterize the hazard.
- While the most common information on an MSDS may be familiar, why are the Physical Properties of the chemical so important?
Physical Properties to Consider

Using water as an example to demonstrate physical properties of chemicals, consider the following:

- what happens to water when it is maintained below 0 degree C?
- what happens when water is outside in a sunny atmosphere?
- what happens when water is boiled?
- what happens when water vapour comes in contact with a cool object?
Physical Properties on Previous Slide Demonstrate:

- freezing point (low vapour pressure)
- evaporation (moderate vapour pressure)
- boiling (very high vapour pressure)
- condensation (process of the chemical being concentrated at a particular location)
Process Flow

(customize for each site)
Assessing the Hazards

whether or not something is a risk depends on a number of factors
Assessing the Hazard

- factors to be considered
  - chemical factors
  - exposure factors

- useful evaluation tools
  - Material Safety Data Sheets (MSDS)
  - Threshold Limit Values (TLVs)
  - databases/classification systems
Factors to be considered

• the chemical factors
  – toxicity of the chemical
  – the exact chemical form (speciation)
  – the route of entry
  – the concomitants exposures
  – ...

Factors To Be Considered

- the exposure factors
  - intensity of the exposure
  - duration of the exposure
  - controls in place
  - ...

Useful Evaluation Tools

- MSDS contain a lot of information on the toxicity of different chemicals
- Web sites with MSDS databases
Useful Evaluation Tools

- TLVs are also indicators of risk
  - definition of TLV
  - definition of TWA
  - definition of STEL
  - definition of Ceiling
Threshold Limit Value

- refers to airborne substances

- introduced by the ACGIH, these values are established for repetitive exposures over conventional workdays (8 hrs/day, 5 days/week)

- it is believed that nearly all workers may be exposed repeatedly to such concentrations without adverse effects
TLV

- TWA

  - Time-Weighted Average of the exposure concentrations over an 8-hour work shift
TLV

• STEL
  – excursion concentration for short periods (15 minutes, 4 times/day) within an 8-hour shift to which workers can be exposed providing that the daily TWA is not exceeded
  
  – recommended only when toxic effects have been reported for high short-term exposures in humans or animals
TLV

STEL

TWA

Work Shift Duration
TLV

Ceiling (C)
- concentration that should not be exceeded during any part of the working day
Non-conventional Work Shifts

- what do we do for shifts that are longer than 8 hours:
  - adjustment of the TWA (different approaches)
  - keep the same excursion limits
  - ceiling values generally unchanged
Useful Evaluation Tools

- databases and classification of specialized organizations are also useful tools for classification of risk
  - e.g. Micromedex (environmental health & safety series)
  - International Agency for Research on Cancer (IARC)
IARC Classification System

- The term "carcinogenic risk" in IARC Monograph series is taken to mean the probability that exposure to an agent will lead to cancer in humans.
- IARC has developed a five-point system to classify chemicals in terms of their likelihood of causing cancer.
IARC Classification System

1: The agent (mixture) is carcinogenic to humans
2A: The agent (mixture) is probably carcinogenic to humans
2B: The agent (mixture) is possibly carcinogenic to humans
3: The agent (mixture or exposure circumstance) is not classifiable as to its carcinogenicity to humans
4: The agent (mixture) is probably not carcinogenic to humans
Measurement of Exposure

- air sampling
  - essential tool for the development and implementation of an infrastructure and systems for risk assessment of metals and metal species
Measurement of Exposure

- air sampling
  - to ensure compliance with regulations
  - to choose proper protective equipment
  - to evaluate the effectiveness of controls
  - to perform epidemiological studies
Air Sampling Strategy

- are there common exposures to metals and other contaminants?
- is there a list of priority substances for measurement?
- has the toxicological information on species and compounds been considered?
Air Sampling Strategy

- how should the exposures be measured?
- should air sampling and/or biological monitoring be used?
- should air sampling include personal and/or area samples?
Air Sampling Strategy

