جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Industrial Hygiene (IH) Manual

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Health, Safety and Environment Department

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1 Introduction

King Abdullah University of Science and Technology (KAUST) is an international research institution with a strong commitment to protecting the health and safety of its faculty, staff, students, and visitors, as well as protecting its assets and the environment. Moreover, it is the objective of KAUST to be a leader among its peers in the international research community for its health, safety, and environmental performance.

The Health, Safety & Environment (HSE) Department has the responsibility to manage all safety aspects within the University research facilities. The mission of HSE is to promote a safe and healthy work environment by providing and coordinating programs and services related to safety and also by developing safety related policies.

Industrial Hygiene is the science of anticipation, recognition, evaluation and control of occupational hazards (i.e. chemical, biological, physical, ergonomic, and psychological) or other workplace conditions that may cause sickness, immediate or delayed impairment of health and well-being, discomfort, or physical discontent.

KAUST Industrial Hygiene (IH) program encompasses the occupational hazards associated in the research facilities and laboratories with chemical agents, biological agents, physical agents such as noise, radiation, temperature extremes, vibration; as well as ergonomic hazards. Through the identification and assessment of exposure risks, the HSE professionals dedicated to industrial hygiene activities work towards protection of individuals from these hazards within the academic and research communities.

In industrial hygiene, workplace exposures are measured to both estimate individual risk, and verify effectiveness of controls. KAUST emphasize not only the importance of compliance with the occupational exposure limits (OELs), but ensure the appropriate principles and methods of controls are applied.

Scope

The foundation of the IH program is exposure assessment. Workplace exposure assessment (e.g. Health Risk Assessment) will apply to all research operations (including laboratory design, construction, operation, decontamination/ decommissioning, and environmental restoration activities). This Manual provides direction for consistent implementation of KAUST's industrial hygiene methodology and assessment strategies.

To implement a comprehensive and effective industrial hygiene program that will eliminate or minimize the risk of occupational injury or illness to all research staff at KAUST.

Objectives

- Ensure industrial hygiene hazards are identified, evaluated, assessed, and controlled consistently across sites, utilizing identified rationale, methodology and tools to characterize, monitor, communicate and document potential and actual exposures to occupational hazards.
- Assure that potential health hazards in the work environment are identified, risk ranked and prioritized, technically evaluated, and where appropriate eliminated or controlled to the extent feasible.
- Provide for systematic monitoring, surveillance and inspection of potentially hazardous tasks/operations with subsequent recommendations for elimination, substitution, engineering, administrative and/or personal protective controls to ensure staff protection.
- To maintain personal exposures below KAUST adopted Occupational Exposure Limits (OELs).

- Establish methods to conduct industrial hygiene assessments based on recognized and accepted practices.
- Provide for the consistent dissemination of industrial hygiene assessment results as appropriate.
- Ensure a method to prompt review and implementation of industrial hygiene recommendations.
- Establish responsibilities for the various elements of the program including: monitoring survey requests, corrective actions, and information dissemination and recordkeeping.
- Provide methods for follow-up and program auditing activities.
- Provide a mechanism whereby industrial hygiene results may be provided to Occupational Health (OH) to determine if health/ medical surveillance is required, as appropriate.

2 Definitions

Absorbed Dose: The amount of a substance penetrating a worker's exchange boundaries (e.g., lungs, skin, gastrointestinal tract) after contact (exposure).

Action Level: Unless specifically defined in regulatory standards, the action level will be defined as half (50%) of the Occupational Exposure Limit (OEL). An action level triggers the initiation of required activities, such as exposure monitoring, medical surveillance or additional controls to lower the OEL where possible.

Air sampling: The collection of samples of air followed by laboratory analysis to measure the presence and concentration of chemical, physical, or biological pollutants in the air.

Analytical method: A standardized laboratory procedure used to determine the amount or concentration of a certain contaminant in an air or wipe sample.

Area air sampling: The collection of air samples from a fixed location in a work area.

As Low As Reasonably Practicable (ALARP): Reasonably practicable involves weighing a risk against the trouble, time and money needed to control it. Thus, ALARP describes the level to which we expect to see workplace risks controlled.

Baseline monitoring: The measurement of exposure levels and their variability for workers in a similar exposure group (SEG). Baseline monitoring generally uses a random sampling strategy directed at determining the exposure profile of an SEG for a given time period.

Biological hazard: Hazard from biological agents such as viruses, bacteria, spores, fungi, blood borne pathogens.

Breathing Zone: A zone of air in the vicinity of a worker from which air is breathed. Personal breathing zone measurements of air contamination concentrations frequently are made by directly packing monitors in the breathing zone of workers.

Carcinogen: A hazardous substance that causes the development of cancerous growth in living tissue.

Chemical hazard: Hazards posed from hazardous materials such as acids, bases, solvents, cryogens, etc.

Dose: The amount of agent available for interaction with any specific organ or cell.

Exposure Assessment: The process of estimating or measuring the exposure to an agent in the environment, or estimating future exposures, involving the systematic collection and analysis of exposure determinants such as work tasks; magnitude, frequency, variability, duration, and route of exposure; and the linkage of the resulting exposure profiles of individuals and similarly exposed groups for the purposes of risk management and health surveillance.

Exposure Rating: An estimate of exposure level relative to the OEL assuming the absence of PPE. In the absence of an OEL, a "working OEL" can be based on the toxicological information collected during the basic identification phase.

Exposure Route: Means of entry of the agent into the body - through a body opening (e.g. as eating, drinking, or inhaling) or uptake through absorption of tissues, (e.g. through the skin or eye)

Hazard Characterization: Defines the relationship between the degree of exposure (or amount of dose) observed in animal or human studies and the magnitude of the observed adverse health effects. This usually includes a quantitative measure of adverse health effects for a range of doses. For carcinogens, dose-response data are used to calculate quantitative estimates of the increased risk of developing cancer per unit of exposure. For chemicals that cause adverse health effects other than cancer (i.e., non-

cancer effects), dose-response data are used to calculate “safe” levels). The development of these values usually involves extensive review of available relevant data, the use of mathematical models, the application of uncertainty factors and dose conversions, and other considerations.

Hazard control ventilation: An industrial exhaust system that captures and removes contaminants emitted from local sources before dilution into ambient workplace air can occur; includes chemical fume hoods, soldering bench hoods, extractor arms, glove boxes, and biological safety hoods or cabinets.

Hazard Identification: The review of relevant toxicological, biological, and chemical information to identify the adverse health effects associated with a potential hazard under various exposure scenarios.

Hazardous Exposure: Exposure to any toxic substance, harmful physical agent, ergonomic stressor, or harmful biological agent that poses or may pose a recognized hazard to the health of employees.

Health Risk Assessment (HRA): The identification of health hazards in the workplace and subsequent assessment of risk to health. This assessment takes into account existing or proposed control measures. Where appropriate, the need for further measures to control exposure is identified.

High-efficiency particulate air (HEPA) filter: A filter capable of removing from the air at least 99.97 percent of dust, pollen, mold, bacteria and any airborne particles with a size of 0.3 micrometers or larger.

Industrial hygiene (IH): The science devoted to the anticipation, recognition, evaluation, prevention, and control of those occupational factors or stresses arising in or from the workplace which may cause sickness, impaired health and well-being, or significant discomfort among workers or citizens of the community.

Industrial hygiene assessment: Workplace survey/evaluation for hazardous substances and contaminants, often including air sampling.

Industrial hygienist: A professional qualified by education, training, and experience to anticipate, recognize, evaluate and develop controls for occupational health hazards and environmental issues.

Medical surveillance: Periodic medical evaluation for personnel potentially exposed to designated chemical, biological, and physical hazards.

Occupational Carcinogen

A chemical substance utilized in the workplace that has been designated in the following sources as a carcinogen or potential carcinogen:

- National Toxicology Program, Annual Report on Carcinogens (latest edition)
- International Agency for Research on Cancer, Monographs (latest editions)
- OSHA standard 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances
- American Conference of 10 Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents
- EU European Chemicals Agency (ECHA) - Substances which are classified as carcinogen category 1A or 1B in Part 3 of Annex VI to Regulation (EC) No 1272/2008

Occupational Exposure Limit (OEL): An exposure limit to represent:

- The concentration or intensity of the agent that is allowable;
- The time period over which workplace concentrations are averaged to compare with the allowable intensity, and
- The allowable level of a determinant in a biological sample.

Some substances may have several OELs (e.g., one for 8 hours, one for 15 minutes, and a not-to-exceed ceiling). OELs include regulated limits [e.g., OSHA's Permissible Exposure Limits (PELs)] and recommended limits [e.g., the Threshold Limit Values (TLVs).

Occupational Safety and Health Administration (OSHA): Regulatory agency under the United States Department of Labor created by Congress to ensure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance.

Permissible exposure limit (PEL): An exposure limit published and enforced by the US federal Occupational Health and Safety Administration (OSHA) as a legal standard. PEL may be either a time-weighted-average (TWA) exposure limit (eight hour), a 15-minute short term exposure limit (STEL), a ceiling (C), and may have a skin designation.

Personal air sampling: The collection of air samples at the worker's breathing zone to reflect the level of a worker's exposure to a contaminant throughout a work day.

Personal noise sampling: The collection of noise samples at the worker's hearing zone to reflect the level of a worker's exposure throughout a work day.

Physical hazard: Hazard from physical agents such as noise, non-ionizing radiation, and magnetic fields.

Potential dose: The amount of agent that is ingested, inhaled, or applied to the skin

Professional judgment: That capability of an experienced professional to draw correct inferences from incomplete data. Such judgment is based on observation, analogy, past experience, and peer review.

Process: A stand-alone manufacturing or service operation. Departments may represent a unique process, or there may be multiple major processes may exist within one department.

Qualitative exposure assessment: The estimation of the magnitude, frequency, duration, and route of exposure based on integration of available information and professional judgment.

Quantitative exposure assessment: The determination of the magnitude, frequency, duration, and route of exposure based on collection and quantitative analysis of data sufficient to adequately characterize exposures.

Risk Assessment: A basis for estimating and evaluating the potential health effects that individuals or populations may experience as a result of exposure to hazardous substances. Risk assessments typically involve both qualitative and quantitative information including:

- Hazard identification;
- Hazard characterization, including dose-response assessment;
- Exposure assessment; and
- Risk characterization.

The integration of the hazard identification, hazard characterization, including dose-response, and exposure assessments to describe the nature and magnitude of the health risk in a given population. - includes a presentation of the uncertainties in the assessment, discussion of degree of confidence, data gaps, limitations, and other considerations to help describe the potential risks.

Risk Profile: A representation, commonly as a matrix or other means, of the analysis of exposure assessment data and medical profile data, resulting in a qualitative or quantitative estimation of the risk of health effects. This estimation is used to guide risk management decisions and decisions about the need for additional health effects, epidemiological, or toxicological studies. The profile should, at a

minimum, relate the potential for exceeding the Occupational Exposure Limit to the observed or measured medical monitoring data or trends.

Sample Type – Area: An environmental sample collected at a fixed point in the workplace that reflects chemical contaminant concentrations or levels of physical or biological agents present at that point. Results from area sampling should be interpreted with caution because they do not represent employees' actual exposures to hazardous agents.

Sample Type – Bulk: One or more increments taken from a larger quantity of a material that is to be analyzed.

Sample Type – Personal: The process of measuring the concentration of a hazardous chemical in the breathing zone of an individual, using a method such as a personal air pump to gather a sample for analysis, a direct-reading instrument, or a monitor worn by the worker in the breathing zone. For physical or biological agents, it is the process of measuring the quantity that potentially contacts or affects any part of an exposed individual. Area monitoring is not considered personal monitoring.

Sample Type – Wipe: Collection of agent(s) on wipe media (typically a wipe of filter paper on an area 100 cm^2); results are useful indices of contamination level, but they are not direct estimators of exposure. A procedure to check for contaminants by wiping a representative surface of known area with an acceptable wipe material, which is analyzed by chemical extraction.

Sampling Strategies: Methods for measuring airborne contaminants for compliance to the Occupational Exposure Limits (OELs) - a strategy that accounts for individual exceedance and group exceedance for between-shift variation and between-worker variation of measurements above or below 3 standard deviations.

Similar Exposure Group (SEG): A group of employees whose exposures to chemical substances have been determined to be similar enough that monitoring the exposures of randomly selected workers in the group provides data useful for predicting the exposures or exposure profiles of the remaining workers. An SEG is also defined as a group of individuals who perform the same jobs or tasks and who have similar potentials for exposure to a single hazardous agent.

Each employee should be classified into similar exposure groups/exposure zones so that they may be linked to hazards and work tasks/activities. Breaking out this information helps to make worker exposure assessment more manageable and is important for proper medical surveillance and evaluation of health risks.

Task: A work element or series of work elements.

Threshold limit value (TLV): Recommended guidelines for occupational exposure to airborne contaminants published by the American Conference of Governmental Industrial Hygienists (ACGIH). TLVs represent the average concentration for an eight-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed without adverse effect.

3 Roles and Responsibilities

The responsibility for health and safety within laboratories falls on the Center Director or Principal Investigator to ensure that personnel working in the laboratory have received all appropriate training and have been provided with all the necessary information to work safely in laboratories under their supervision. Center Directors and Principal Investigators have numerous resources available to them to ensure a safe laboratory.

3.1 Center Directors/Principal Investigators (PI)

Principal Investigators and Laboratory Managers are accountable for the health and safety of personnel engaged in the use of hazardous substances under their supervision. Their responsibilities include:

- Review lab activities and experiments to determine any potential exposure to hazardous substances under their supervision;
- Coordinate with the Industrial Hygienist for IH assessments and management of exposures to hazardous substances or conditions;
- Notify the Industrial Hygienist or Research Safety Team (RST) regarding to personnel exposure concerns or complaints;
- Review IH assessment report and discuss the risk of exposure with impacted personnel;
- Responsible for corrective actions from recommended action items arising from exposure monitoring data; and
- Implement, support and enforce KAUST Industrial Hygiene Manual and Occupational Health policy requirements.

3.2 Laboratory Personnel

Laboratory personnel consists of those individuals who conduct their work in a laboratory and are at risk of possible exposure to hazardous substances or other health and physical hazards on a regular or periodic basis. Personnel include laboratory technicians, instructors and researchers, visiting researchers, graduate assistants, and students. The responsibilities of laboratory personnel include:

- Follow all appropriate laboratory practices and safety requirements for the work being performed as per this Industrial Hygiene Manual and the KAUST Laboratory Safety Manual;
- Complete required health and safety trainings as designated by your supervisor;
- Inform your supervisor any safety hazards or unsafe working conditions in the workplace, classroom, or laboratory (e.g., faulty fume hoods, or malfunctions of emergency safety equipment);
- Participate in industrial hygiene sampling or surveys when requested;
- Use all control methods and/or equipment provided (e.g. ventilation, personal protective equipment) to prevent exposures; and
- Report any changes in the work environment that could adversely impact worker health or safety to supervisor, RST or use the online Report It System.

3.3 Industrial Hygienist

The Industrial Hygienist is responsible for the industrial hygiene program, which includes:

- Conduct industrial hygiene assessments;
- Manage the Respiratory Protection Program;
- Notify PI's, supervisors and personnel of exposure monitoring results;
- Verify that added controls are sufficient to reduce exposure below OEL limits;
- Recommend mitigation controls to prevent personnel exposure to chemical, physical, biological, or ergonomic hazards;
- Recommend warning signs where appropriate;
- Maintain industrial hygiene survey and calibration equipment;
- Maintain industrial hygiene assessment/survey records, notifications of personal monitoring memos, and equipment calibration logs;
- Provide or coordinate hazard-specific training for personnel who work with particularly hazardous substances or energy sources;
- Review plans for new operations and significant changes to ongoing operations that involve particularly hazardous substances or energy sources;
- Provide industrial hygiene oversight for contractor activities; and
- Review the Industrial Hygiene Program annually.

3.4 Health, Safety and Environment (HSE)

The HSE department will provide technical program and information support to assist in compliance with the Industrial Hygiene Manual. This includes developing policies, recommendations, and guidelines (including those found in this Industrial Hygiene Manual, Biosafety Manual, Radiation Protection Manual, Laser Safety Manual and Laboratory Safety Manual), competency, and serving as consultants in providing health and safety information to laboratory personnel. HSE organization responsibilities include:

- Provide support and resources to maintain the industrial hygiene program;
- Develop, implement and maintain HSE training;
- Work with appropriate department/staff to identify and control health hazards;
- Support the industrial hygienist in IH monitoring plan;
- Serve as a resource for HSE related questions and assistance; and
- Periodically review/audit HSE programs including industrial hygiene.

3.5 Occupational Health

The Occupational Health (OH) Department plays an important role in managing and surveying health and wellbeing risks. The OH is responsible for:

- Notify and coordinate with the IH regarding staff reports of actual or potential occupational exposures;
- Where IH assessments identified exposures above the Occupational Exposure Limits (OELs) or where local regulation requires medical surveillance for specific IH hazards; OH will

implement and maintain a medical surveillance program to protect the health and safety of personnel;

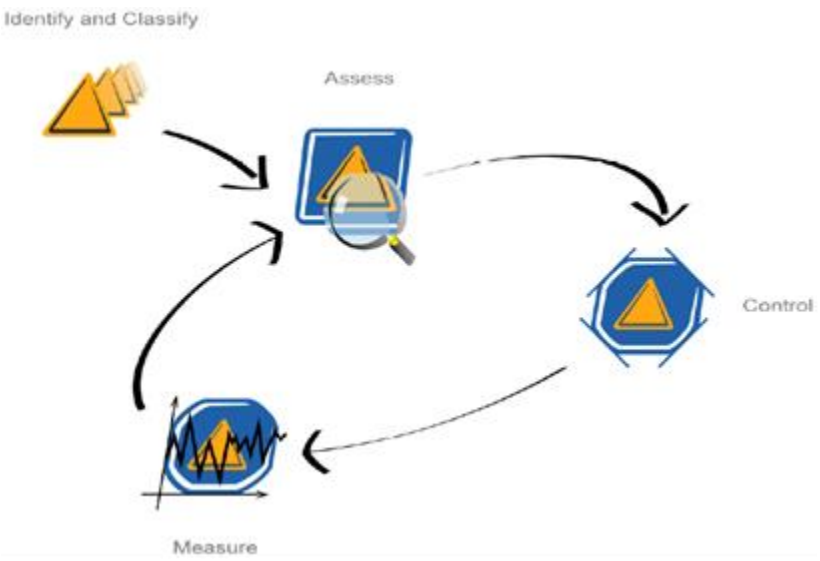
- Maintain the appropriate occupational health records for KAUST personnel;
- Ensure confidentiality and preservation of health records; and
- Retain and provide access to health records as per KAUST policy.

3.6 Guests and Visitors

As per the KAUST Laboratory Safety Manual, due to the potential hazards and liability issues, guests or other persons (in particular children under the age of 16) are not permitted in hazardous work areas, with the exception of KAUST-sanctioned activities, e.g., tours, open houses, or other KAUST- related business as authorized by the Center Director or Principal Investigator. In these instances, all children under the age of 16 must be under careful and continuous supervision.

4 Exposure Assessment Strategy

Exposure assessment involves four key components: Identify, Assess, Control and Measure.