- should the air sampling be based on long-term and/or short-term sampling?
- what exposure level should trigger the need for controls?
Air Sampling Strategy

- who should be sampled?
- how many samples should be taken?
- how often should samples be collected?
- when should sampling occur?
Air Sampling Strategy

- should samples be taken on a person, job, occupational group or similar exposure group basis?
- should a common methodology for sampling and analysis be used?
- who should design the strategy and make the measurements?
Sampling and Analysis Methods

- must be able to compare with other data
  - historical, existing
  - between departments
  - between companies
  - between countries
Sampling and Analysis Methods

- regulated methods
  - Ontario, Quebec, U.S.A.
- standards
  - CSA, ANSI
- recognized authorities
  - NIOSH, ACGIH
Assessing the Hazards and Exposures

- measurement of individual metal species
- appropriate sampling and analysis of metal species
- consideration of route of exposure
Air Sampling

- **active sampling**
  - pump
  - sampling medium

- **passive sampling**
  - no pump
  - static air layer or permeation through a membrane
Active Sampling

- sampling pump
  - battery
  - air flow (litres per minute, +/- 5 %)
- calibrator
  - before and after every sample
  - primary versus secondary
Air Sampling Pump
Active Sampling

- collection media
  - filter
    - PVC, cellulose ester, silver
  - sorbent tube
    - charcoal, silica gel
  - grab/bulk sample
    - air bag/container
  - impinger
    - liquid
Sampling for Dust

Filter/Cassette

Gas/Vapour

Dust

Gas/Vapour
Sampling for Gas and Vapour

Charcoal or other Media Tube

Specific gases and vapours adsorb onto the media and can later be stripped and analyzed in the laboratory.
Sampling for Dust, Fume and Vapour

Filter/Cassette

Charcoal Type Tube

Adsorption of Gas on Media

Dust

Gas/Vapour
Impinger Sampling
Passive Monitor
Airborne Particles

- potential for hazard depends on:
  - particle size
    - site of material deposition
  - mass concentration
    - amount of material deposited
Airborne Dust

- **inhalable particulate mass**
  - materials that are hazardous when deposited anywhere in the respiratory tract (diameter of 100 microns or less)

- **respirable particulate mass**
  - materials that are hazardous when deposited in the gas-exchange region of the lungs (diameter of 5-10 microns or less)
Airborne Dust

- **total dust**
  - closed-face filter cassette at 2 L/min
  - no size selection

- **respirable dust**
  - nylon cyclone at 1.7 L/min
  - selects particles below 10 microns
IOM Sampler

(developed by J.H. Vincent and D. Mark of the Institute of Occupational Medicine (IOM), Scotland)

- developed for sampling inhalable fraction
- simulates dust collected by nose and mouth
IOM Sampler

- considerations
  - personal sampler
  - conductive plastic
  - 15-mm opening
  - standard 25mm filters
  - lightweight
  - flow Rate of 2 L/min
  - weigh cassette and filter together
IOM Sampler
## Methods

<table>
<thead>
<tr>
<th>Substance</th>
<th>Apparatus, Method of Sampling &amp; Analysis</th>
<th>Reference</th>
</tr>
</thead>
</table>
| Total Dust      | - personal sampling pump  
                  - 25 or 37mm mixed cellulose ester (MCE) or polyvinyl chloride (PVC) filter  
                  - air sampling flow rate of 2 L/min  
                  - weigh on microbalance                                                                | NIOSH method #0500       |
| Inhalable Dust  | - personal sampling pump  
                  - IOM inhalable aerosol sampler  
                  - 25mm diameter MCE/PVC filter  
                  - air sampling flow rate of 2 L/min  
                  - weigh on microbalance                                                                | Vincent                  |
| Respirable Dust | - personal sampling pump  
                  - 10mm nylon cyclone  
                  - 25mm or 37mm MCE/PVC filter  
                  - air sampling flow rate of 1.7 L/min  
                  - weigh on microbalance                                                                | NIOSH method #0600       |
## Methods