4.1 Identify – Evaluate and Classify Workplace Hazards

Initial hazard identification begins with a review of various site resources. Then evaluations of priority personnel and tasks for exposure groupings should be developed. Resources for hazard identification may include:

- Walk-through observations
  - Review work tasks and identify potential hazard(s)
  - Quantities handled
  - Sources of release
  - Temperature, pressure, humidity, etc. of process and environment
  - Frequency, duration and intensity of task/activity
  - Housekeeping
- Work schedules and rotation
- SOPs, controls, training, PPE
- Site maps
- Engineering control reviews (e.g. Toxic Gas Management (TGM))
- Laboratory notebooks including chemical reactions, processes and diagrams
- Facility operating manuals
- Procurement documents

- Incident investigation reports
- Particularly Hazardous Substances (PHS) – refers to *KAUST PHS Procedure No. HSE-I-P003*
- Laboratory chemical inventories
    - Include chemical mixtures in use and components – use Safety Data Sheets (SDSs) as a resource
- Carcinogen control program data
- Job Hazard Analysis (JHAs) if available
- Observations, comments and data from PI's, researchers, staff, supervisors/managers, etc.
- Reproductive hazards – refers to *KAUST Reproductive Hazard Guideline*

Recognized resources to review for relevant toxicological, biological, and chemical information for include but are not limited to:

- National Toxicology Program, Annual Report on Carcinogens (latest edition);
- International Agency for Research on Cancer, Monographs (latest editions);
- OSHA standard 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances;
- American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents; and
- The European Chemicals Agency (ECHA) Registration, Evaluation, Authorization and Restriction of Chemicals Regulation (REACH).

4.2 Evaluation – Factors to Consider When Evaluating Substances

After the substance(s) have been identified, they can be classified based on their inherent hazards, properties and effects. The evaluation of the hazard of a substance requires many different factors to be taken into consideration:

- An inert severity based inventory of hazards
- Potential exposures based on work activities/tasks
- A list of potentially exposed workers
- If available, prior exposure monitoring data or an estimate of potential exposures for similarly exposed groups of workers
- Judgment of the acceptability and uncertainty of the exposures.

4.2.1 Lead Effect

Although exposure to substances can cause more than one undesirable effect, the reaction that determines the classification, is called the Lead Effect. The Lead Effect typically occurs at the lowest level of exposure.

Lead Effect Examples:

- Toxic (Acute or Chronic) - Acute exposures are typically associated with a large exposure over a short period of time, while chronic exposures are associated with lower and prolonged or repeated exposures.

- Irritancy
- Allergy or Sensitization
- Carcinogenicity, Mutagenicity or Reproductive Hazards (CMRs)
- Pharmacological effects

Certain lead effects are more serious than others; both the Response (effect) as well as the Dose at which it occurs must be taken into account when determining the lead effect.

Information found in Safety Data Sheets (SDSs) can be used to assess the hazard of a material. Information to be considered includes:

- Toxic properties
- Physical and chemical properties
- Biological or pharmacological effects

4.2.2 Lead Effect

Toxic Properties

Toxic effects include:

- Target organ toxicity (liver toxicity)
- Destruction of living tissue (burns)
- Irritation or allergic reactions
- Reproductive effects
- Capable of causing cancer
- Reproductive and/or developmental toxicity
- Agents having a regulatory prescribed substance-specific standard (e.g. U.S. OSHA, U.K. HSE, etc.)
- Agents with short-term acute effects
- Toxic substances - include workplace chemicals that may pose a risk to workers because of a lack of an occupational exposure limit or because the occupational exposure limit is based on a less protective endpoint (e.g., irritation instead of cancer).
- Harmful physical agents
- Ergonomic stressors
- Harmful biological agents

Toxic effects are also characterized by its SEVERITY and POTENCY.

SEVERITY

Some effects are more severe than others. The severity may depend on whether the effect is reversible or transient. Even a transient effect such as “sedation” can be serious, if for example it results in an accident.

POTENCY

Potency is an indication of the quantity required to elicit an effect. The more potent the substance, the smaller the dose required to cause an effect. Do not confuse severity with potency. For example, death is a serious effect; however, if it is necessary to swallow more than a kilogram of material to cause it, then the potency is very weak.

4.2.3 Physical and Chemical Properties

An assessment should always start with the physical and/or chemical properties. The body must come in contact with a material to be affected by it and the risk of contact is principally a function of its physical/chemical properties.

- Is it a solid or liquid?
- Is the substance water or fat-soluble?
  - Fat-soluble materials absorb well through the skin.
- Is the material corrosive?
  - Corrosive substances react with the tissues to cause damage at the point of contact.

The rate if absorption and elimination from the body depends on the following:

- Physical state
- Solubility
- Volatility
- Mass
- Molecular size
- Pharmacokinetics

The rate of absorption/elimination plays an important role in determining the toxicity/hazard risk of the chemical.

4.2.4 Establishing Similar Exposure Groups (SEGs)

Similar exposure groups (SEGs) are intended to characterize exposures of large and diverse working populations, and “represent” exposures of everyone in the group. SEGs are made up of groups of workers expected to have the same general exposure profile because of the similarity and frequency of the processes and tasks they perform and materials handled. The SEG links workers, hazards, and exposures which can help target medical monitoring.

The determination of SEGs can be a useful tool for both qualitative and quantitative exposure assessments. Once the available data has been collected and analyzed, a matrix may be generated to show the exposure potentials and risk for each task which compares the jobs or tasks with the risks and any monitoring data.

Collectively, these matrices are useful in the development of a site’s baseline hazard, risk, and exposure profile. This site profile can help determine priorities, the resources needed to manage those priorities, and the vulnerabilities that will remain by not addressing the lower priorities.

SEGs can be determined either by “Observation” or “Sampling”. Observational SEGs can be verified by Sampling when critical.

Observational SEGs

Staff are assigned to the SEGs based on activities and expected similarity of exposures identified during the initial hazard identification phase. Staff are usually grouped by:

- Process (e.g. maintenance)
- Job title (e.g. lab researcher, electrician, maintenance mechanic, workshop worker) – often not a useful category as this classification may be assigned based on seniority (e.g. Sr. Welder, Welder, Associate Welder or Welder I, II, III) though similar tasks are performed; or the category itself may be too broad (e.g. technician)
- Task (e.g. welding); and
- Chemical agent (e.g. welding fumes and ozone)

Or

- Work Team – shared responsibilities, personnel may rotate among position (e.g. lead, supervisor, manager).

It is difficult to identify all tasks in most operations; however sometimes the additional detail will contribute significantly to understanding and managing the exposure(s).

Specific tasks should be identified when assessing exposures relative to a ceiling (C), Short-term exposure limit (STEL), or 8-hour time-weighted average (TWA) that does not occur daily. For example, welding may be performed only two days a week by a maintenance mechanic.

It is less important (and certainly more difficult) to identify specific tasks when identifying SEGs in workplaces where continuous change is characteristic (e.g. R&D).

Initial judgments can be made and prioritized for potential monitoring or controls.

It is not unusual for an individual employee to spend time working in more than one exposure group over relatively short time periods such as a day, week or month. The employee's time by exposure group should be documented.

Sampling SEGs

Staff are assigned to the SEG based on measurements and statistical analysis (e.g. analysis of variance) of the exposure data. Large numbers of random measurements are required and multiple measurements are made on individual employee to calculate the within-employee and between-employee components of exposure variability for accurate grouping. Although this method minimizes the misclassification of individual employees, this method often negates the reason for forming the SEGs in the first place (to reduce the number of exposure assessments needed).

4.3 Assess the Risk Factors

A risk assessment is carried out for work tasks to:

- Assess exposure risks to prioritize SEGs.
- Verify the effectiveness of control measures.

Risk Assessments are conducted for:

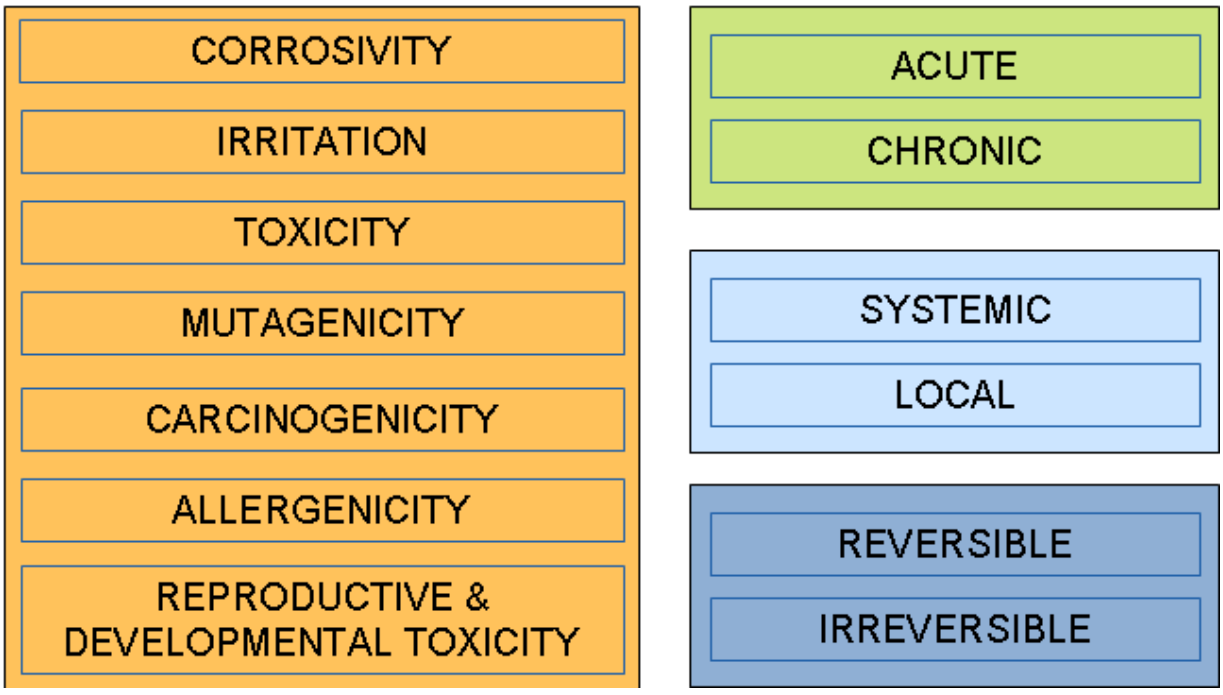
- New experiments, processes or when a process passes to another phase of development - taking into consideration new quantities handled and equipment.
- Changes to processes or experiments that may create a new or different hazard, or a change in risk outcome (e.g. medium to high).
- Documentation and verification of the appropriate control measures (e.g. ventilation systems, process modifications, selection of PPE).

4.3.1 Severity and Potency

Some effects are more severe than other. The severity may depend on whether the effect is reversible or transient. Even a transient effect such as “sedation” can be serious, if for example it results in an accident.

Potency is an indication of the quantity required to elicit an effect. The more potent the substance, the smaller the dose required to cause an effect. Do not confuse severity with potency. For example, death is a serious effect; however, if it is necessary to swallow more than a kilogram of material to cause it, then the potency is very weak.

Consider the identity of the hazardous substances, the route of exposure, and the following potentially hazardous health effects:



4.3.2 Properties of the Material

Consider the physicochemical properties of the substance:

- Solids - Particle size and density determine their dustiness and tendency to remain airborne.
    - Granular or lumpy powders generate lower dust concentrations

- Milled, micronized or sieved powders generate higher dust concentrations.

- Liquids – Vaporization depends on the volatility of the liquid and the ambient temperature. The more volatile it is the greater the risk. Volatility is depended according to the boiling point of the substance and the temperature of the process (or the product).

Process Temperature	Volatility		
	High	Average	Low
	Temp > 0.5 x BP	0.5 x BP > Temp > 0.2 x BP	0.2 x BP > Temp

BP = Boiling Point of the substance

Note: Handling liquids at high temperature increases the volatility.

4.3.3 Duration

The longer the task and the greater the exposure potential; the more significant will be the absorption. The concern with longer duration exposures and longer work shifts is that the material may accumulate in the body due to inadequate time for clearance, thus increasing the risk of adverse effects.

4.3.4 Exposure Level

Each task is associated with an exposure range. We can use an expected exposure range based upon the nature of the task considering with and without containment, the quantity of material used, its physical properties and the operating method.

For example, in general, laboratories handle small quantities of substance for short periods of time. In addition, the control measures used in laboratories provide a high level of protection. As a consequence, the health risk to laboratory employees is much lower than to those involved in industrial settings.

4.3.5 Frequency

Exposure frequency maybe daily, weekly, monthly, quarterly or annually.

4.3.6 Scale of Process

The scale of the process is important when conducting the assessment. In a research laboratory setting, the process scale is likely to be small, chemicals in small quantities and chemical reaction conducted inside a fume hood. As the process is scaled up, the equipment may be too large to be conducted inside a fume hood (containment), chemicals will be used in larger quantities and the reliance of PPE greater. As a result, the risk of exposure will be higher.

4.3.7 Number of People

The number of people performing the task or number of people working in the same area where there is a risk of exposure is a contributor factor and is incorporated to the risk assessment process.

4.3.8 Existing Controls

The risk assessment must take into account the existing (current) control measures:

- Engineering Controls – Include precise information on the type of engineering controls in place and their effectiveness.
    - Glove box
    - Chemical fume hood/ biosafety cabinet (BSC)
        - Example: Fume hood face velocity at 0.5 m/s → Good effectiveness

- Local exhaust ventilation (LEV) such as canopy/ slot hood, snorkel, etc.
    - Example: LEV positioned next to receiver → Vapors not captured effectively

- Administrative - identify manuals and procedures (SOPs), job hazard assessments, training, signage, labelling, and the handling method or operating techniques used by observing the work task and discussing the situation with lab personnel.
- Personal Protective Equipment - Note the type of RPE or PPE (gloves, coverall), the model and the type of filters used with the respirator (if necessary).
    - Respirators (Assigned Protection Factor – APF)
    - Safety gloves
    - Safety glasses/ face shields
    - Lab coat

4.3.9 Assessing Non-repetitive/ Non-routine Work Activity/ Task

In cases where there is continuous change in tasks and agents (e.g. R&D) or the task is done infrequently (e.g. annual PM) instead of determining SEG the focus should be on the objective of the assessment.

Example:

1. Assess worst-case scenario: Identifying worst-case scenarios and then evaluate and control exposures accordingly.
2. Develop an exposure profile: Designate a project, experiment or product as the process or task and conduct assessments to obtain an exposure baseline.

4.4 Health Risk Matrix

Health risk is a function of the exposure level (exposure rating) and the severity (health effect rating) for a given amount of exposure (toxicity). SEGs can be prioritized into the exposure programs based on the health risk defined by the exposure ratings and health effects ratings. SEGs or tasks are ranked from low to high potential health risk and subsequently assigned priority for action.

Consequence	Likelihood				
	Negligible	Low	Moderate	Likely	Almost Certain
1					
2					
3					
4					
5					

Health Effects Ratings

1 – Negligible or no known or suspected adverse health effects.

2 – Reversible health effects of concern.

3 – Severe, reversible health effects of concern.

4 – Irreversible health effects of concern.

5 – Life-threatening or disabling injury or illness.

Exposure Ratings

1 – X 0.95 ≤ 0.01 x Exposure Limit (EL)

2 – 0.01 x EL < X 0.95 ≤ 0.1 x EL

3 – 0.1 x EL < X 0.95 ≤ 0.5 x EL

4 – 0.5 x EL < X 0.95 ≤ EL

5 – X 0.95 > EL

Interpretations of Exposure Rating are based on:

- Professional judgment
- Modeling
- Chemical and physical properties
- Determinants of exposure
- Statistics (e.g. Bayesian)
- Quantitative measurements

4.4.1 Health Risk Ranking Actions

Risk outcome which fall in the lower-right corner would be given the highest priority because they represent the highest health risk. Risk outcome that fall in the lower-left corner would be given the lowest priority for action.

Uncertainty adds additional risk because either the exposure or the toxicity may be higher than stated. SEGs with uncertain health risk ratings should be given priority for information gathering.

Blue	Maintain current controls/practices Re-evaluate if change in process/ practice/equipment
Yellow	Perform detailed IH assessment (e.g. quantitative) Identify and implement controls to reduce risk to ALARP.
Red	Immediate action(s) required to control exposures and reduce risk to ALARP. Assess controls to ensure effectiveness.

4.4.2 Qualitative IH Assessment

Qualitative assessment results should be analyzed to determine the need for and provide the basis for a quantitative exposure monitoring plan.

A qualitative assessment plan describes the processes and work areas to be evaluated for the assessment, specific observations to be made, and would include applicable preliminary measurements, if available (such as air flows, noise levels) as well as untargeted risk factors such as other airborne chemical levels).

Determinants considered during the qualitative exposure assessment include:

- Frequency and duration of exposure
- Variability of exposure and tasks
- Potentials for short-duration tasks and exposures (acute) and long-term or frequently repeated tasks and exposures (chronic); and
- Magnitude
    - Quantities handled
    - Distance from source
    - Size of container opening
    - Surface area
- Adequacy and potential for failure of engineering and work practice controls
    - Type of control
    - Efficiency of control
    - Canopy hood vs. Fume hood
- An evaluation of potential exposures via inhalation, ingestion, dermal contact
- Agent Determinants:
    - Agent surface area
    - Vapor hazard index
    - Composition
    - Quantity of agent
    - Absorption rate
    - Application method

The actual analysis should focus on only those tasks that are directly linked to the identified hazards and exposure potentials. More focused qualitative or quantitative assessments should be based on the highest-risk work.

A *Chemical Health Risk Assessment* database is provided to assist in assessing chemical hazards.

4.4.3 Administrative Control Levels (ACLs)

Document interpretations around potential adverse health effects, limits of effective or feasible risk management actions, and need for further data or better understanding of health effects/outcomes.

Include the likelihood of exceeding the OEL, which is usually based on comparison with an Administrative Control Level (ACL). The ACL represents a "trigger point" for a more detailed assessment. ACLs are usually set at one-half the OEL (Action Level). Sometimes one-tenth or one-fourth the OEL may be more appropriate. Whichever ACL is used, it should also be documented and the rationale provided.

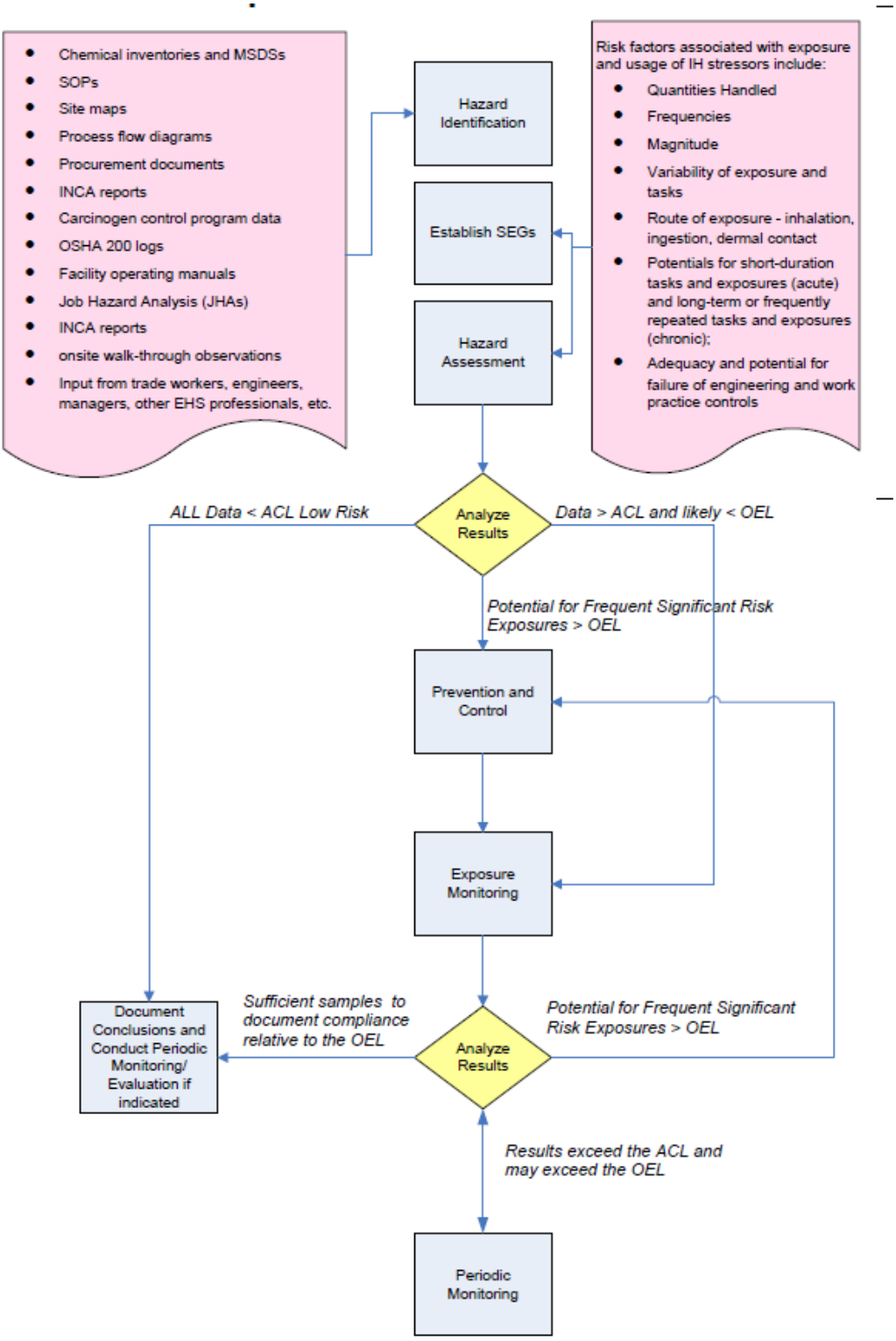
If exposures exceed (or are likely to exceed) the OEL, as indicated by qualitative exposure monitoring, a quantitative exposure assessment should be performed.

4.4.4 Determining Next Steps

If…	Then…
Example: Historical data shows a measured concentration that is below the OEL (e.g. 10% of the OEL)	Expect minor or no risk of exposure. No further action (such as quantitative monitoring or the implementation of prevention and control measures) is required.
Documentation exists that the control measure (e.g. chemical fume hood) is current and effective and properly used.	Document the conclusions including the identified factors.
For unacceptable exposure risk (estimated to be above 10 percent of the OEL), or if exposure risk is uncertain …	Perform a quantitative exposure assessment and implement prevention and control methods as necessary

The IH Exposure Assessment Process Flowchart below outlines the process and decision for conducting a health hazard assessment.

IH Exposure Assessment Process Flowchart

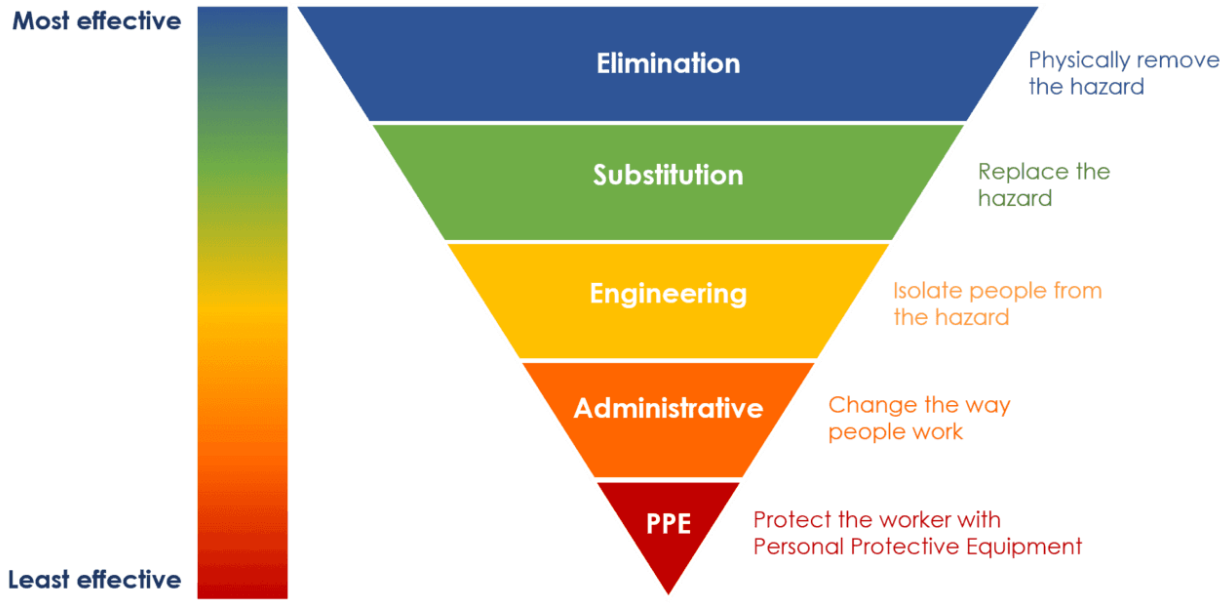


5 Controls

Qualitative and quantitative data are used to determine the adequacy of existing work controls. This may be done by comparing the exposure levels under existing controls with the OELs. Once levels under existing controls have been examined, it may be necessary to modify the controls or add new controls.

Once individuals or SEGs with potential for uncertain or unacceptable exposures have been identified and prioritized, engineering controls and other worker protection efforts should be implemented. As an interim measure, the decision -making process should take into account short-term vs. long-term controls, feasibility and priority of controls, exposure levels, toxicity, and level of uncertainty.

The standard of Hierarchy of Controls in safety includes five different controls as shown below. Elimination is the most effective while Personal Protective Equipment (PPE) is the least effective.



For industrial hygiene, the standard of hierarchy of controls is modified to include:

- Elimination of hazard
- Substitution with less hazardous agent
- Containment
- Capture
- Isolation
- Dilution
- Administrative
- Personal Protective Equipment (PPE)

PPE (particularly Respiratory Protection) should be considered the last resort and not the first step in mitigation control. All protective measures must be used to keep the exposure levels within the limits prescribed (or OEL).

Control measures are not mutually exclusive. There may be circumstances where more than one control measure should be used to reduce exposure to the hazard. In addition, the least preferred control measure may be necessary for a short period to immediately make the work safe, while the longer term, more effective control measures are developed and implemented.

5.1 Elimination and Substitution

Eliminate by physically removing the hazard is always the first consideration in the hierarchy of control. This can be done by changing a work process in a way that will get rid of a hazard such as removing a toxic chemical from the process or removing flammable gas cylinder from a hot work area.

The second best way to control a hazard is to substitute something else in its place that would be nonhazardous or less hazardous to staff. For example, a non-toxic (or less toxic) chemical could be substituted for a hazardous one.

5.2 Engineering Controls

Engineering controls can involve the use of:

- Chemical fume hoods, biosafety cabinets and gloveboxes (containment)
- Exhaust and general ventilation (dilution)
- Enclosure of the source of emissions (isolation/capture)
- Process and equipment modifications that reduce emissions

5.3 Administrative Control

Administrative controls involve changes in workplace policies and procedures. They can include such things as:

- Warning alarms
- Labeling systems
- Reducing the time workers are exposed to a hazard,
- Health/medical surveillance, and
- Training.

Making changes to the way employees work to reduce the period of time of exposure and alert them to safe working requirements. These include, but are not restricted to, job rotation, shift changes and task time limits; implementing procedures, work permits, warning signs and access restrictions, supervision and training to enable employees to work safely.

5.4 Personal Protective Equipment

The use of personal protective equipment (PPE) is a way of controlling hazards by placing protective equipment directly on workers' bodies. Examples of personal protective equipment include: respirators, gloves, protective clothing such as lab coats, face shields, safety glasses/goggles, and ear plugs.

Personal protective equipment is the least effective method for protecting workers from hazards. PPE should be used only while other more effective controls are being developed or installed, or if there are no other more effective ways to control the hazard.

This is because:

- The hazard is not eliminated or changed.
- If the equipment is inadequate or fails, the worker is not protected.
- No personal protective equipment is fool-proof (for example, respirators leak).

- Personal protective equipment is often uncomfortable and can place an additional physical burden on a worker.
- Personal protective equipment can actually create hazards. For example, the use of respirators for long periods of time can put a strain on the heart and lungs.

PPE used for controls should provide adequate protection of the worker while avoiding any unnecessary stress that may be associated with wearing PPE. If exposure levels are found to be consistently below the ACL and PPE is no longer required, the monitoring portion may be terminated and documented as such.

The use of respirators requires specific requirements under KAUST Respiratory Protection Program (RRP) including risk assessment, medical evaluation, training and fit testing (refers to Respiratory Protection Program).

6 Measure

6.1 Quantitative Exposure Assessment

Preliminary Quantitative Assessments (Screening)

During preliminary sampling or screening, the ACL is used to demonstrate confidence that exposures are below the OEL, with the intention that later sufficient samples will be obtained to perform appropriate statistical analysis to document that exposures are acceptable with respect to the OEL.

If ALL Data Are < ACL Low Risk

For example - site history and planned activities indicate that there is either low or no potential for employee exposure to chemicals, or other physical agents. In such cases:

- Routine exposure assessments may not be necessary;
- Additional controls are not necessary; and
- Periodic re-evaluation may be indicated if changes have occurred that can adversely affect exposures.

These conclusions and the supporting rationale should be documented.

If ANY of the Data Are > ACL

There may be a significant risk - Evaluate further as compliance with the OEL may be uncertain:

- All employees in those work areas should be identified as potentially at risk and should be more fully evaluated for exposure and potential health effects.

If the Data Indicate a Potential for Frequent Significant Risk Exposures > OEL, then:

- Immediate action may be necessary. Perform a more detailed hazard characterization and increase monitoring.

Comprehensive Quantitative Exposure Assessments

If exposures exceed (or are likely to exceed) the OEL, as indicated by preliminary screening, a comprehensive quantitative exposure assessment should be performed which includes:

- Determining an Exposure Assessment plan for each process or work area;
    - Discussion with Occupational Health to determine the need for medical/biological monitoring and evaluation of the potential for ingestion or skin absorption, which could contribute to the employee's exposure, as appropriate.
- Conducting the Exposure Monitoring utilizing methods such as those described in the US NIOSH Occupational Exposure Sampling Strategy Manual, US OSHA Sampling Methods, UK HSE, and other recognized methods from IH/OH organizations and laboratories; and
- Entering and maintaining exposure monitoring data in a database such that:
    - The resulting exposure measurements and tasks can be linked to the employee or the SEG; and
    - The EA records can be made available to employees and their supervisors.

Documentation should, as a minimum, describe:

- Occupational Exposure Limits (OELs);
- Results;
- Description of the tasks and identified work practices and any other factors that may have affected sampling results;
- Locations where monitoring occurred;
- Identification of those monitored or represented by the monitoring;
- Sampling methods;
- Sampling and task durations;
- Control measures in place during monitoring (including the use of PPE); and
- An explanation/notation as to whether the results were task based, averaged over an 8-hour period, or whether additional (overall) results are provided for consecutive samples (staff performing separately sampled - multiple tasks).

Where results approach or exceed OELs, it is especially important to accurately describe possible or identified contributing factors, as well as protection afforded by PPE if applicable, and specific recommendations to ensure against future occurrences.

6.2 Occupational Exposure Limits (OELs)

OELs are levels of substances in workplace air which it is believed are low enough to protect nearly all workers from discomfort and adverse health effects arising from breathing the air, over a series of eight hour (8-hr) shifts for a working lifetime. They should be used as guidelines rather than not safe / safe limits.

'Official' OELs established by national or international standard setting bodies exist for some 1000 substances. Although these OELs generally cover the highest tonnage and most widely used chemicals, the total number of existing chemical substances is much higher than this. There are thus many substances for which there is no 'official' OEL, although most substances commonly used in the mining and mineral processing industries do have one.

An OEL must be available for comparison with workplace exposure data to assess potential health risks. This might be a value derived from regulatory compliance limits such as OSHA PELs, ACGIH TLVs, UK HSE MEL/OEL, German MAK, EU IOEL, etc. It should be noted that each of the different types of OEL is often derived using different background principles, such that there can be a wide variation in the numerical value of OELs for the same substance. The Kingdom of Saudi Arabia (KSA) currently does not have regulatory compliance OELs. As the result, KAUST has made a decision to adopt the following OELs from the recognized government agencies or organizations:

- U.S. OSHA Permissible Exposure Limits (PEL)
- U.S. American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV)
- U.K. HSE MEL or OEL
- German MAK (Maximum Concentrations)
- EU Indicative Occupational Exposure Limit Values (IOELV)

Where a contaminant or chemical has multiple OELs, the most stringent OEL value will be adopted to ensure the 'As Low As Reasonably Practicable' (ALARP) principle, which is KAUST's approach to risk management.

OELs should reflect the type of harmful effect of the substance. OEL values are most usually presented as a time weighted average (TWA) value, and often as a long-term average (LTA) value, for substances that have an effect over a number of years. Note that there are also short-term exposure limit (STEL) and Ceiling or Peak Limitation values for substances that act rapidly or that are irritants. Note also that absorption through the skin may be a significant source of exposure, which is not taken into consideration for most 'official' OELs. Substances with this potential are often assigned a 'skin absorption notice' (sk), and will require specialist input for assessing potential exposure.

6.2.1 Excursion Limit

The STEL and Ceiling or Peak Limitation each represents an exposure *excursion limit*. Where these are absent, the following general principle should be followed: short-term excursions in worker exposure levels for any agent may exceed 3 times the TWA-OEL for no more than a total of 30 minutes during a work day, and under no circumstances should they exceed 5 times the TWA-OEL, even when the 8-hour average exposure does not exceeded the TWA-OEL.

6.2.2 Biological Test Limit (BTL)

The OEL standard also covers Biological Test Limit (BTL) values. They provide a method of determining total exposure to a chemical by measurement of a chemical, a metabolite or a biochemical change in the body. As with OELs, BTLs should be used as guidelines only, rather than *not safe* / *safe* limits.[1] On occasion reference may also be made to a benchmark guideline value (BGV) for biological monitoring. This type of guidance value can give no direct guide to the risk of ill-health. The benchmark guidance value gives an indication of how well exposure is being controlled, and should only be used as a trigger for further investigation. An example of such would be the UK HSE BGV of 4.0 µmol/mole creatinine for 1-hydroxypyrene in urine to assess exposure to polycyclic aromatic hydrocarbons (PAHs).

Biological monitoring should only be undertaken as a result of risk assessment, for which workplace assessments suggest the probability of over exposure (e.g. particularly for substances with a skin absorption notice or where a route of exposure may include ingestion), and validated testing methods and limit values exist. An exception to this rule is lead exposures, for which lead in blood monitoring is often mandated.

6.2.3 Carcinogens, Mutagens, Teratogens and Reproductive Hazards

There are instances when conformance to an OEL is not adequate. Exposure to carcinogens and reproductive toxicants (known and suspected) must be 'As Low As Reasonably Practicable' (ALARP). The ALARP principle should ensure that exposure data be statistically valid on an annual basis for known and suspected human carcinogens, mutagenic and reproductive toxicants.

6.3 Sampling Strategy

The decision to perform air monitoring or sampling should be based on risk. Where qualitative risk assessment identified an exposure as significantly high there is no need to conduct monitoring but to implement corrective and preventive actions (CAPAs) to prevent or lower the risk of exposure.

[1] Note that BTLs are provided by a number of organisations: Biological Exposure Indices (BEIs – ACGIH); Biological Monitoring Guidance Values (BMGVs – UK HSE); Biological Limit Values (BLVs – EU).

Conversely, where the risk assessment identified exposure as 'very low' there is no further need to conduct exposure monitoring but to maintain current controls.

Sampling strategy for measuring airborne contaminants for compliance to the Occupational Exposure Limits (OELs):

- Assess air concentrations associated with specified levels of workplace chemicals;
- Describe the methodologies used to calculate air concentrations for selected workplace chemicals;
- Make recommendations to provide consistent protection from health risks associated with exposure;
- Perform periodic resurveys and/or exposure monitoring as appropriate;
- Document exposure assessments using recognized exposure assessment methodologies; and
- Use accredited industrial hygiene laboratories as appropriate.

6.4 Data Analysis

Utilizing the American Industrial Hygiene Association (AIHA) IHSTAT, the statistical data report should include:

- Distributions of the exposure data, to include geometric mean, geometric standard deviation, variance, and cumulative dose for each worker for each hazardous agent;
- The distribution of exposures within similarly exposed groups, using accepted statistical methods; and
- Trends in exposure for individuals and groups of individuals (i.e., exposure groups).

Compliance with occupational exposure limits (OELs) can be determined by comparing the monitoring results with the ACL or statistically to the OELs.

As data are gathered from qualitative screening and quantitative exposure monitoring, they are used to make a number of decisions about the need for continuing or ending exposure assessments; the adequacy of control measures; the sufficiency of monitoring strategies; etc. The conclusions, rationale, and actions at each exposure assessment decision stage should be documented and kept current.

Note: Exposure distributions can include results which are several times the median value, not because of a failure of control but because there is a statistical chance that the many factors which determine exposure combine in a way which produces an outlying result.

6.5 The Need for Further Monitoring

Monitoring efforts should be reevaluated as the job or task progresses. Where the tasks are highly variable or where there is a potential for high exposures, more frequent monitoring should be considered as should increasing the number of workers to be monitored.

After the monitoring data has been collected and analyzed, judgments can be made about potential risk, in relation to the ACLs and potential health effects.

Example:

If …	Then …	
Monitoring results are below an established ACL	No further monitoring is needed. Document rationale.	Based on professional judgment, perform periodic monitoring to verify conditions have not changed and controls remain adequate.
Monitoring results are above the ACL but the data provide statistical confidence that exposures will not exceed the OEL	Periodic re-evaluation should be conducted.	
Monitoring results exceed the ACL and may exceed the OEL or The available information is inadequate to define the extent to which health hazards exist.	Develop a plan for additional quantitative monitoring conduct monitoring, analyze data, and continue until the worksite situation improves or until sufficient samples are obtained to document compliance relative to the OEL.	

6.6 Management of Findings

The exposure assessment process will provide the fodder for decisions regarding:

- Compliance with health based exposure limits (OELs)
- Compliance with regulations
- Chemical approval program
- Personal protective equipment (PPE) assessment
- Respiratory protection selection
- Process change
- Introduction of new process
- Ventilation requirements associated with
- Introduction of new material
- Process hazard reviews
- Investigations
- Training needs
- Management systems

6.7 Assessing potential of upsets (non-routine) and their impact

- Emergency planning
- Retrospective exposure assessment

- Epidemiology studies
- Toxic tort
- Illness clustering

6.8 Documentation

Data related to the industrial hygiene reports are maintained in **Appendix 1 - Industrial Hygiene Qualitative/Quantitative Database (temporary using the Chemical Health Risk Assessment Database).** Documentation and subsequent reports shall:

- Describe the tasks and locations where monitoring occurred;
- Identify workers monitored or represented by the monitoring;
- Identify the sampling methods and durations;
- Identify control measures in place during monitoring [including the use of personal protective equipment (PPE)], and
- Include any other factors that may have affected sampling results.

6.9 Job Hazard Analysis (JHA)/ Job Safety Analysis (JSA)

A JHA/JSA is generally conducted as part of the work control process when a specific task or project is planned. It applies the hazard analysis and exposure assessment information to delineate potential hazards and specify control requirements. They are fundamentally safe, effective work control systems. JHAs break down tasks and serve to identify and evaluate potential safety and health hazards and may also be used to specify exposure monitoring and assessment for the specific activity. Relative to those hazards, the JHA specifies minimum hazard control requirements.

The JHAs along with hazard characterization and analysis information, is incorporated into the site-specific safety and health plan.