<table>
<thead>
<tr>
<th>Substance</th>
<th>Apparatus, Method of Sampling &amp; Analysis</th>
<th>Reference</th>
</tr>
</thead>
</table>
| Respirable Silica | • personal sampling pump  
• 10mm nylon cyclone  
• 25mm or 37mm MCE/PVC filter  
• air sampling flow rate of 1.7LPM  
• weigh on microbalance  
• infrared spectrophotometer (IR)  
• x-ray defraction (XRD)  
• colourmetric metals | NIOSH method #7500 (XRD)  
NIOSH method #7601(UV-VIS)  
NIOSH method #7602 (IR)  
NIOSH method #7603 (IR) |
| Metals          | • same as total dust or inhalable dust  
• use only MCE filters  
• atomic absorption spectrophotometer (AA)  
• inductively coupled plasma spectrophotometer (ICP) | NIOSH method #7300 (ICP)  
NIOSH methods for general metals #7300  
specific methods for other metals  
NIOSH method #7300 (ICP) |
Assessing the Exposures

- wherever possible, an exposure assessment strategy should be based on five principles:
  - Homogeneous Exposure Groups
  - full shift personal sampling
  - random sampling
  - statistical reliability
  - statistical summary
Homogenous Exposure Groups (HEG)

- an HEG is the core idea in making detailed workplace exposure assessments

- an HEG can be defined as a group of workers with exactly the same likelihood of exposure to a single agent
Homogeneous Exposure Groups (HEG)

- a group is homogeneous in the sense that probability distribution of exposures is the same for all members of the group

- the term homogeneous does not mean that all members have identical exposures any single day
Homogeneous Exposure Groups (HEG)

- Use of the HEG has great practical value in terms of time spent collecting data.
- The statistical definition of an HEG means that a small number of randomly selected samples can be used to define exposure distributions and trends within the HEG.
Assessing the Exposures

- **full shift personal sampling**
  - use full shift personal sampling as much as possible
  - at least 75% of the shift should be covered, including highest exposure time

- **random sampling**
  - within an HEG, the person, the day and the shift must be randomly sampled
  - random sampling is essential for statistical purposes
Assessing the Exposures

- **statistical reliability**
  - to be reliable, a sufficient number of samples should be collected
  - a general rule of thumb is to collect at least 10 samples from each HEG
  - variability of the exposure concentrations will influence the number of samples required
  - statistical analysis will tell you the exact number of samples you need
Assessing the Exposures

- **statistical summary**
  - this involves calculating the arithmetic mean (AM) and standard deviation (SD) of the measured exposures
  - exposure data distributions tend to show many more extreme results on the high side of the concentration scale
  - as a result, statistical summaries should be put together after the measured exposures have been transformed into logarithms with reference to the geometric mean (GM) and the geometric standard deviation (GSD)
Normal Distribution

Normal or Gaussian Distribution

![Graph of a normal distribution with a bell curve and a bar chart showing the frequency distribution.](image-url)
Standard Deviation

Empirical Rule
Lognormal Distribution

- lognormal distribution, GM/GSD
Number of Samples

- confidence interval and number of samples
Assessing the Exposures

- store in a database
- treat and analyze statistically
- continue (+++) sampling to obtain statistical significance
- look for HEG
- reduce (- - -) sampling frequency by building HEG
Who should design and carry out the IH program

- as much as possible, a qualified industrial hygienist should design the occupational exposure program and perform the initial hazard and exposure assessment
Occupational Exposure Database

- occupational exposure databases containing complete and reliable data are needed:
  - for testing compliance against a standard
  - for occupational health assessments
  - for occupational epidemiological studies
  - for quantitative risk assessment
Occupational Exposure Database

guidelines for the collection of industrial hygiene exposure assessment data for epidemiological use have been published

– see Checkoway et al. (1987), and Harris (1995)
Occupational Exposure Database

- a basic-level program will permit a reasonable level of retrieval and epidemiological interpretation of IH exposure data that are routinely collected
Step 3