6.10 Communication

Following assessments, final reports which include results and recommendations should be sent to the monitored staff, their supervisors and Occupational Health as appropriate. Recommendations made should be incorporated into existing JHAs/JSAs or SOPs (as appropriate).

Metrics related to both qualitative and quantitative assessments should be tracked and summary information reported to RST Manager on quarterly basis.

6.10.1 Elevated Exposure Levels

To ensure consistent and comprehensive exposure assessment information, the following type of hazard and task information should be included in the employee and supervisor/manager/PI exposure assessment reports.

Health effect information – The OEL information should be included and explained for result comparison, however unless there are unique conditions of use or controls associated with a material, the health effects information would not be included in the written report and instead communicated via Hazard Communication.

The following information should be included to explain results:

- Health hazard(s)

- Sample number(s)
- OEL(s)
- Results
- Description of the tasks and identified work practices and any other factors that may have affected sampling results
- Locations where monitoring occurred
- Identification of those monitored or represented by the monitoring
- Sampling methods
- Sampling and task durations
- Control measures in place during monitoring (including the use of PPE)
- An explanation/notation as to whether the results were task based, averaged over an 8-hour period, or whether additional (overall) results are provided for consecutive samples (staff performing separately sampled - multiple tasks).

Where results approach or exceed OELs, it is especially important to accurately describe possible or identified contributing factors, as well as protection afforded by PPE if applicable, and specific recommendations to ensure against future occurrences.

6.10.2 Follow-up

On a quarterly or annual basis, performance objectives, measures, and commitments can be reviewed and updated. Resources can be assessed to ensure that the safety objectives and performance commitments have been met.

To measure the effectiveness of exposure assessment activities, and to ensure appropriate determination or revision of these goals, consideration should be given to the following:

- Are we identifying workers with a significant risk and conducting exposure assessment on the highest-risk activities first?
- Are we identifying and evaluating contributing factors to exposures and implementing strategies to prevent and mitigate exposure based on significant risks and potential health effects to workers?
- Are we supplying Occupational Health with data about exposures of individuals and groups in order to prioritize and target medical monitoring efforts?
- Are we retaining job, task, and hazard identification and risk-estimating information and making it available to workers and worker protection staff?
- Are we targeting exposure assessments to specific hazards and risks and measuring the exposure levels that may create a significant risk of illness?
- Are we looking at high-risk tasks from the point of view of promoting safe acts and behaviors that reduce exposure? Are we also trending the improvement toward safe acts as an indicator of the success of our programs?

6.11 IH Sampling Methodologies

Hazard evaluation surveys often include some type of monitoring, such as air or wipe sampling, to measure the amount or concentration of the hazards and verify adequate controls are in place.

To obtain a representative estimate of exposure, a sufficient number of samples must be collected. Concentrations can vary with production levels, location, job task, and between individuals performing the same task based on their work practices. The appropriate number of samples will depend on the error of measurement (collection and analysis technique) and the differences between results.

Sampling methodologies must be sound, tested and recognized from regulatory agencies, institutions and/or organizations. The following sources are recognized:

- NIOSH Manual of Analytical Methods: NIOSH IH Sampling Analytical Methods
- OSHA Sampling and Analytical Methods: https://www.osha.gov/dts/sltc/methods/toc.html
- UK HSE Methods for the Determination of Hazardous Substances (MDHS): https://www.hse.gov.uk/pubns/mdhs/index.htm
- SKC Inc.: https://www.skcinc.com/catalog/osha-niosh.php
- Bureau Veritas Laboratory Sampling Guide: https://orders.bvlabs.com/sampling-guide/

It should be noted that for novel substances and compounds they may not have a sampling methodology and some sampling methodologies are trademarked by private laboratories and only provided to their customers.

Types of IH Monitoring include:

6.11.1 Personal Monitoring

Measures employee exposure to IH stressors. Workplace air or noise, representative of the individual's breathing zone or hearing level is sampled over an eight-hour period (or for the full work shift) or for the duration of specific tasks. Observations are recorded along with general information about the specific work process.

When possible, to evaluate the potential for over exposures, observations of work practices and screening samples should be conducted prior to personal sampling.

6.11.2 Area Monitoring

Defines the extent of contamination, background levels, or to measure the effectiveness of engineering controls. The monitor may be placed in a fixed location in the work area or near the suspected source of the hazard.

6.11.3 Surface/Wipe Sampling

Measures surface contamination for selected hazardous materials. Wipe sampling may be used to confirm medical monitoring results when the main entry route of a chemical is through the skin or mouth.

6.12 Sampling and Monitoring Equipment

Before committing resources and to provide justification for time consuming personal monitoring and costly and lengthy laboratory analysis, screening should be considered as a tool which provides real-time estimates of exposure.

Screening is recommended to evaluate:

- Potential exposures to substances with high OELs
- Intermittent processes involving substances without short-term exposure limits (STELs)
- Engineering controls, work practices or isolation of process
- Substances with Ceiling exposure limits
- Complaints such as odors

Direct reading instruments including detector tubes, particulate counters, Sound Level Meters, etc. can provide real-time data to assess the risk of exposures.

6.12.1 Direct Reading

Direct–reading instruments (sometimes termed real-time instruments) provide information at the time of sampling, thus enabling rapid decision-making. These instruments can provide the capability to determine if employees are exposed to concentrations which exceed instantaneous (ceiling or peak) exposure limits for specific hazardous materials. Direct-reading monitors can be useful in identifying

- Oxygen-deficient or oxygen-enriched atmospheres;
- Immediately dangerous to life or health (IDLH) conditions;
- Elevated levels of airborne contaminants;
- Flammable atmospheres; and
- Radioactive hazards.

Periodic monitoring of airborne levels with a real-time monitor is often appropriate before and during new work activities. This data can then be used to evaluate existing health and/or safety programs and to assure proper selection of personnel protective equipment (PPE), engineering controls and work practices.

A. Photoionization Meters - Photoionization detectors (PIDs) use a high energy ultraviolet (UV) light source to ionize chemicals in an air stream. The charged molecules are collected on a charged surface which generates a current which is directly proportional to the concentration of the chemical in the air being sampled.

B. Infrared Analyzers - Infrared (IR) analyzers measure a broad range of inorganic and organic chemicals in air. Depending upon the chemical, the sensitivity of IR analyzers can be sufficient for industrial hygiene purposes. Because most chemicals absorb IR light, an infrared analyzer may not be selective unless the chemical of interest can be measured at a wavelength which is unique for that chemical in the air sample, or the industrial hygienist is able to determine that other interfering chemicals are not present in the work environment. Some of the routine applications for IR analyzers include measuring carbon dioxide in indoor air quality (IAQ) assessments; anesthetic gases, including, nitrous oxide, halothane, and isoflurane; ethylene oxide; ethylene dibromide, and methyl bromide.

C. Gas Monitors - Use an electrochemical voltammetric sensor or polarography cell to provide continuous analyses and electronic recording. Sample gas is drawn through the sensor and absorbed on an electro catalytic sensing electrode after passing through a diffusion medium. An electrochemical reaction generates an electric current directly proportional to the gas concentration. The sample concentration is displayed directly in parts per million, % oxygen or % LEL (lower explosive limit). Since the method of analysis is not absolute, prior calibration against a known standard is required. Calibration at a single concentration, along with checking the zero point, is sufficient. The oxygen meter displays the concentration of oxygen in percent by volume measured with a galvanic cell. Other electrochemical sensors are available to measure carbon monoxide, hydrogen sulfide, and other gases. Some units have an audible and/or visual alarm that warns of low oxygen levels, LEL or malfunction. These pieces of equipment generally rely on the passive diffusion of air into the detector, however, some applications will require the user to attach a mechanical pump to actively draw air into the sensor.

D. Oxygen Monitors - Oxygen measurements are usually made along with combustible gas measurements for confined spaces. Oxygen meters typically use galvanic electrochemical cells (sensors). The generated current in the sensor, which is produced from an oxidation reaction, is directly proportional to the rate of oxygen diffusion into the cell. Most meters are calibrated to measure oxygen concentrations between 0 and 25% by volume in air. Normal air contains about 20.9% oxygen. Meter alarms are usually set to indicate an oxygen-deficient atmosphere at concentrations lower than 19.5% and an oxygen-rich atmosphere at concentrations greater than 23.5%.

E. Explosibility/Combustible Gas Monitors -These meters use elements which are made of various materials such as platinum or palladium as an oxidizing catalyst. The element is one leg of a Wheatstone bridge circuit. These meters measure gas concentration as a percentage of the lower explosive limit of the calibrated gas.

F. Detector Tubes - Detector tubes and their associated pumps are portable equipment capable of measuring concentrations of a large number of gases and vapors present in industrial atmospheres. Detector tubes of a given brand are to be used only with a pump of the same brand. A brand of tubes is calibrated specifically for the same brand of pump and may give erroneous results if used with a pump of another brand.

G. Mercury Analyzer-Gold Film Analyzer - Measures mercury in air by drawing an air sample over a gold film. The Jerome Model 431X model has a reported practical detection limit of 0.01 mg/m3. The mercury adsorbed onto the gold surface changes the resistance of current flow. The change in resistance is a function of the mass of mercury collected on the gold film. Results can be displayed in mg/m3 of mercury or total mass of mercury in the air sample collected. Potential interferences which can produce a positive reading include chlorine, nitrogen dioxide, hydrogen sulfide, high concentrations of ammonia, and most mercaptans. These interferences are removed from the air stream ahead of the gold film by drawing the air sample through an "acidic gas filter" which contains sodium hydroxide and soda lime. For use in high chlorine environments, an optional chlorine filter can be used.

H. Particle Monitors (Condensation Nuclei) - Particles that are too small to be easily detected are enlarged to a detectable size, and counted. Sub micrometer particles are grown with alcohol vapor as they pass through a heated saturator lined with alcohol–soaked felt, and then condense the alcohol on the particles in a cooled condenser. Optics focus laser light into a sensing volume. As the droplets pass through the sensing volume, the particles scatter the light. The light is directed onto a photodiode which generates an electrical pulse from each droplet. The concentration of particles is counted by determining the number of pulses generated. Applications include the testing of respirators and real-time dust monitors. A counter totals individual airborne particles from sources such as smoke, dust, and exhaust fumes. Models typically operate in one of three possible modes, each with a particular

application. In the "count" mode, the counter measures the concentration of these airborne particles. In "test" (or fit test) mode, measurements are taken inside and outside a respirator and a fit factor is calculated. In the "sequential" mode, the instrument measures the concentration on either side of a filter and calculates filter penetration.

I. Photodetection - Photodetectors operate by detecting scattered electromagnetic radiation in the near infrared region. Photodetectors can be used to monitor total and respirable particulates. The device measures the concentration of airborne particulates and aerosols including dust, fumes, smoke, fog, mist, etc.

6.12.2 Indirect Reading

A. Solid Sorbent Tube Sampling

Solid sorbent tubes include large and small charcoal tubes, porous polymer tubes such as XAD and XAD-7, large and small silica gel tubes, DNPH (dinitrophenyl hydrazine) tubes, Orbo tubes, Porapak Q, Tenax tubes, and Florisil tubes. Sampling should be performed in the following manner:

1. Calibrate each pump at the recommended flow rate for the analyte of interest, using a representative solid-sorbent tube (not the actual tube to be used during sampling) in-line. Calibrate each pump with a bubble meter or equivalent flow measuring device.

2. Break the ends of the solid sorbent tube immediately before sampling. The openings should be at least ½ of the internal diameter of the tube. Use a tube tip breaker or file.

3. Connect the solid sorbent tube to the tube holder, making sure the smaller sorbent section (backup section) is nearest the pump. The air that is being sampled should not pass through any hose or tubing before entering the solid sorbent tube. To avoid channeling and premature breakthrough, position the tube vertically during sampling.

4. Prepare field blanks by breaking the ends of tubes from the same lot as the tubes that are being used for sampling and then cap them. Handle the blanks in the same manner as the samples, but do not draw air through the blanks.

5. Sample at an accurately known flow rate for the length of time necessary to obtain the specified air volume. Check the pump periodically during sampling to detect any changes in flow rate. If the accurate measurement of volume cannot be determined due to inconsistent flow rates, discard the sample.

6. Be sure to keep an accurate record of sample data including date, sample location, pre and post flow-rate, beginning and ending times or air sampling, (if applicable - temperature, relative humidity, atmospheric pressure or elevation above sea level), and name of employee or area.

7. Seal the ends of the tubes with plastic caps immediately after sampling. Clearly label each sample with an appropriate identification number. Label each blank tube as a blank.

8. Pack the tubes tightly for shipment to the laboratory, with adequate packing to minimize the possibility of breakage. Enclose a completed sample analytical request form (chain of custody) with each batch.

9. Bulk samples are recommended when sampling chemical mixtures. When it is necessary to ship a bulk sample along with the air samples, the bulk sample must be shipped in a separate package to avoid possible cross contamination.

B. Sampling Using Filters

Filters include glass fiber filters, Teflon filters, mixed cellulose ester membranes, polyvinyl chloride filters, and treated filters and pads. Sampling with filters can be done open or closed faced.

Closed-faced sampling is performed with only the buttons removed from the cassette thus the analyte deposits near the center of the cassette. This is the most common case for particulate sampling.

Open-faced sampling is done with three (3) piece cassettes with just the top of the cassette removed. This type of sampling is used where even dispersal of the analyte over the filter is desired, for example, when sampling asbestos or for certain coated filters such as used for isocyanate sampling.

Filter Sampling methodology:

1. Calibrate the sampling pump at the recommended flow rate with a *representative* filter (*not the actual filter to be used during sampling*) in line using a bubble meter or equivalent flow measuring device.

2. Remove the cassette buttons (closed faced sampling) or cassette top (open faced sampling). *Air being sampled should not pass through any hose or tubing before entering the cassette*.

3. Attach the cassette to the sampling pump using flexible tubing (a cassette holder may be used), making sure the filter pad end of the cassette is closest to the pump.

4. Prepare field blanks using cassettes from the same lot by briefly removing and replacing cassette buttons and handling these blanks in the same manner as the samples, without drawing air through the blanks.

5. Sample at a known flow rate for the length of time necessary to obtain the specified air volume, or until there is evidence of excessive filter loading. Check the pump during sampling to detect any changes in flow rate. If the accurate measurement of volume cannot be determined due to inconsistent flow rates, discard the sample.

6. Disconnect the filter after sampling. Replace the buttons (or top) and properly label the sample and blanks. Be sure to keep an accurate record of sample data including date, sample location, pre and post flow-rate, beginning and ending times or air sampling, *(if applicable - temperature, relative humidity, atmospheric pressure or elevation above sea level),* and name of employee or area.

7. Ship the samples to the laboratory as soon as possible in a container designed to prevent damage in shipment. Enclose a completed chain of custody with each batch.

C. Sampling for Respirable Aerosols

Respirable aerosol sampling is performed using a cyclone and filter sampler. Sampling for respirable aerosols should be performed in the same manner as sampling a filter except:

1. Calibrate each pump at the flow designated by the type of cyclone being used with a representative cyclone and filter in line. Note that the filter is mounted upside down with the cyclone in place.

2. Inspect the interior of the cyclone. If there is visible scoring or damage inside, discard the cyclone since the dust separation characteristics may have been altered. Clean the interior of the cyclone.

3. Attach the cyclone to the filter according to the manufacturer's instructions. Connect the assembly to the sampling pump. During sampling, make sure the cyclone hangs vertically and that the assembly does not get inverted during sampling. If an accurate and consistent flow rate cannot be maintained, discard the sample.

D. Control and Blank Samples

The use of sampling blanks and controls for active and passive sampling enables assessment of interfering contaminants that may be inherent in the sampling medium or collected by the sampling adsorbents during non-sampling periods (i.e. transportation). Sample blanks and controls are to be

identical in the type and batch number as those to be used for sampling. Controls should always be included with samples.

Ideally, data for the controls and blanks should always be below the limit of detection of the system. If they are not the source of the contaminant can be identified and accounted for in that instance and corrected for future sampling campaigns.

Blanks

Blanks are pristine samplers that have only just been removed from their packaging. Blanks should not leave the laboratory and are used to check the analytical procedure and determine any background levels of the analyte in the medium.

Controls

Controls are samplers that have undergone all the same movements and handling except for the fact they have not had air drawn through them, or been exposed for more than a few seconds in the case of diffusive samplers. Controls will determine whether the samples have been exposed to and contaminated by analytes outside of the recorded sampling period.

Controls should be prepared in exactly the same way as all other samples. The inlet and outlet points should be broken or unplugged as applicable then immediately resealed and labelled as a control sample and put into appropriate storage.

To ensure a sufficient number of controls include 10% more samples than the number calculated as required. As an absolute minimum there must be 2 blanks.

D. IH Equipment Calibration

This Section has been compiled for the purpose of ensuring uniformity of approach to calibrating secondary flow meters using the primary soap film flowmeter

The procedure is for the calibration of both bubble and rotameter flow meters. However rotameters are generally not accurate and precise enough to use as secondary flow meters.

Principle of the method

An air flow is provided by a sampling pump linked to a soap film flow meters (the primary flowmeter) and a secondary flowmeter. The time taken for a soap film to travel from point A to point B in the burette provides a primary flow rate. The error on the secondary flowmeter is determined by relating the primary flow rate to flow rate measured by the secondary flowmeter.

Rotameter

- Ensure when reading the rotameter that the ball is level with your eye and read off the flowrate level with the midpoint of the ball. This is necessary to reduce any systematic bias due to parallax error.
- Prior to timing the bubble read the flowrate from the rotameter.
- Use the stopwatch to measure the time taken for the bubble to travel the required length of the graduated scale of the burette, or from one line to the other.
- After timing the bubble, read the flowrate from the rotameter again and average the before and after values.
- For calibration, every 3 months. If after 3 consecutive tests, i.e. 6 months, and showing results within $\pm$ 3% of the expected result, the interval can be extended to 2 years.

DryCal

- Where the DryCal is being calibrated, activate the automatic averaging mode according to manufacturer's instructions to determine the flow rate before timing the bubble.
- Use the stopwatch to measure the time taken for the bubble to travel the required length of the graduated scale of the burette, or from one line to the other.
- Note the average flowrate from the DryCal during the test if possible.
- After timing the bubble, read the average flowrate from the DryCal again and average all the values.
- For DyCal calibration, the manufacturer's recommendation is annually unless otherwise indicated.

IH equipment periodic calibration, servicing and certification will be performed based on the manufacturer's recommendations. All calibration certificates will be documented in Salute.

6.13 Surface Sampling

6.13.1 Methods for sampling surface dusts

The sampling method used for collecting settled dust depends upon where the settled dust has collected. Sample areas are usually 30cm x 30cm areas to ensure a reasonable limit of detection, however, if a high concentration is suspected this may be reduced to a 10cm x 10cm area. If neither of these areas is achievable then samples must be collected as practicable. It may be possible to collect samples from more than one site; ideally 10 sites would be considered representative of the surface contamination.

6.13.2 Swabbing

These may be used wet or dry to sample what has been deposited on surfaces. Note that swabs may be used to sample dry or moist/wet deposits on surfaces or small liquid amounts that cannot be sampled using a pipette or syringe.

Sample preparation

Isopropyl alcohol swabs, or lint and static free tissues may be used with organic free, glass-distilled water or methanol. It is important that these swabs are used because other swabs may contain chemicals that will interfere with analyses.

Use round nose, metal tweezers or nitrile gloves at all times to prevent contamination of the swabs and you:

- Always rinse the tweezers in between each sample using the distilled water followed by the HPLC grade acetone, shake them allowing them to air dry; or
- Remove gloves after collecting each sample.

Method for isopropyl alcohol swabs

Tear open the swab. Handle the swab with the tweezers or gloved hands for 5-10 seconds then place the swab into a 20 mL scintillation vial and cap it. Label the vial as a "CONTROL ISOPROPYL SWAB" before placing in a sealable bag. Label the bag with "CONTROL ISOPROPYL SWAB".

Remove a second swab and swab a noted area. Put the swab in a scintillation vial and cap it. Label the vial and place the capped vial in a sealable bag. Label the bag with a marker pen.

Method for moist lint and static free tissues

Use moist tissues for dry/moist deposits.

Remove a tissue from the pack and moisten with distilled water, do not make it dripping wet. Handle the swab for 5-10 seconds then place the swab into a 20 mL scintillation vial and cap it. Label the vial as a "CONTROL WATER SWAB" before placing in a sealable bag. Label the bag with "CONTROL WATER SWAB".

Remove a second again moisten with distilled water and swab a noted area. Put the swab in a scintillation vial and cap it, if it will not go into a scintillation vial then use a glass jar. Label the vial and place the capped vial in a sealable bag. Label the bag with a marker pen.

Method for dry lint and static free tissues

Use dry tissues for small volumes of liquid samples.

Remove a tissue from the pack. Handle the swab for 5-10 seconds then place the swab into a 20 mL scintillation vial and cap it. Label the vial as a "CONTROL DRY SWAB" before placing in a sealable bag. Label the bag with "CONTROL DRY SWAB".

Remove a second and swab a noted area. Put the swab in a scintillation vial and cap it, if it will not go into a scintillation vial then use a glass jar. Label the vial and place in a sealable bag. Label the bag with a marker pen.

6.13.3 Surface vacuuming

Dust accumulations in crevices etc. are difficult to sample using the adhesive tape or swabs. In these instances the surface vacuum method is most suitable. Instead an air flow pump will be used as a low flow vacuum to collect the settled dust. More than one site may be sampled on the same filter and sample areas will depend upon the situation in hand.

Surface samples are usually collected over areas of 30cm x 30cm areas to ensure a reasonable limit of detection, however, if a high concentration is suspected this may be reduced to a 10cm x 10cm area. If neither of these areas is achievable or practical then samples must be collected as the situation dictates.

Method

- Select an air flow sampling pump capable of maintaining a sampling rate of 2L/min and turn on for 15 minutes to allow the flow rate to stabilize.
- Calibrate the air flow rate to approximately 2 L/min and turn off.
- A 37 mm cassette is loaded with a filter. The usual filter type is the 37 mm PVC filter with a nominal pore size of 5.0 um. However, these filters have a problem with electrostatic charge, therefore, prior to use the filter must have any static accumulation discharged. This activity is performed by the analyzing laboratory. To circumvent this problem a vinyl/acrylic copolymer filter (such as the Pall DM Metricel®) can be used that does not have electrostatic problems.
- Connect the outlet of the cassette to the pump.

- Fit a short length of tubing to the inlet of the cassette.
- Prepare a diagram of the site to be sampled and mark 'X' on the diagram for the position collected samples.
- Start the pump and use the short length of tubing on the cassette as a vacuum cleaner, moving over the entire area of each of the sites chosen for sampling.

6.13.4 Storage and transport of samples

- Samples are to be stored at ambient temperature.
- Ensure packaging prevents any jarring during transport which may dislodge or break the dust layer on the filers.
- Samples should be transported at ambient temperature.
- Chain of custody form and request for analysis form are sent with the samples to the analytical laboratory.
- Complete all details on **Appendix 6 - Air Sampling Field Data Sheet** and Laboratory Analysis request and chain-of-custody forms (provided by the laboratory). Attach the latter with the samples to be sent to the laboratory for analysis.

6.14 Laboratory Analysis

6.14.1 Accredited Laboratories

Where tubes or badges are required for laboratory analysis, they must be performed in accredited laboratories such as the AIHA Accreditation Laboratory Programs (AIHA Accredited Labs) or by local governmental certified laboratories. These laboratories also require an Analysis request and chain-of-custody to be completed, which must accompany the samples.

6.14.2 Storage and Transportation of Samples

- Seal tubes and badges with airtight caps to prevent further sorption or loss of analytes.
- All particulate samplers must be capped using specific holders: Inhalable, IOM particulate cassette holder.
- All sealed tubes and badges are to be stored in a clean, airtight container and refrigerated as required. Refrigeration minimizes migration of the analyte within sections of a tube, which prevents cross contamination between sorbent sections within sampler and maintains the integrity of the samples.
- All particulate samplers must be kept upright to prevent loss of sample from the filter surface and jolts and vibration minimized.
- All samples are to be packed into a transportation box to minimize any breakage or effects from jarring or vibration during transit to the laboratory.
- Samples in transport are to be kept cool and should not be exposed to sunlight or warm conditions. The box is to be labelled 'keep cool', 'Treat like glass' and 'This way up'.
- The sampling tubes and badges should be sent to the analyzing laboratory as soon as possible.

6.15 IH Calculations

To accurately ascertain employee exposure, exposures to workplace chemicals must be accurately collected, analyzed, calculated and interpreted for comparison to exposure limits. This requires applying the appropriate calculations to analytical results.

One type of Occupational Exposure Limit (OEL) is the ACGIH TLVs (Threshold Limit Values), which is often used as compliance limit in the U.S. and other countries. For compliance based sampling, TLVs are predominantly used. There are TLVs for various forms of approximately 750 chemical substances. The TLVs provide numeric standards that determine how long a worker may be exposed in the workplace to a threshold amount of an airborne contaminant without adverse effects on health.

6.15.1 Computing Exposure

Use the following formula to determine whether an employee is exposed above the regulatory limit for an air contaminant (one that does not have a ceiling value), for an 8-hour work shift:

$E = (C_1T_1) + (C_2T_2) + ... (C_nT_n) / 8$

"E" = equivalent exposure for the work shift. "C" = concentration during any period of time, "T," where the concentration remains constant. "T" = duration, in hours, of the exposure at the concentration "C."

"E" must not exceed the 8-hour time-weighted average (TWA) specified in the Z tables for the material involved.

Example: Assume that Substance A has an 8-hour TWA limit of 100 ppm in ACGIH TLVs table. Assume the employee has the following exposure to the substance:

2 hours at 150 ppm 2 hours at 75 ppm 4 hours at 50 ppm

The formula to determine exposure would be as follows:

(2 x 150) + (2 x 75) + (4 x 50) / 8 = 81.25 ppm

Since 81.25 ppm is less than 100 ppm, the 8-hour TWA exposure is acceptable.

Computing Exposure to a Mixture of Substances

Use following formula to determine the equivalent 8-hour TWA exposure limit for a mixture of air contaminants:

$Em = (C_1/L_1) + (C_2/L_2) +... (C_n/L_n)$

"Em" = equivalent exposure for the mixture. "C" = concentration of a particular contaminant measured in the workplace. "L" = exposure limit for the particular contaminant found in the Z tables.

The value of E must not exceed 1.0.

Example: Consider the following exposures:

Substance Concentration 8-hr TWA TLV		
	ppm	ppm
A	500	1000
B	45	200
C	40	200

The formula for determining mixtures of contaminants:

(500/1,000) + (45/200) + (40/200) = 0.925

Since 0.925 is less than 1.0, the exposure to the mixture of contaminants is within acceptable limits.

6.15.2 Contaminants with Ceiling Values

An employee's exposure to any substance which is preceded by a "C" (Ceiling Values) shall not exceed the exposure limit given for that substance. If instantaneous monitoring is not feasible, then the ceiling

shall be assessed as a 15-minute time weighted average exposure which shall not be exceeded at any time during the working day.

An employee's exposure to a substance listed in ACGIH TLVs shall not exceed at any time during an 8-hour shift the acceptable ceiling concentration limit given for the substance in the table, except for a time period, and up to a concentration not exceeding the maximum duration and concentration allowed in the column under "acceptable maximum peak above the acceptable ceiling concentration for an 8-hour “shift".

Example: During an 8-hour work shift, an employee may be exposed to a concentration of Substance A (with a 10 ppm TWA, 25 ppm ceiling and 50 ppm peak) above 25 ppm (but never above 50 ppm) only for a maximum period of 10 minutes. Such exposure must be compensated by exposures to concentrations less than 10 ppm so that the cumulative exposure for the entire 8-hour work shift does not exceed a weighted average of 10 ppm.

7 Indoor Air Quality (IAQ) Assessment

Most IAQ problems can be effectively diagnosed with educated observations, an awareness of odors, a sense of temperature and relative humidity, and a smoke tube to verify the existence of and direction of air flows.

Occasionally, it may be appropriate to measure:

- Airflow through, or out of ducts/vents, or calculate the percent of outdoor air in the supply air stream.
- Thermal comfort - temperature and relative humidity.
- Carbon dioxide levels in occupied spaces over the course of the occupancy period, or to compare CO_2 levels in the complaint area with levels in non-complaint areas.
- IAQ pollutants such carbon monoxide, nitrogen dioxide, VOCs, lead, dust, biological contaminants including mold, etc. when the source has been identified.

7.1 Odor Investigation

The Industrial Hygienist or HSE staff will investigate all odor complaints. Attempts will be made to locate the source of the odor and resolve the issue, with the help of the appropriate departments.

Recurrent odor complaints will be investigated as an IAQ problem.

7.2 IAQ Complaint

IH/HSE will conduct IAQ investigations if there is a complaint, and will partner with Occupational Health/ KAUST Health if there is a complaint which includes health related signs or symptoms. The investigations generally consist of the following:

- Staff will be asked a series of questions or provided an IAQ questionnaire as appropriate. At a minimum, information regarding the following will be obtained:
    - Description of the odor, symptoms or complaints
    - Onset of symptoms – timing patterns
    - Spatial Patterns

It may be helpful to perform parts of the investigation including measurements with the building facility staff. They generally have maintenance records that can be referred to, have certain measurement equipment, and can easily direct you to potential equipment sources.

- A walkthrough of the area will be conducted to identify possible sources which may include:
    - Chemical or particle causes (e.g. vapors from painting operations, adhesives, solvents, fiberglass, and dust.)
    - Biological causes (e.g. allergen, microbial contamination, mold)
    - Excessive dust accumulation
    - Potential ventilation problems
- As indicated, initial monitoring may be conducted, including monitoring for:
    - Airflow

- Carbon dioxide/ carbon monoxide levels
- Temperature
- Humidity - Relative humidity should be below 60% at all times

- Follow up (generally within a month) will determine whether:
  - The solutions proposed were enacted
  - The symptoms/concerns have been eliminated/resolved
  - Any new concerns have been identified
- Recordkeeping
  - A final letter will be sent to close the investigation
  - All checklists, questionnaires, copies of memo's and letters will be kept in the building IAQ file
  - IAQ action file crossed referenced by person

7.3 Basic Measurements - Observing or Measuring Airflow

7.3.1 Using Smoke Tubes

Smoke tubes can provide a quick visualization of the path of the airstream and help identify pressure differentials. Dispensing a series of small “puffs” of smoke can provide more information that a single large “cloud.” For example, in occupied areas - if the smoke is dispersed in several seconds, this suggests good air circulation.

Smoke tubes have a variety of uses:

- Near supply air outlets - the dispersal pattern provides information about the velocity and direction of the supply air.
- Near exhaust vents to make sure the exhaust is drawing air out of the room.
- Near combustion chamber of combustion appliances to insure that there is no backdraft of flue gases.
- Close all doors or other openings that might possibly be closed in normal operating conditions, and turn on all exhaust fans or other equipment that may exhaust air from the room.
- Release puffs of smoke next to the combustion chamber and around the flue fittings (where flue gases might leak into the room) to detect any air movement from the flue or combustion chamber into the room.
- At drain trap openings to make sure no air is flowing up from the trap.
- At duct seams to check for leakage.
- At the entrance to an exhausted room to insure the room is under negative pressure relative to the occupied spaces.
- At the entrance to a clean room to ensure room is under positive pressure.

7.3.2 Measuring Outdoor Air Flow

The quantity of outdoor air supplied to a building can be determined using a flow hood or air velocity meter. To check that outside air requirements are being met under all operating conditions, take measurements at minimum airflow.

- If an economizer is operating, turn the economizer off, or set the economizer shutoff temperature to the lowest setting.
- Since airflow varies during the day and over the seasons in VAV systems, VAV system controls should be made to operate at minimum flow conditions.

7.3.3 Measuring Air Flow with a Flow Hood (Preferred)

Flow hoods are designed to measure airflow through an opening (e.g., at supply air diffusers or return air grills, outdoor air intake) by placing the face of the flow hood over the opening and reading the computed airflow volume. The flow hood must completely cover the opening. If the opening is larger than the flow hood, obtain a reasonable estimate by following manufacturer's recommendations. Flow hoods will show the airflow in an easier, quicker, and more consistent manner than using a series of pitot tube or rotating-vane anemometer readings.

7.3.4 Measuring Air Flow with a Velocity Meter (Less Preferred)

Velocity meters (anemometer or pitot tube) are less expensive than flow hoods, but their accuracy is more problematic and they require greater attention to detail. An anemometer or Pitot tube measures the velocity of air passing over a point. To accurately represent the velocity through a duct or opening, multiple measurements must be taken. It is important to follow measurement instructions supplied with the equipment to obtain an accurate reading.

Airflow through the duct or opening is then measured by multiplying the area of the opening (e.g., square feet) by the average velocity of the air (e.g., feet per minute) to obtain airflow (cubic feet per minute).

Airflow = Free Open Area X Average Velocity

(ft^3/m or m^3/m)= (ft^2 or m^2) (ft/min or m/min)

7.3.5 Calculating the Outdoor Air Supply Using Carbon Dioxide (CO_2) Measurements (Not Preferred)

When outdoor air cannot be measured directly, the outdoor air supply can be calculated using CO_2 measurements and by measuring the supply airflow.

- Measure the total **supply airflow** using a flow hood or velocity meter.
- In quick succession, measure **carbon dioxide in the supply air, the return air, and outdoor air** (do not use calorimetric tubes for these measurements). An average of more than one measurement in each air stream is advisable to obtain accurate estimates.
- Calculate the percent outdoor air as follows:

  $$\frac{\{CO_2 \text{ (return)} - CO_2 \text{ (supply)}\} \times 100}{\{CO_2 \text{ (return)} - CO_2 \text{ (outside)}\}} = \% \text{ outdoor air}$$

  Outdoor air supply = (Supply airflow) X (% outdoor air)

Measurement of supply and return are best accomplished in an indoor space serviced by an AHU of interest. Outdoor air should be measured at the outdoor air intake of the AHU. Percent outdoor air is the same throughout the supply air stream of the AHU.

Note: It may be tempting to use temperature rather than CO_2 to measure percent outdoor air. This is not advisable because as the three airstreams approach each other, varying temperatures affect accuracy and the calculated result can deteriorate very significantly. For the same reason, the difference in CO_2 measurements in each air stream should be at least 200 ppm to insure an acceptable level of accuracy for this method.

7.4 Measuring Thermal Comfort

Generally, independent measurements of temperature and relative humidity will be sufficient. However, some instruments will integrate these and other measurements and provide a read out of thermal comfort consistent with ASHRAE Standard 55-2017 *Thermal Environmental Conditions for Human Occupancy.*

7.4.1 Temperature and Humidity

For temperature and humidity measurements, instruments can be a simple thermometer and humidity gauge, a sling psychrometer, or an electronic thermo hygrometer. Accuracy to within + or – 1˚F and + or – 5% RH is the objective of thermal comfort measurements. Readings should be made 3-6 feet off the floor, and at floor level. Persons suffering from cold feet may report that the room is "too cold."

Be sure that the meter is located away from direct sunlight or near a supply air outlet, or other heating/cooling sources. Refer to the manufacturer recommendations for the time needed to stabilize the reading, and maintain the frequency of calibration.

7.4.2 Acceptable Values

Direct reading instruments are readily available which describe readings within acceptable ranges for thermal comfort.

Alternatively, a thermal comfort meter can be used. Such meters integrate several thermal comfort parameters and will provide a direct indication as to whether thermal comfort is in the acceptable range according to ASHRAE Standard 55-2017.

7.5 Measuring Carbon Dioxide

The exhaled breath of occupants is the main source of carbon dioxide (CO_2) in buildings. Because the concentration of CO_2 is highly correlated with levels of human bioeffluents (body odor), CO_2 measurements are often used to indicate whether the outdoor air ventilation rate in the building is sufficient to handle the bioeffluents load.

7.5.1 CO_2 Measuring Instruments

Direct reading instruments using infrared spectrometry with digital read-outs are accurate and appropriate. An example includes TSI Indoor Air Quality Meter 7545 that simultaneously measures and data logs multiple parameters, including CO_2, CO, temperature, humidity; and calculations are dew point, wet bulb temperature, and percent of outside air.

7.5.2 CO_2 Value Indicators

ASHRAE Standard 62.1-2019 *Ventilation for Acceptable Indoor Air Quality* requires 15-20 cfm of outdoor air per occupant are designed to dilute human bioeffluents odor to an acceptable level. In general, 15

cfm per occupant will keep indoor minus outdoor CO_2 levels below 700 ppm, while 20 cfm will keep indoor minus outdoor CO_2 levels below 500 ppm. (This corresponds to indoor values of 1000 ppm and 800 ppm when outdoor values are 300 ppm, which is assumed by ASHRAE.)

Interpreting CO_2 Measurements above Threshold Values

Indoor CO_2 should be measured at peak values. Peaks usually occur around 11am and 3pm in a typical office environment. However, if measurements in the occupied space are ever above 1000 ppm:

- Check for improperly vented combustion appliances, which could also be producing carbon monoxide.
- Check the CO_2 levels outside; and calculate the indoor-outdoor values and compare with the above mentioned thresholds for 15 and 20 cfm per occupant.

If neither of these conditions can explain why the CO_2 levels are above 1000 ppm, it is a valid presumption that the outdoor air ventilation rate is too low.

Interpreting CO_2 below Threshold Values

If CO_2 levels are below the identified guidelines, this does not necessarily mean that the ventilation rate or that indoor air quality is satisfactory. CO_2 measurements below the designated threshold levels are not an indicator that either IAQ or outdoor air ventilation rates are satisfactory.

As a general measure of indoor air quality, CO_2 measurements do not account for non-occupant related contaminants, which can dominate the indoor environment. And as an indicator of the outdoor air ventilation rate, the use of CO_2 measurements will almost always tend to overestimate the true outdoor air ventilation rate, often by as much as 100% to 200%.

This is because the threshold values are based on the assumption that CO_2 has risen to its theoretical steady state condition. As people occupy the building, when occupancy stabilizes, and when ventilation rates remain constant, CO_2 levels will rise and eventually reach steady state condition, and go no higher. The steady state value will be greater with higher occupant densities and lower outdoor air ventilation rates.

Unfortunately, it is extremely unlikely that steady state will have been reached.

Under a typical outdoor air exchange rate of 0.5 air changes per hour, it would take 6 hours to achieve 95% of steady state conditions.

- But constant full occupancy in a building is seldom longer than 3 hours in the morning or 3 hours in the afternoon.
- Thus, measuring CO_2 prior to steady state will always underestimate the true ventilation rate.

The extent of overestimation increases as occupant density decreases, and as the outdoor air ventilation rate decreases. In the majority of circumstances, CO_2 levels in occupied spaces will not achieve 1,000 PPM even when outdoor air ventilation rates are unacceptably low. The matter is further complicated by the fact that outdoor air ventilation rates are often not steady in VAV systems.

Observing Changes to CO_2 Values over Time

Real-time measurements of CO_2 with data-logging equipment can be also be used to see how CO_2 values rise and fall in an occupied space during the day, reflecting the pattern of changing occupancy, or changing outdoor air ventilation rates. This can provide clues as to what is happening in the building and this information can help in the diagnostic process.