Defining the Worker–Workplace Interface
Defining the Worker–Workplace Interface

- to understand the relation between exposure to metals and metal species on human health, it is necessary to estimate cumulative exposure for each employee

- personnel records should contain:
  - clear job descriptions
  - job duration
1. Clear Job Descriptions

- reference to each job performed by a particular employee
- consistent classification process
- clearly identify and classify job
2. Job Duration

- record should include time spent in a particular job
- start and ending date for each job category
- work shift regime (i.e. days, shift, 12-hours, etc.)
Worker–Workplace Interface

- also requires the estimate of Cumulative Exposure

- this is a function of all of the Job / Duration/Exposure Information
Step 4

Assessing Health Outcomes
Assessing the Health Outcomes

Step 4 (Infrastructure and Systems for RA)

- Medical information is an essential part of an employee’s file
- **Occupational Health** evaluations are based on risk
- **General Health** medical evaluations offered as required
- Med. Evaluation to ensure *fitness to work* without risk to self or others such as for:
  - Mobile equipment operator / critical jobs
  - Jobs with higher physical demands (Rescue)
Medical evaluations

- **Company guidelines: 2 types**

  1. **Occupational risks related** (mandatory/regulated)
     - biological monitoring/questionnaire (**lead/cadmium etc.**)
     - no risk = no specific evaluation (office employee)
  
  2. **General health risks oriented**
     - Offered to employees on a periodical basis
     - Based on personal health risk i.d.
       - Cholesterol / High Blood Pressure / Overweight
     - Facilitating risk elimination through lifestyle improvements
     - In cooperation with and **not substituting** for personal physicians
Basic Information

- employee i.d.
- date of hiring
- date of examination
- full name of employee
- date of birth
- personal physician’s name
- height and weight

name/signature of health professional
A written and communicated policy on confidentiality of medical records is a must at each site.
Past & present history

- Work history and exposures
  - from HR or IH
- Pertinent family medical history
- Past personal medical history
  - illnesses, accidents, injuries, known allergies
- Current medical concerns
  - symptoms, medication, restrictions
Personal habits

- Smoking history
  - age started, age stopped, # /day
  - pack/years = average # per day X years smoked
    - Example: 1 pack a day for 20 years = 20 pack/years
    - 1/2 pack a day for 30 years = 15 pack/years

- Alcohol consumption
  - wine / beer / hard liquor
  - drinks per day, current and past

- Controlled substances (reliability)
Information Collected

- Subjective questionnaire and objective examination (note abnormal findings)
  - eyes
  - ears
  - skin
  - respiratory system
  - cardiovascular system
  - digestive system
  - musculoskeletal system
  - nervous systems
Types of evaluations (tests)

- fitness to wear respirators
- chest x-rays (routine lumbar spine x-rays)
- respiratory questionnaire (*ATS*)
- spirometry
- audiometry
- biological monitoring
- mobility
- exercise tolerance in some instances

* American Thoracic Society
Why all this information?

- **Smoking data**
  - confounding factor in many epidemiological studies
  - a must in all data

- **Previous occupational exposures**
  - Knowing all the factors in evaluating an occupational disease
    - example: asbestos exposure and mesothelioma
    - may be very helpful in helping to settle claims after retirement
Health evaluation / surveillance

Health surveillance programs to
- monitor workers’ health
- provide useful information for studying effects of exposure to *speciated* metals

They include activities related to
- risk exposures
- and job requirements
Health surveillance programs

- history
- subjective questionnaires
- objective findings
- screening tests
- biological monitoring

- follow-up testing
- information to employee
- results communication
- trends analysis
  - stratified reports
  - averages
  - others
Hazards vs. Health Effects

- Review process for Hazard Identification:
  - managers
  - process engineers
  - IH-OH & S professionals team

- Identify potential health problems
  - Create list of relevant questions for use in medical examinations (specific potential symptoms)
  - Identify biological markers
    - of exposure: blood lead / urinary cadmium levels
    - of toxicity (effects): $\beta_2$ microglobulins
Biological Monitoring