Comparing CO_2 Values of Different Spaces in the Same Building

The investigator may wish to compare CO_2 values in the complaint area with values in other parts of the building. CO_2 values in the complaint area higher than values in non-complaint areas suggest that outdoor air ventilation rates in the complaint area may be causing the problem.

7.6 IAQ Contaminants

Common indoor contaminants include excessive moisture, volatile organic compounds (VOCs), formaldehyde, combustion products (CO, NO_2, SO_2), radon, pesticides, dust particles, viruses, and bacteria. There are many sources of indoor air pollution. These can include:

- Fuel-burning combustion appliances
- Tobacco products
- Building materials and furnishings as diverse as:
  - Deteriorated asbestos-containing insulation
  - Newly installed flooring, upholstery or carpet
  - Cabinetry or furniture made of certain pressed wood products
- Products for household cleaning and maintenance, personal care, or hobbies
- Central heating and cooling systems and humidification devices
- Excess moisture and water intrusions
- Outdoor sources such as:
  - Radon
  - Pesticides
  - Outdoor air pollution

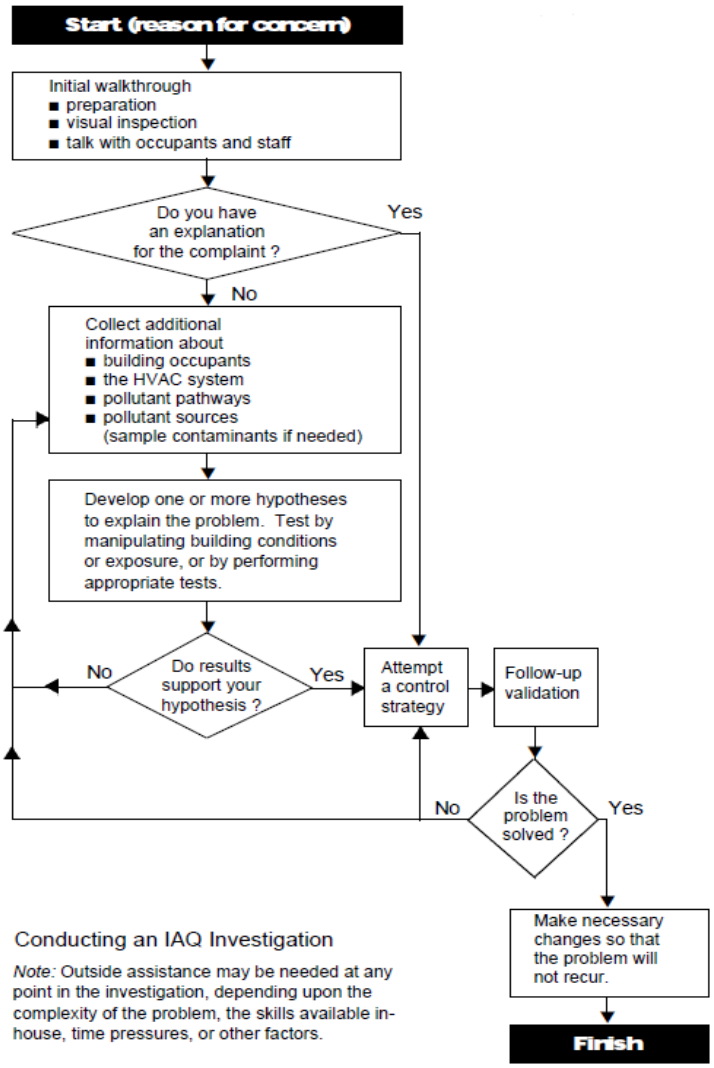
The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings and products like air fresheners, can release pollutants more or less continuously. Other sources, related to activities like smoking, cleaning, redecorating or doing hobbies release pollutants intermittently. Unvented or malfunctioning appliances or improperly used products can release higher and sometimes dangerous levels of pollutants indoors.

Pollutant concentrations can remain in the air for long periods after some activities.

7.6.1 IAQ Investigation

Figure 7.1. IAQ investigation process flowchart.



Most often IAQ issues can be solved without measuring specific contaminants. It is prudent to perform air monitoring only when it is necessary, particularly if it is related to mold and water moisture issues. Where the contaminant source(s) have been identified, mitigation controls should be implemented as a priority to resolve the IAQ issue.

Measurements and/or air monitoring are sometimes helpful to:

- Test for clearly identified sources and clearly identified target contaminants;
- Measure specific contaminants, such as radon, that have no acute affects but which could cause serious long term illness;
- Test for mitigation effectiveness in controlling a source;
- Compare with levels found in non-complaint buildings; and
- Ensure the containment of a work area/construction area in an occupied building.

IAQ assessment, measurements and field notes must be documented for liability, other legal or administrative reasons. When measurements are taken, qualified, experienced persons should take them and adhere to protocols and quality assurance procedures. **Appendix 3 – IAQ Investigation Form** provides a template to conduct the initial IAQ walkthrough investigation.

8 Illuminance (Lighting) Assessment

Illuminance or lighting can affect the place of work:

- Poor lighting can be a safety hazard – misjudgment of the position, shape or speed of an object can lead to incidents and injury.
- Poor lighting can affect the quality of work, specifically in situation where precision is required, and overall productivity.
- Poor lighting can be a health hazard – too much or too little light strains eyes and may cause eye discomfort (burning, etc.) and headaches.

8.1 Lighting Surveys

Measurement of the average illuminance may be necessary to:

- Check the calculated value of a new lighting system;
- Determine compliance with standards, as well as legislative and company requirements;
- Identify the need for maintenance, modifications or replacement of lighting;
- Assist in improving workplace lighting conditions where there is concern about lighting adequacy; or
- Identify specific lighting needs for visually impaired employees.

8.2 Instrumentation – Photometers

A photometer does not need to conform to any particular requirements except to be suitable and accurate for the purpose of the measurements and type of survey to be undertaken.

8.2.1 Measurement

The illuminance (light) falling on an area is measured by a photocell in the measuring instrument, the photometer. The output is a direct and instantaneous readout in lux. This illuminance can be a summation of direct and indirect light, the latter reflected from other surfaces in the measurement area.

8.2.2 Calibration of photometer

The calibration procedure for the photometer is to be according to manufacturer instruction. The photometer is to be calibrated at least every 12 months.

8.3 Determining representative measurement locations

To obtain representative averages of the illuminance value a sufficient number of measurements must be taken. In addition, the accuracy of the mean illuminance depends on the way the measurements were taken, the number of measurement points, and the uniformity of illuminance.

8.3.1 For a workstation

Measurement positions are to include the positions where employees are normally positioned within their workstation for the visual work tasks. This may require measurements on the horizontal, vertical or inclined working plane even where a shadow falls on the photoreceptor.

8.3.2 For an interior

Determining the number of measurement positions

To determine the number of measurement positions for the interior of a room, a 'Room Index' (K) is calculated see Section 2.7.3. The value of K is related to Table 2.1 to determine the MINIMUM number of measurement positions for that interior, according to the accuracy for the average illuminance required.

Table 1. Relationship between room index and the minimum number of measurement points

Room index (K)*	Minimum number of measurement points
Below 1	4
1 and below 2	9
2 and below 3	16
3 and above	25

*Refer to section 2.12 to for Room Index calculations.

Where an accuracy of ± 10% is required the number of measurement points should be no less than that specified in Table 1. This number can be increased to suit the grid pattern where the room is an unusual shape.

Room Index calculations

The Room Index (K) of a room is determined from the following calculation. For rectangular rooms the Room Index is given by the equation:

$$K = \frac{a \times b}{h\,(a + b)}$$

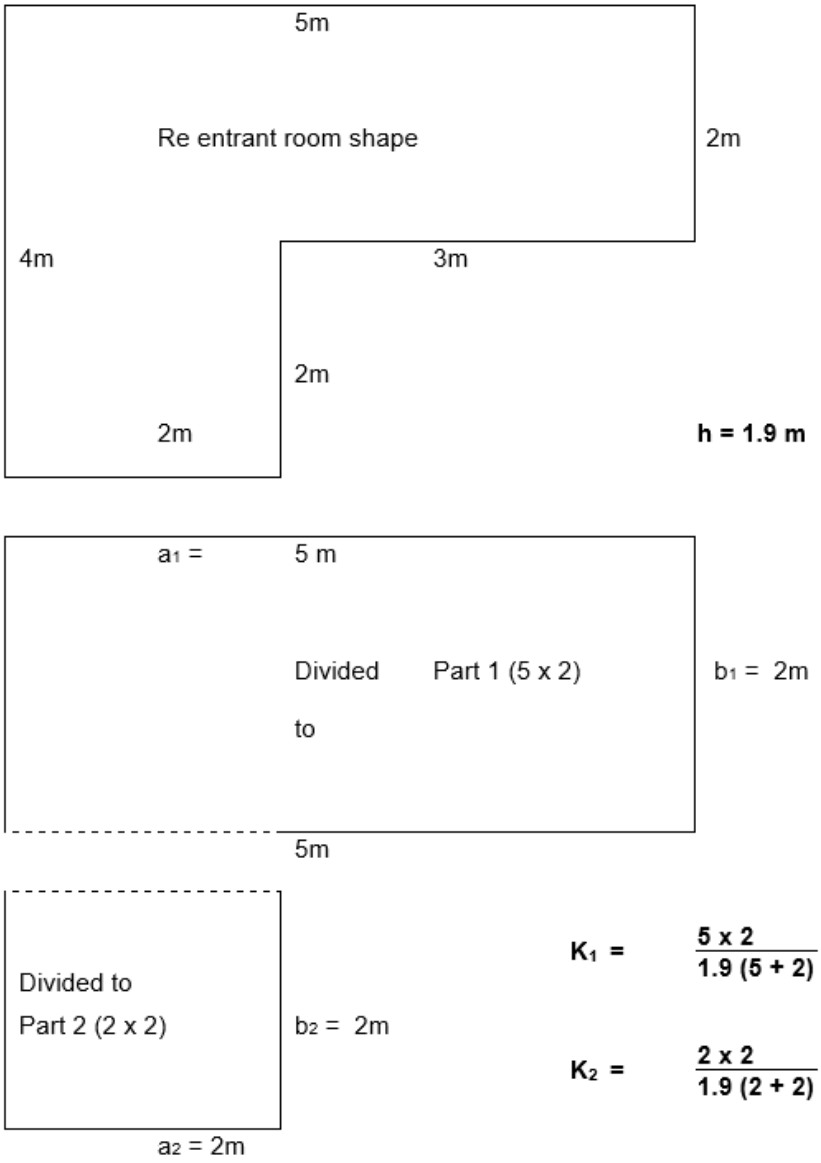
Where:

a, b = the dimensions of the sides of the room

h = the vertical distance between the horizontal reference plane and the luminaire plane.

Results can be rounded to the nearest value in the series 0.75, 1.00, 1.25, 1.50, 2.00, 2.50, 3.00, 4.00.

Below is an example of a 'L-shaped' room.



If the plane of a room is re-entrant 'L-shaped' room, then it should be divided into two or more non re-entrant parts. These parts are treated separately for these calculations, as shown below where a re-entrant room divided into 2 rectangular 'rooms' for the calculation of the Room Index.

8.4 Conducting a light survey

8.4.1 Preparation for taking illuminance measurements

Preparations depend upon the purpose of the survey and the survey type: whether for a work area or task assessment.

- Ensure lamps in the areas to be measured have been operated for at least 100 hours for discharge lamps (including fluorescent lamps) and 20 hours for incandescent lamps. Note: unless all lamps are changed at the one time then lamps may have aged for different times.

- To determine illuminance from an electric lighting system, take measurements in the dark or else exclude any external lighting from entering the interior.
- Turn on lights and leave to stabilize for up to 1 hour.
- Ensure air conditioning and ventilation systems are operating normally.
- Turn on the photometer and allow it to stabilize by exposing it to an approximate level of illuminance to that to be measured.

8.4.2 Workstations

Sketch the layout of the workstation, employee work positions, planes for working, and mark the intended measurement positions.

Set the photometer at the measurement position in the appropriate working plane this can be on the horizontal, vertical or on an incline.

8.4.3 Interiors

Obtain a room layout to scale, sketch in the grid pattern (unless provided from previous surveys) and mark the intended measurement position in center of each 'square'.

The illuminance is measured in the center of each square and at the height of the working plane, so set the photometer at the measurement position in the horizontal working plane.

8.4.4 Taking the measurements

Measurements can be taken to determine whether lighting conditions are adequate for the space. Use of a light meter to measure at the working surface in a horizontal plane 30 inches above the floor. Since the objective is to measure the task illuminant, daylight should be excluded. Thus, in an occupied area with windows, readings should be taken with the full use of interior shading (blinds or draperies) to reduce direct solar gain. When measurements are taken, the reflections from other strong light sources should be minimized. Also ensure that the observer's shadow does not affect the measurement. Take the lux measurement when the reading has stabilized and record on the sketch. As required, determine the cosine correction according to manufacturer instructions.

Light meters are generally sensitive to ambient temperatures, and should be only operated according the temperature range recommended by the manufacturer. Calibration is as important for light meters as it is for temperature and humidity measuring instruments.

Record the state and cleanliness of the luminaires, type of fittings, luminaire type and age, if known, and any other relevant details. Where local lighting is used, take additional measurements for comparison of illuminance before and after turning on local lighting.

Determine average illuminance and compare to the relevant maintenance illuminance levels recommendations for that area/activity.

8.5 Reporting of results

The lighting measurements are to be noted on the interior or work station plan as the survey progresses. Lighting assessment report should include:

- Type of task being done (such as demands for speed and accuracy).
- Type of surfaces (does it reflect or absorb light).
- General work area.

- Individual's vision.

8.6 Acceptable Levels

The amount of light falling on a surface is measured in units called lux. Acceptable general lighting is usually between 500 and 1000 lux when measured 76 cm (30 inches) above the floor. Reference

Table 2. Recommended maintenance illuminance levels for industrial and office tasks.

Recommended Illumination Levels*	
Type of Activity	**Ranges of Illuminations (Lux)****
Public spaces with dark surroundings	20-50
Simple orientation for short temporary visits	50-100
Working spaces where visual tasks are only occasionally performed	100-200
Performance of visual tasks of high contrast or large scale	200-500
Performance of visual tasks of medium contrast or small size	500-1000
Performance of visual tasks of low contrast or very small size	1000-2000
Performance of visual tasks of low contrast and very small size over a prolonged period	2000-5000
Performance of very prolonged and exacting visual tasks	5000-10000

* From: IESNA Lighting Handbook. 9th ed. Illuminating Engineering Society of North America, 2000. page 10-13.

**Lux = Lumens (quantity of light) per square meter.

Acceptable general lighting limits can also be found in ISO 8995 and BS EN 12464-1.

When reviewing a work area ensure that illuminance levels in smaller areas within the overall work area do not change dramatically. Such changes can result in eyestrain and associated symptoms and lead to accidents.

Where fine or detailed work is performed higher illuminance levels are required. Local lighting may be a suitable alternative, especially if the work is intermittent or the required direction of the lighting may need to be changed. It is important that the employee(s) performing detailed tasks, or others in the work area, are not exposed to glare from any local lighting that may be in use.

9 Noise Assessment

Effective workplace noise management relies on objective sound measurements being taken according to standardized procedures. These results are then valid for evaluation against predetermined criteria for acceptability.

Noise assessments are conducted to:

- Identify and quantify exposures to workplace noise where noise may exceed 85 dB (A), measured as an 8-hour Time-weighted Average (TWA), using a 3 dB doubling rate;
- Obtain specific information to assist management decide what measures are required to reduce noise, including ranking the severity of noise problems and deciding on noise control priorities;
- Provide sufficient information about the noise to which employees are exposed to enable effective engineering or administrative noise control measures to be planned;
- Check the effectiveness of control measures already in place;
- Assist in the selection of appropriate personal hearing protection where other control measures are not practicable;
- Provide information and training to employees in the risks associated with noise exposure and the precautions necessary to reduce those risks;
- Ensure proper signage is posted at access points where noise levels routinely exceed 85 dB(A);
- Ensure that health surveillance is carried out for employees exposed to noise in excess of 85 dB(A) 8-hour TWA;
- Assist in determining practicable short-term controls in non-routine maintenance or construction related activities where noise emission may be a concern;
- Audit environmental noise levels for compliance with the requirements of the department of environment; and
- Address concerns arising from the workforce where increased noise levels or exposures are perceived.

9.1 Types of noise assessment

The procedures used for the measurement of noise will depend upon the type of noise assessment required. These types may depend on the type of workplace, the location and type of noise source, the noise characteristics, work patterns, and how the information collected is to be used.

9.1.1 General workplace noise exposure

An assessment of employee exposure to noise is necessary where exposure to excessive noise is known, or is likely, to occur.

There are three (3) types of assessment:

Area Noise Surveys

An area noise survey is a screening process for noise exposures where results from spot readings can be used to determine the need for a more complete evaluation. Area monitoring can be used to estimate noise exposure when the noise levels are relatively constant and employees are not mobile. In workplaces where employees move about in different areas or where the noise intensity tends to

fluctuate over time, noise exposure is generally more accurately estimated by the personal monitoring approach.

This assessment is required to document the noise environment, or changes to the noise environment, and to establish whether or not the workplace is considered to contain excessive noise.

Personal noise dosimetry

Personal noise dosimetry follows on from the preliminary assessment when the likelihood of exposure to excessive noise in an area is identified. Each employee likely to be exposed to the excessive noise shall be monitored. The results will presented as a Le_a, 8-hr or LEA,T and L_{eak} for each employee and compared to the OELs (ACGIH TLVs). The assessment also shall provide information for future engineering control measures as well as for the selection of hearing protection.

Follow-up assessments

The Preliminary and Detailed Assessments are to be followed by other assessments as necessary to document the current status of exposures in a workplace. Follow up assessments can be Five Year assessment and Supplementary assessments.

9.2 Assessment for engineering noise reduction considerations

These are required where noise assessments indicate the likelihood of exposure to excessive noise. Further investigations are needed to identify the source of the noise and to determine priorities for noise reduction.

9.3 Assessment for personal hearing protection selection

This assessment is necessary when excessive noise levels are indicated and employees are required to wear personal hearing protection as part of the noise management program. Assessments of this type require the use of dosimeters to identify a specific worker's noise exposure.

The information obtained shall be used to ensure the selection of personal hearing protection devices that provide attenuation appropriate to the sound characteristics and level. Calculation of sound attenuation requirements is to be in accordance with recognized standards.

9.4 Instrumentation – sound level meters

For all instrumentation, the manufacturer's operating instructions must be followed where relevant.

An integrating—averaging sound level meter, Type 1, is the preferred instrument for noise measurements, however, a Type 2 may be used except in situations marginally above or below the exposure standards. Type 3 instruments are only to be used for preliminary measurements.

Note: Octave band filters fitted to the SLM must comply with the Type 1 requirements according to ANSI S1.4 or IEC 61672-1.

The measurements are to be LA_{eq},T or EA,T, during a representative time interval T and L_{peak}.

Measurements may be personal or static, depending on measurement requirements. However, personal monitoring rather than static monitoring must be used for defining potential employee exposures.

All measurements are to be recorded on the Noise Survey Forms in Appendix 4.

9.4.1 Microphones

Some SLMs are supplied with a variety of microphones. Where the microphone is detachable it is possible to:

- Use an extension cable or rod.
- Fit either a ‘free-field’ or ‘pressure type’ microphone to optimize measurement accuracy according to sound field type.
- Fit microphones of different diameters to optimize frequency range, sensitivity or the internal noise level of the SLM.

Where a selection of microphones is available, consult the manufacturer’s instructions to determine the correct microphone for the noise measurement requirements.

9.4.2 Accessories

The following accessories are those most frequently used in noise measurement work. They are intended as aids where the normal measurement capability of the SLM may be reduced due to existing environmental conditions. The use of these accessories when they are not required can negatively affect the accuracy of the measurement.

Windscreens

Air currents produced by fast moving vehicles and wind can affect the performance of the microphone resulting in a low frequency ‘wind generated noise’. The use of a good quality windscreen can reduce this so the measurement reflects the noise level and characteristics under investigation. However, when a windscreen is fitted to a microphone, it tends to change the middle to higher frequencies being measured. This can lead to inaccuracies of several decibels in the final measurement.

Extension rods and cables

The presence of the observer’s body and the SLM, under certain circumstances, can modify the sound field existing at the measurement location. This may result in significant errors to the noise measurements. For optimum accuracy of results the microphone should be extended so the observer and SLM are not interfering significantly with the sound field.

Extension cables can vary between 15 cm and 50 cm in length. However, an extension cable is not always practicable. In these cases an extension rod or goose neck rod may be an alternative.

The extension rod or cable accessories must be those supplied by the manufacturer for the SLM and microphone to be used, and correction factors will occur.

Factors affecting reliability of measurement

The use of integrating instruments requires additional care when determining measurement parameters and taking measurements. This is because integrating instruments incorporate all the sound signals recorded, independent of the sound origin or the time of occurrence, into the final measurement.

Environmental factors

Permissible environmental conditions will be listed in the manufacturer’s handbook and should be checked prior to using the SLM where conditions may be doubtful. In particular the microphone can be damaged in unfavorable environments resulting in expensive repairs as well as affecting the reliability of the results. Environmental factors that can affect the operation of SLM include:

- Gross or rapid temperature changes between environments;
- High humidity and moisture, especially from rain or salt water spray;
- Corrosive liquids and atmospheres;
- Dust, oil and grease;

- Wind;
- Vibration of the SLM; and
- Electric and magnetic fields.

Other factors

Factors that can occur during the measurement (integration) time period that can invalidate results include:

- Undue force operating the start/stop controls when using a short integration time; and
- The signal going above or below the selected measurement range for a significant part of the integration time.

A preliminary study of expected noise levels is advisable before taking actual measurements. This will assist in determining an integration time period appropriate to the time scale of the event being investigated.

9.4.3 Prevention of overloading SLM amplifier during measurements

The operation of the SLM requires setting of the range and weighting. Though these functions are independently set, they are inter-related during measurement. Incorrect selection of these settings may result in an overload of the SLM amplifier leading to incorrect measurements.

Overloading is most likely where:

- There are strong low frequency components in the noise being measured, subsequently reduced by an a weighting setting; or
- Where the noise may be too impulsive in character for the particular SLM being used.

To minimize a potential overload occurring, a preliminary assessment of the noise characteristics using a linear or C weighted setting should be made before measuring in the A weighted setting. Weighted levels measured on a range setting substantially below that recorded for the linear frequency or C weighted response should NOT BE USED.

Where an overload meter is fitted to the SLM, the attenuation should be increased to the higher range until indication of the overload disappears.

9.4.4 Calibration of instrumentation

To ensure reliability of the results the SLM must be checked to determine that measurement performance is within specifications. There are two checks required:

- Complete internal calibration; and
- Field (acoustic) calibration checks.

Complete laboratory calibration

Before the use of a new SLM and from then on, at a minimum of every 2 years, a complete calibration must be performed on the SLM by an accredited testing Laboratory. This includes the calibration of the microphone, Octave Band Filter and Field Calibrator.

Where the measurements to be taken require the SLM to be calibrated to manufacturer's certification then any accessories to be used e.g. extension cables, rods must be included for calibration. The date of the most recent calibration must be recorded on a label attached to each instrument.

Field (acoustic) calibration checks

The setting of the reference level of measuring instruments shall be checked using a calibrated sound reference source. This check must be carried out according to manufacturer instructions. This must be conducted:

- Immediately BEFORE and AFTER a sequence of measurements;
- AFTER the instrument has been switched 'On' and BEFORE being switched 'Off'; and
- Approximately every 30 minutes where the SLM is used for an extended time, unless being used for a continuous integrating measurement.

If a discrepancy of more than $\pm$ 0.5 dB in the reference level, or, $\pm$ 10% in the reference noise exposure reading is found between TWO successive checks, then the measurements taken in between the two checks shall be considered invalid.

Note: The sensitivity of microphones and calibrators is generally dependent on the ambient temperature and air pressure. If a variation outside these limits cannot be explained by temperature and pressure considerations, then faulty operation of the SLM should be suspected and results rejected.

Limitations to field calibration checks

Most calibrators check for one frequency and one sound pressure level. This does not guarantee that the SLM is operating correctly at other frequencies and sound pressure levels. Checks for other frequencies and sound pressure levels can be conducted as required using a range of calibrators.

Storage of instrumentation and accessories

SLM and accessories must be stored according to the manufacturer's instructions. Generally, this requires a clean, dry environment where the instruments are not subject to extremes of humidity, temperature or vibration, or to dust and chemicals.

For extended storage, batteries must be removed to prevent leakage and instrument corrosion.

9.5 Instrumentation – noise dosimeters

Noise dosimeters are used for determining an employee's noise exposure while performing their work. The employee wears the instrument for the measuring period.

Dosimeters are already preset to the parameters for measuring noise exposure over the time period the instrument is in use. Two types of dosimeters may be used - sealed units with microphone contained in the dosimeter that are attached the lapel or dosimeter-and-microphone models.

Where a dosimeter is to be worn by an employee during their work there may be intended or non-intended misuse of the instrumentation. This may result in incorrect measurements being obtained. Therefore, the employee shall be advised not to:

- Clap near, or speak loudly into, the microphone;
- Remove the microphone from where it is positioned;
- Remove the dosimeter and microphone and place in either a quiet or a noisy location;
- Adjust controls; or
- Interfere with the microphone or else cover or shield the microphone from noise sources, for instance through clothing adjustments or by personal protective equipment.

Where there is concern that interference may occur measurements should be taken over several days to ensure the results are reliable.

9.5.1 Procedures for dosimetry

- Calibrate the dosimeter according to the manufacturer's instructions.
- Fit the tamper proof covering or else lock the keypad.
- Place the dosimeter on the employee's lapel, belt or in a pocket.
- Attach the microphone, if required, to the employee's collar.
- Pin the microphone lead to their clothing so it will not hinder their work, or catch.
- Advise employee of instructions for wearing the device, and a contact number if needed.
- Record details on the dosimetry field data sheet Appendix 4.
- Check with the employee an hour into the measurement period if possible and note their work activities and environmental conditions.
- Check from then on every 2 hours as able.
- At end of measurement period remove the dosimeter, unlock the keypad, check the calibration and record the details.
- Discuss any immediate findings with the employee.
- Download information from the dosimeter at the earliest convenience after monitoring.

9.5.2 Dosimeter use as an SLM

Some dosimeters may be used for measuring general workplace noise. Refer to the manufacturer's handbook to determine suitability of the dosimeter for this application. There may be restrictions to the precision of the instrument which affect its reliability for this use.

9.6 Conducting a noise assessment

9.6.1 Considerations for the time period of the noise measurement

The occupational noise exposure of an employee comprises all noise to which they are exposed to at work e.g. machinery, radios, warnings, reversing sirens, communication systems and external noise entering the workplace. All measurements are quantitative and, therefore, are to be representative of the noise exposure the employee would normally receive during the work. Worst case noise exposure should also be evaluated if possible.

Where an employee works at more than one work location noise assessment for each of the differing work locations, or for the employees occupying these work locations, need to be conducted. This enables the determination of the cumulative (daily) noise exposure during the work shift from the summation of the partial noise exposure received when carrying out each task. Measurement time intervals are to be chosen so that all significant variations of noise levels in the workplace are taken into account. The time interval should either be for the duration of the work period or shift, or, if for a representative portion, for sufficient time to obtain a stabilized reading within $\pm$ 0.5 dB.

Where the noise exposure may vary on a daily basis, several measurements will need to be taken to get a representative exposure profile.

The following THREE measurement times may be used to determine representative noise exposure. Noise exposure may be measured:

- Over the TOTAL work shift—to determine the total noise exposure directly.
- For PART of the work shift—must be representative of noise exposure for the entire shift.
- For different noise level exposures—to determine the partial noise exposure values, to then be adjusted to the full working day to provide the total daily noise exposure.

Any of the above methods may be extended to several work shifts.

The measurement duration shall take into account any fluctuations or cyclic nature of the noise level. Where the noise has a pronounced cyclic nature, the minimum measurement period is to be over two cycles.

9.6.2 Fitting microphone and accessories

- Ensure power is 'Off'.
- Discharge any static electricity buildup, especially if in a dry atmosphere.
- Assemble microphones, extensions and adaptors ONLY when they are at the same temperature as the SLM.
- Do not over tighten fittings; light finger torque is adequate.
- If applicable, fit the external Octave Band filter.

9.6.3 Internal and microphone calibration checks

If an internal reference is provided, perform the check according to manufacturer's instructions.

- Couple the field calibrator to the microphone.
- Ensure range, time weighting and frequency weighting settings applicable for the field calibrator tests are set on the SLM.
- Switch on the calibrator and allow the reading to stabilize.
- Make adjustments as required to adjust the gain of the SLM.
- Uncouple the field calibrator from the microphone.

Note: Regular checks on calibration will be required where the measurement period extends for longer than 30 minutes.

All calibration checks are to be recorded on field data sheet.

9.6.4 Microphone positions

The reference direction of the microphone shall be in accordance with the manufacturer's instruction depending on whether the microphone is a 'pressure response' or 'free field' type. The actual positioning of the microphone is to be determined according to work requirements.

<u>Employee in their work location</u>

The microphone is to be located whenever practicable, approximately 10 cm but not more than 20 cm horizontally from the entrance of the external ear canal of the ear receiving the highest noise level.

Locating the microphone on top of the shoulder is acceptable providing the microphone does not interfere with personal protective equipment, or where clothing needs to be changed during the measurement period.

Employee not available at the work location

The microphone is to be positioned approximately where the employee's head would be expected to be when performing the work.

If the head position cannot be well defined, the following microphone heights are to be used:

- For standing employee work positions: 1.5 m above the ground on which the employee would normally be standing; or
- For seated employee work positions: 0.8 m above the middle of the seat plane with seat set at, or as near as possible to the midpoint of its horizontal and vertical adjustment.

Static monitoring

The microphone position will depend upon the survey purpose. Refer to the previous information or the manufacturer's instructions for guidance.

9.6.5 Using a windscreen

Fit windscreen over microphone only if required by the existing environmental conditions. It is advisable to avoid using a windscreen where:

- Air movement is not involved; or
- Wind speeds are low and the sound pressure is high.

If the measurements are for non-statutory purposes where there are no legal implications, a windscreen may be used in the following situations.

- In gusty wind conditions where the wind speed is above 5 m/s.
- As a protective measure against dust or rain.
- Where the windscreen effects a significant reduction in SLM overload.
- Where the manufacturer's information states that the frequency response of the microphone is not significantly affected by use of a windscreen.

9.6.6 Correction factors for extension rods and cables

Correction factors supplied by the manufacturer to correct the effect of using an extension should be applied to the results. Alternatively, the manufacturer may accept recalibration of the SLM with the extension connected.

9.6.7 Batteries

For some measurements integrating instruments need to be used for long periods, in particular for personal dosimetry. To ensure the reliability of the instrument, the battery condition and life must be checked prior to the start of the measuring period. Where the battery life is not known, or the battery indicator on the instrument indicates that the battery may fail during the measurement period, fresh batteries should be used. When in doubt, replace the batteries.

Battery check

- Set the range selector control to the highest range position.

- Turn on the power.
- Check the battery voltage and change batteries if they would not have adequate life for the measurement period, in particular for dosimetry. When in doubt, replace with fresh batteries. Note: Turn off power before changing batteries.
- Allow 30 seconds for the instrument to stabilize.

9.6.8 Checks during operation

Calibration and battery voltage checks must be performed regularly unless the check would interfere with an integrating measurement, and at the completion of measurements. Intervals of 30 minutes for calibration checks and 2 hours for battery checks are recommended as a guide.

Re-calibration is required when batteries are replaced.

9.7 Noise measurement definitions

9.7.1 Measurement of LA_{eq},T

In practice the sound pressure level experienced by a worker is rarely constant because sound varies or workers move. To take this into account the term equivalent noise level (or average sound level) is used to indicate the level of steady sound that has the same energy as that experienced by the worker, over a given time period.

ACGIH TLV for LA_{eq},8 is 85dB(A).

- 'L_{eq}' equivalent noise level.
- 'A' is the frequency weighting.
- 'T' time weighting in hours.
- Measurement quantity dB (A).

9.7.2 Measurement of EA,T

EA,T is noise exposure. It is defined as "the time integral of the squared, instantaneous A-weighted sound pressure over a particular time period". For practical purposes a noise exposure of 1.0 Pa2h corresponds to LA_{eq}, T of 85 dB(A).

- 'E' is the noise exposure.
- 'A' is the frequency weighting.
- 'T' time weighting in hours.
- Measurement quantity Pa2h.

If the time period is short, more accurate measurements can be made using the accelerated count rate setting of the dosimeter.

9.7.3 Measurement of Lpeak

It is defined as "10 times the logarithm (base 10) of the ratio of the square of the maximum instantaneous sound pressure to the square of the reference sound pressure (20μPa)". For peak noise the ACGIH TLV is a C-weighted peak sound pressure level.

- ACGIH TLV $LC_{,peak}$ is 140 dB(C).

- 'L_{peak}' is the peak sound pressure level.
- 'C' is the frequency weighting.
- Measurement quantity dB (C).

9.7.4 Measurement of impulse noise

Use the settings recommended in the manufacturer's instructions.

9.8 Noise exposure calculations

9.8.1 Determination of noise exposures

The preferred method of measurement for LA_{eq},T and EA,T is to use an integrating averaging SLM to measure the LA_{eq},T during the time interval T.

9.8.2 Normalizing noise exposures to an 8 hour working day

Where the working day is other than 8 hours the LA_{eq},T can for this time period can be normalized to that exposure for an 8 hour by use of the calculation:

LAeq,8 = 10 log 10 (EA,T / 3.2 x 10–9) or,

LAeq,8 = LA_{eq},T + 10 log10 (T / 8)

In addition to this correction shift lengths of 10 hours or more require the adjustments given in Table 9.1. For example for a shift length of 11 hours:

LAeq,8h = LA_{eq} + $10\log^{10}$ [T/8] + 1

Table 9.1. Adjustments to normalized exposure level LA_{eq},8h for extended work shifts.

Shift Length (hours)	Adjustments to LA_{eq},8h (dB)
<10	+0
≥10 to <14	+1
≥14 to <20	+2
≥20	+3

9.8.3 Corrections for background noise

The measurement of noise from any source will generally include background noise. Where it is necessary to determine the noise only from the source, the level of background noise will need to be measured when the noise source of interest is not operating.

The observer should also attempt to determine if any fluctuations in background noise levels occur, and measure these as well. This may require a subjective determination. Fluctuations can also arise from changes in wind conditions.

To adjust the source/background noise measurement to determine noise attributed to the noise source only, then the correction is made according to Table 4.2.

Table 9.2 Corrections of Background Levels

Difference between level measured with sound source operating and background level when source not operating (dB)	Correction to be subtracted from level measured with sound source operating. This provides the level from the sound source alone (dB)
5	2
6 to 9	1
10 or more	0

9.9 Procedures for noise reduction

9.9.1 Procedures for assessment of engineering noise reduction considerations

Engineering controls require changes to equipment or processes to reduce or eliminate noise: e.g. changing a procedure from using nails and a hammer to screws and a screw driver; or using insulation.

Where a likely exposure to excessive noise is identified, further investigations are needed to identify the source(s) of noise and the priorities for noise reduction. It is preferable that the assessor be competent in both noise assessment AND has appropriate expertise in noise engineering controls. Therefore, this work may need to be contracted to noise engineering specialists.

9.9.2 Procedures for measurements for selection of hearing protective devices (HPD)

There are several methods that may be used to select appropriate hearing protection. KAUST has adopted the Noise Reduction Rating (NRR) and Classification System.

Noise Reduction Rating (NRR)

The NRR is a scale that summarizes a hearing protection device's performance. NRR is labelled on every HPD. To calculate for noise reduction, HPD is subtracted from the C-weighted average noise level (over an 8-h period) to obtain the A-weighted noise level at the users ear. Where only the A-weighted average noise level is available, the NRR value for a HPD, minus 7 dB, is subtracted from the A-weighted average noise level to obtain the A-weighted noise level at the user's ear.

In the field, actual noise reduction by hearing protection devices is much less than in the lab, therefore NRRs should be adjusted from the manufacturers' claims:

- Earmuffs: Subtract 25% from the manufacturer's labelled NRR
- Foam earplugs: Subtract 50% from the manufacturer's labelled NRR
- Molded (custom) earplugs: Subtract 70% from the manufacturer's labelled NRR

Effective Noise Level (when worn) = Workplace noise level in dBA - (adjusted NRR - 7) (NIOSH Adjusted)

For example:	Measured workplace noise level	= 104 dBA
	Peltor Optime II earmuffs NRR	= 31
	Adjusted NRR	= 0.25 x 31 = 7.75
		= 31 – 7.75 = 23.25
	Effective noise level when worn	= 104 - (23.25 - 7)
		= 87.75 dBA

Classification System

To use this method only the $LA_{eq},8$ value to which the wearer is exposed needs to be known. Hearing protection is assigned using Table 9.3: from the $LA_{eq},8$ value a corresponding class in column 2 is obtained. Care must be taken to not over protect the employee as problems with isolation of the individual may occur.

Table 9.3. For the selection of hearing protection according to the classification method using a noise exposure standard of 85 dB(A).

$LA_{eq,8}$ dB(A)	Class
< 90	1
90 to <95	2
95 to <100	3
100 to <105	4
105 to <110	5
≥110	Seek specialist advice

Octave-band method

If the LAeq,8 is ≥110 dB (A) or the noise is tonal then the octave-band method for selecting hearing protection must be used. Real-ear attenuation testing is required. This provides a mean attenuation with SD in a range of octave-band center frequencies (125, 250, 500, 1000, 2000, 40000 and 8000Hz). Approximately 80% of the subjects tested received protection of at least the mean minus SD of the measured values.

To select appropriate hearing protection the 'octave-band method' of noise assessment must be used to assess the noise level in a workplace at each octave-band center frequency, over a representative time period T. A hearing protector is then selected from the real-ear attenuation testing mean minus SD data subtracted from the measured noise levels. This provides an attenuated noise level at each octave-band center frequency. Each noise level is then corrected using the A-weighting. Finally the A-weighted octave-band levels are combined:

$$Lp\ dB(A) = 10 \log 10 \left[10^{Lp1/10} + 10^{Lp2/10} + \ldots \right]$$

to give a predicted A-weighted noise exposure that 80% of the population would have protected exposures less than or equal to.

For the lower frequency octave bands 'space averaging' is required. This necessitates moving the SLM through an arc at arm's length to take into consideration possible sound pressure variations due to standing waves.

9.10 Reporting of results

All noise measurements and details relating to the measurements are to be recorded on the appropriate Field Data Sheet. The details must be recorded at the time of the measurements to ensure accurate reporting and that all details are provided.

9.10.1 Communications with employees involved in noise measurements

Depending on the reason for initiating the noise survey, some employees may be concerned as to why noise measurements are being conducted. When conducting any monitoring it is necessary to advise the employees to be monitored, and those in the work area who may observe the monitoring activities, why the monitoring is being carried out and to the distribution of results and report. In addition it is

necessary to be open with the noise measurements and to discuss these measurements and their implications with them at the time.