- tracks total exposure to substances from *all sources* (air/food/water/at work and home)
- provides opportunity for early intervention by using *action levels*
- *links with industrial hygiene* efforts in the evaluation of the work environment and work practices
- provides good *indicators* of the efforts and changes in improving the work environment
Biological Monitoring Program (BMP) Characteristics:

- Categories of employees
  - according to exposure duration
  - type of exposure
  - type of metal
  - species of metal (Oxides/sulfides/metallic)

- Frequency of biological monitoring according to
  - exposure duration
  - species of metal
  - previous results

- Type of health assessment according to employee status and job
BMP as per categories

*Example of protocols*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Frequency of Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I (minimal exposure)</td>
<td>Pre-placement</td>
</tr>
<tr>
<td>Category II (less than 20% time)</td>
<td>Pre-placement and depending on exposure</td>
</tr>
<tr>
<td>Category III (more than 20% time)</td>
<td>Pre-placement and as per specific hazardous substance</td>
</tr>
</tbody>
</table>
# BMP as per employee status

<table>
<thead>
<tr>
<th>Employee Status</th>
<th>Health Assessment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>New employees</td>
<td>Pre-placement health assessments and biological monitoring baseline</td>
</tr>
<tr>
<td>Regular employees</td>
<td>Periodic exams and biological monitoring</td>
</tr>
<tr>
<td>Exiting employees</td>
<td>Biological monitoring if not done in the previous month</td>
</tr>
</tbody>
</table>
BMP: numbers & categories

- Normal levels
- Action levels
- Relocation levels
- Return-to-work levels
- Optimal levels (CHUL)
- Maximal levels (CHUL)
BMP: numbers

Definitions for result levels

- “Normal levels” ($Pb: < 10 \mu g/dl$)
  - average level found in the general population
  - may vary according to location:
    - large city vs. countryside / industrial area / farming
    - potable water (Chile and arsenic)
Action level \((Pb: 35 \mu g/dl)\)

- A level which is safe, but serves as an indication of potentially significant exposure.

- It is the level at which prevention activities are carried out to prevent going to the higher relocation levels for some substances (metals).
Note on Action Level: Prevention

- Find out why an exposed worker has reached the action level
  - Compare to coworkers (same exposure)
  - Overtime?
  - Process incident?
  - Protective equipment?
  - Susceptibility? Endogenous exposure?
  - Outside exposure?

➤ Implement corrective actions
Relocation level

- a level at which there is concern about an employee’s level of exposure and he/she is relocated temporarily or permanently to a location where exposure levels are non-existent or low

- **examples for lead:**
  - 44 ug/l at Noranda
  - 60 in Quebec
  - 80 in Belgium
Return-to-work level

- A level at which it is safe for the relocated worker to return to previous duty
- Implies the same actions as the action levels
Quebec CHUL results

- **Optimal level:** “A level at which the likely occurrence of toxic effects is close to zero”

  - Example: Pb (blood) : 40 µg/dl

- **Maximal level** “A level at which the likelihood of toxic effects is most likely to occur”

  - Example: Pb: 60 µg/dl
BMP: implementation

- Establish a list of substances/hazards that need to be biologically monitored regularly
- Assure due process for
  - appropriate scheduling
  - follow-up
  - communication of results & feedback to employees
BMP: implementation (continued)

- **Ensure process to review**
  - results of monitoring
  - trend analysis
  - communication to workers
  - problem identification and recommendations

- **Periodically review protocols**
  - process change
  - work practices modifications
  - new scientific evidence
  - new regulations and standards
Hazard information

- Hazardous substance guidelines
  - route of entry
    - target organs
  - biological tests done
    - marker of exposure
    - marker of toxicity (if any)
  - frequency of testing
  - normal values
  - action levels etc.
Hazardous substance guidelines

- relocation level and/or criteria when it applies
- “return to regular duties” level when it applies
- “permanent relocation criteria” and other relevant actions when indicated (ex: specialist evaluation)
  - according to the characteristics of the substance
  - based on medical evidence
Health Surveillance DATA

- Maintain health status records for employees who have left the company for:
  - illness
  - death
  - retirement
  - new company

- WHY?
  - Delayed effects of some metals (and substances) long after employees leave the company
  - Examples: Beryllium / Silica / Asbestos / Cadmium
Health Surveillance Data

- use for epidemiological studies
  - schedule exit interview
  - trace former employees through unions, newspaper, relatives
Speciation: Why Is It So Important?

- Health effects of metals will vary depending on their *chemical form*:

- Examples:
  - Lead oxides: very soluble
  - Lead sulfide: poorly soluble
  - Zinc oxides: Metal Fume Fever
  - Metallic Copper: no effect
  - Selenium dioxide: strong irritant
  - Selenium yeast: nutrition supplement
Speciation: Why Is It So Important?

- Regulations are usually made for the same metal for all its chemical forms/species
  - over-protection?
  - Under-protection?
- Need to use scientific data to adjust process control / personal protection/biological monitoring to the speciated exposures:
  - less invasive programs for some species
  - focus on the real issues (risks i.d.)
  - better returns on the investments in H & S
Step 5

Developing the Data Collection and Management System
Database Management

- computer
- flexible
- useful and accurate information
- tables
- common fields
Designing a Database

- understand the purpose
- identify the tables
- identify the fields
- establish unique identifiers
- identify common fields
- avoid data redundancy
- construct queries, forms and reports
- test design and redesign
Developing a System

- human resources
  - payroll
  - benefits
- computer systems
- occupational health
- industrial hygiene
- environment
- purchasing
Principles of Database Design

- compatibility with other databases
- unique identifier as key field
- centralized employee database
- quality assurance program
- flow of information
- confidentiality
- prevention of information loss
Section 3

Internal Benchmarking

A step towards improvement
Why?????

With respect to the system(s) in place for sampling and/or controlling worker exposures to contaminants:

– Evaluate how well the system is working
– Determine if the system continues to meet the needs of the organization
– Make the existing systems more efficient
– Integrate changes where they are needed
Internal Benchmarking

- A process:
  - to review the data collection system
  - to evaluate the effectiveness of the controls in place
  - to ensure that the specialties involved are working effectively
  - to improve procedures
Basic steps of internal benchmarking

1. Understand the data gathering system
2. Assess the data gathering system
3. Identify and plan improvements
4. Implement changes
You have the data!

- **HOW GOOD IS IT?**
- **WHAT IS IT TELLING YOU?**
Understand the data gathering system

- **How?**
  - sampling strategy
  - sampling procedures
  - recognized techniques
  - state of the art
  - competent technical personnel (field and lab)

- **What?**
  - what data do we need?
  - what criteria are used?
  - objectives of the data gathering process?
  - who will be using the data?
Assess the data gathering system

- **How?**
  - compliance with sampling requirements
  - calibration procedures
  - quality assurance
  - competence of sampling personnel

- **What?**
  - results compared with criteria
  - is it complete?
  - risk assessment based on data
  - priorities for improvement
Identify and plan improvements to the system

- **How?**
  - review observations from the assessment
  - identify corrective actions
  - review their feasibility
  - identify required resources
  - develop an implementation schedule

- **What?**
  - identify control options
  - assess each option and prioritize
  - recommend solutions
  - assess their feasibility
  - participate in implementation
  - report
Implement changes to the system

**How?**
- Modify sampling strategy
- train technical personnel as needed
- implement, upgrade quality control procedures

**What?**
- Follow-up on recommendations
- collect additional supporting data
- review data to assess impact of modifications
- review objectives
Applications of internal benchmarking

- Improve procedures
- Solve specific problems
- Redesign procedures
- Involve employees
- Stimulate new ideas
- Compare performance
- Develop strategy
- Implement changes
Recap

- Four steps of internal benchmarking
  1. Understand
  2. Assess
  3. Identify
  4. Implement