10 Heat Stress Assessment

10.1 General

Heat or thermal stress, the physical stress of hot environments, can be influenced by a combination of factors, such as the type of clothing you wear, physical activity, time spent working, breaks between work activity, medications you may be taking, and environmental factors such as ambient air temperature, air velocity, and relative humidity. There may be brief periods of hot weather that can lead to uncomfortable working conditions, and possibly, heat stress for laboratory personnel on the surface. In addition, heat and humidity may intensify during the summer months in along the coastal areas of Saudi Arabia. A mild or moderate heat stress (i.e., office environments) may cause discomfort, but it is rarely harmful to health. However, as the heat stress approaches human tolerance limits (e.g., exterior work on hot days), the risk of heat-related disorders increases. This section is intended to provide guidance to supervisors and workers on how to recognize and control heat stress in office environments or while working outdoors.

10.2 Recognizing Heat-Related Disorders

Laboratory and office personnel heat complaints provide good cues for the recognition of thermal stress issues in the workplace, particularly when working outdoors. Managers are encouraged to obtain feedback from employees and contractors on their working conditions during periods of hot weather.

Heat-related disorders can be caused by prolonged periods of heat stress. Listed below are some common heat-related disorders, including their symptoms.

10.2.1 Heat Stroke

Heat stroke is the most severe of the heat-related disorders. Heat stroke is a life-threatening emergency that requires immediate medical attention. Heat stroke is more likely to occur in outdoor work. Symptoms include:

- No perspiration on skin
- Hot, red, or flushed skin
- High body temperature, 105° or above
- Rapid pulse
- Difficulty breathing
- Constricted pupils
- High blood pressure
- Headache or dizziness
- Confusion or disorientation
- Weakness
- Nausea or vomiting
- Seizures

10.2.2 Heat Exhaustion

Heat exhaustion occurs when your body's ability to regulate body temperature is overwhelmed but not completely broken down. Symptoms include:

- Clammy, cool, moist, and pale skin
- Fatigue and weakness
- Heavy perspiration
- Intense thirst from dehydration
- Low to normal blood pressure
- Anxiety or agitation
- Clouded senses or impaired judgment
- Fainting or loss of coordination
- Loss of appetite
- Nausea or vomiting
- Rapid breathing
- Slightly low oral temperature

10.2.3 Heat Syncope

Heat syncope is a fainting (syncope) episode or dizziness that usually occurs with prolonged standing or sudden rising from a sitting or lying position. Factors that may contribute to heat syncope include dehydration and lack of acclimatization. Symptoms include:

- Fainting (short duration)
- Dizziness
- Light-headedness during prolonged standing or suddenly rising from a sitting or lying position

10.2.4 Heat Cramps

Heat cramps usually affect workers who sweat a lot during strenuous activity. This sweating depletes the body's salt and moisture levels. Low salt levels in muscles causes painful cramps. Heat cramps may also be a symptom of heat exhaustion. Symptoms include:

- Muscle cramps, pain, or spasms in the abdomen, arms, or legs
- Heavy sweating during strenuous activity

10.2.5 Heat Rash

Heat rash is a skin irritation caused by excessive sweating during hot, humid weather. Symptoms include:

- Looks like red cluster of pimples or small blisters
- Usually appears on the neck, upper chest, groin, under the breasts, and in elbow creases

10.3 Methods for assessing heat stress

There are several methods for assessing the heat stress experienced by an individual or SEG including assessing the work load, environmental factors and dehydration. Heat stress measurement is complicated by the variety of factors that influence an individual's likelihood of ill health. There are, however, some useful methods described below, which are based on urine properties, acclimatization, assessments of tasks, environmental conditions and the heat stress meter.

10.4 Hydration

Hydration testing is a process to determine if the employee is dehydrated by lack of water in the body to function optimally. Hydration assessment can be performed by urine color and specific gravity of urine.

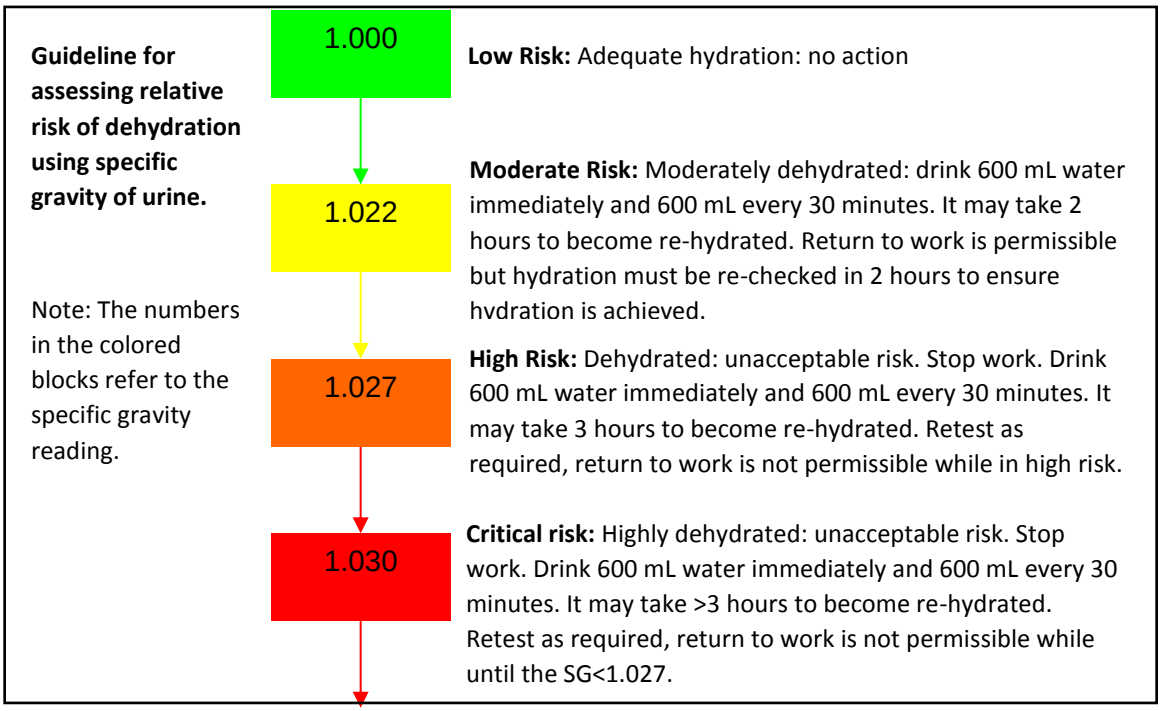
10.4.1 Urine color

Urine color charts are a useful indicator of dehydration. A darker urine color indicates dehydration. Some caution is required since urine color is affected by some dehydrating liquids, such as coffee, cola and alcohol. Urine color will also turn yellow by some colored agents, such as Vitamin B. See **Appendix 7 – Urine Color Chart** for the color chart. It is also difficult to estimate urine color from the toilet bowl and individuals may believe themselves to be more hydrated than they actually are.

10.4.2 Specific gravity of urine

The specific gravity (SG) of urine is an excellent indicator of hydration as it is a measure of the amount of water in the urine relative to other substances. Specific gravity can be measured using 'dip stick' or a 'refractometer'. The SG of an employee's urine can be correlated with work rate and liquid consumption details to assist in the management of heat stress. Use the guidance chart below (Figure 10.1) as an indicator of risk and action.

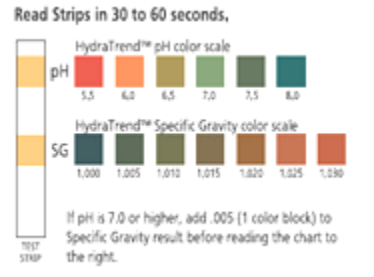
Figure 10.1 Risk levels for urine specific gravity levels and management tools.



Source: Casa, DJ, Armstrong, LE, Hillman, SK, Montain, SJ, Reiff, RV, Rich, BSE (2000). National Athletic Trainers association Position Statement: Fluid replacement for athletes. Journal of Athletic Training, 35(2); pp. 212 - 224.

10.4.3 Dip sticks

Test strips (e.g. Hydratrend, Intect 7, Multistix 10SG) are available through medical suppliers, and are also used during the triage drug testing process. They are a convenient, easy-to-use test strips testing device that, amongst other things, tests the SG to aid in the detection of common attempts to defeat a urine drug test such as dilution or adulteration of the specimen.



To use simply:

1. Decide which of the two ways will be used to collect the sample: either in the sample collection cup or by passing the test strip through a urine stream. If you choose to use the urine stream method, skip to step 3.
2. Collect fresh urine in a clean, dry container and mix well before testing.
3. Remove 1 strip from the container and re-seal container.
4. Dip the reagent strip in the urine sample or pass through the urine stream for 2 seconds and remove immediately, while removing run back of strip over rim of container to remove excess urine.
5. Keep horizontal and turn the reagent strip on its side to allow excess urine to drip on a paper towel, without mixing adjacent reagent areas.
6. Lay the strip horizontally on top of a paper towel for a specific amount of time, check the instructions for your strips.
7. Hold strip close to the SG color chart and compare the test areas with color blocks.

Dip sticks are not accurate and it should be recognized that the refractometer is a more accurate device and has lower levels of uncertainty associated with it. However, its value lies in the fact that it is a simple quick tool for individuals to use.

10.4.4 Refractometers

A more accurate measurement for urine specific gravity can performed using a hand-held digital refractometer. An example is the "Pocket" Urine Specific Gravity Refractometer PAL-10S manufactured by Atago. To operate, simply place a drop of urine on the prism top and press the "Start" key. Then, the urine S.G. value will be displayed on the LCD instantly.

Figure 10.1 - Atago “Pocket” Urine Specific Gravity Refractometer PAL-10S

10.5 Acclimatization

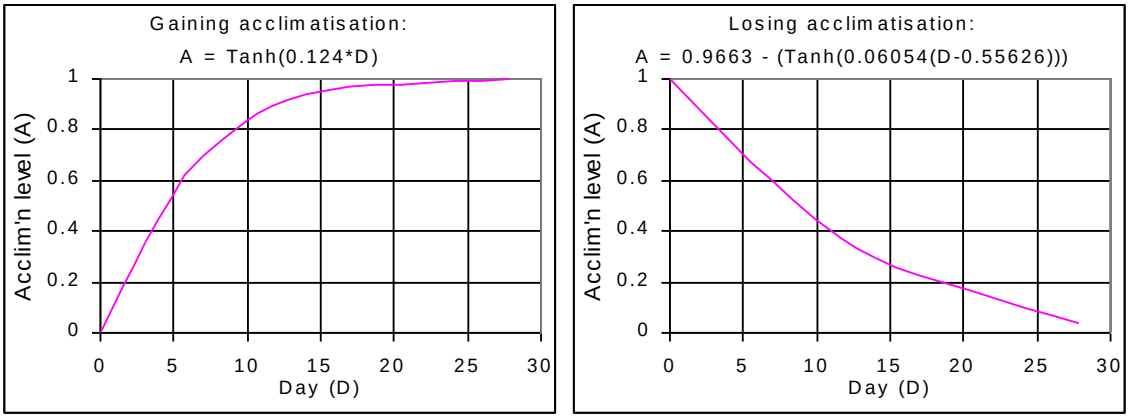
10.5.1 Background

Acclimatization is the process of adaptation that the body goes through to adjust to new environmental conditions: it is a long-term adjustment of an individual to a stressor. Acclimatization is such that an acclimatized person can perform many tasks in a hot and humid work site without adverse health effects where a non-acclimatized person cannot work. In essence, repeated exposure to heat will increase the body's tolerance to thermal stressors allowing individuals to work in conditions that would otherwise be difficult or impossible to tolerate.

Full acclimatization to heat depends on individual factors but usually takes approximately 2 weeks; although 50% can be achieved in as little as 5 days (see Figure 5.3). Heat illness is more likely in the first 5 days of acclimatization.

An individual should be deemed un-acclimatized if they come from climates cooler than the Pilbara (e.g. Perth), if they have been on vacation for more than 1 week or if they have been off work sick for an extended period. Those individuals on Fly-in-fly-out rosters will also lose some acclimatization during their time off (see Figure 5.3). However, they still retain approximately 50% acclimatization after 7 days in a cooler climate.

Figure 10.2. The rates of gaining and loosing acclimatization



10.5.2 Facilitation of acclimatization

The health advisor or hygienist must assess an individual risk before preparing a schedule for reducing risk and aiding acclimatization. This section provides facts details on how individuals may be managed but it is up to the professional judgement of the health advisor or hygienist as to what activities will best suit an individual. Seek advice if required.

To facilitate acclimatization:

- Always drink plenty of water, up to 600 mL per ½ hour for strenuous activities;
- Do not work alone;
- Schedule as many hot activities as practical for the coolest part of the day (early morning or late afternoon);

- Minimize heat exposure by taking advantage of natural or mechanical ventilation (increased air velocities up to 5 mph increase the rate of evaporation and thus the rate of heat loss from the body) and heat shields when applicable;
- Take rest breaks at frequent, regular intervals, preferably in a cool environment sheltered from direct sunlight (the worker may be required to self-pace in this respect);
- Wear clothing that is permeable to air and loose fitting, as long as a risk assessment does not identify the risk of entanglement; and
- Anyone experiencing extreme heat discomfort should rest immediately.

A work schedule for acclimatization was proposed by the U.S. National Institute for Occupational Safety and Health (NIOSH). For new workers, the schedule should be no more than a 20% exposure on day 1 and an increase of no more than 20% on each additional day (See Table 10.1). At other times the employee can reduce the workload or seek alternative cooler placements. If this schedule is not achievable then the worker must be strictly managed according to the points listed above.

Table 10.1. A work schedule for the acclimatisation of new workers.

First Day	**20% exposure**
Second Day	**40% exposure**
Third Day	**60% exposure**
Fourth Day	**80% exposure**
Fifth Day	**100% exposure**

Source: NIOSH Acclimatization (https://www.cdc.gov/niosh/topics/heatstress/acclima.html)

Acclimatized workers who return after nine or more consecutive calendar days of leave, should undergo a four-day acclimatization schedule (see Table 10.2).

Table 10.2. A work schedule for the acclimatisation of returning workers.

First Day	**50% exposure**
Second Day	**60% exposure**
Third Day	**80% exposure**
Fourth Day	**100% exposure**

The risks associated with un-acclimatized new and returning workers are given in Table 10.3.

Table 10.3. The risks associated with un-acclimatized new and returning workers.

	No. of days acclimatized when assessed		
Heat stress risk	**High**	**Medium**	**Low**
New worker	0 to 4	5 to 9	≥ 10
Returning worker	0 to 2	3 to 4	≥ 5

10.6 Heat Stress Monitoring Equipment

The heat stress monitors measure environmental parameters and uses an algorithm based on human data to determine the maximum rate of work that can be maintained for hydrated and acclimatized workers. Typical heat stress monitors measure the following environmental parameters:

- Dry bulb;

- Wet bulb;
- Globe temperatures;
- Wind speed; and
- Atmospheric pressure.

Examples of heat stress monitors include Romteck Heat Stress Monitor (HSM) which also measures the Thermal Work Limit (TWL) index and TSI QUESTemp 34 measures the WGBT index values which can combine with relative humidity measurements to calculate Humidex and Heat Index.

Figure 10.3. Romteck Heat Stress Monitor

Figure 10.4. TSI QUESTemp 34

10.7 Heat Stress Indices

10.7.1 Wet Bulb Globe Temperature (WBGT) Index

The environmental parameters typically measured to identify heat stress are dry bulb (ta) temperature (air temperature), natural wet bulb (t_{nw}) temperature, globe temperature (t_g), air velocity and humidity.

From three of these readings an initial indicator of heat stress, the wet bulb globe temperature (WBGT) index, can be calculated. It is important to note that the WBGT can be calculated via two different formulae depending on the application. These are:

- For inside buildings and outside buildings without a solar load.

  $WBGT = 0.7t_{nw} + 0.3t_g$

- Outside buildings with a solar load.

  $WBGT = 0.7t_{nw} + 0.2t_g + 0.1t_a$

To calculate the WBGT for continuous all-day or several hour exposures, use the average WBGT over a 60-minute period. For intermittent exposures or exposures at different heat levels throughout a workday, average the temperature over a 60 to 120-minute period, depending on the exposure duration. The average WBGT ($WBGT_{avg}$) is calculated using the following equation:

$$WBGT_{avg} = \frac{(WBGT_1)(t_1) + (WBGT_2)(t_2) + \ldots + (WBGT_n)(t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where t_n = time in minutes

Using a meter to measure WBGT while physically at the worksite after a heat-related incident could provide an accurate localized perspective on the probability that there was a heat hazard during the incident. For example, WBGT measurement will capture radiant heat and wind reduction impacts from worksite structures or heat sources that historic weather from a remote location may not represent.

Consider the following when measuring WBGT post incident to determine the potential heat hazards at the time of an incident:

- Measure WBGT at the same time of day and in the same locations where the affected worker was working, resting, and treated, if possible. Consider recreating the worksite setup if structures or protection measures like tents were moved since the incident.
- Take into account weather condition differences on the day WBGT is measured versus the day the incident happened. For example, if conditions are cooler, windier, cloudier, and the WBGT measured indicates a heat hazard is present, it is likely there was a heat hazard present the day of the incident.
- Consider comparing post-incident WBGT measurements to WBGT measurements taken the day of the incident, if available, to qualify data available at the time of the incident.

Add Clothing Adjustment Factor (CAF) to Determine WBGT Effective

Identify the ACGIH CAF based on the clothing workers are wearing from Table 10.4. Add the CAF to the WBGT to determine $WBGT_{eff}$.

Table 10.4. Clothing Adjustment Factors

Clothing Worn	CAF
Work clothes (long sleeves and pants). Examples: Standard cotton shirt/pants.	0
Coveralls (w/only underwear underneath). Examples: Cotton or light polyester material.	0
Double-layer woven clothing.	3
SMS Polypropylene Coveralls	0.5

Polyolefin coveralls. Examples: Micro-porous fabric (e.g., Tyvek™).	1
Limited-use vapor-barrier coveralls. Examples: Encapsulating suits, whole-body chemical protective suites, firefighter turn-out gear.	11

Source: ACGIH "2017 TLVs and BEIs" TABLE 1

The ACGIH provide additional detail on the use of the WBGT and limit values (TLV's) based on the WBGT index. The specified TLV's refer to heat stress conditions under which it is believed that nearly all adequately hydrated, un-medicated, healthy workers, wearing light weight summer clothing may be repeatedly exposed without adverse health effects. In most standards (including ACGIH), maintenance of the core body temperature below 38˚C is the criteria for ensuring no adverse health effects, although some consider this value conservative.

The WBGT index is recognized as being very conservative. The recommended TLV values believed to delineate acceptable from non-acceptable thermal environments should be treated with caution, particularly in the tropics and arid areas; they should only be used as 'screening' values in an initial heat stress assessment. As the result, it is not recommended as the only index to be used to assess outdoor workers.

Table 10.5. TLV WBGT Index below is used as a screening tool to determine the environmental contribution to heat stress in outdoor environments. The temperatures listed in this table take into consideration air temperature, radiant heat, and humidity (web bulb globe temperature [WBGT] Index. In situations where the indoor air temperatures exceed 29.5°C (85°F), supervisors are responsible for exercising their judgment in modifying their employees' work schedules, workloads, etc.

Table 10.5. ACGIH TLV WBGT Index

ACGIH Screening Criteria for Heat Stress Exposure (WBGT values in °C) for 8 hour work day five days per week with conventional breaks								
Allocation of Work in a Work/Rest Cycle	Acclimatized				Action Limit (Unacclimatized)			
	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
75-100%	31.0	28.0	--	--	28.0	25.0	--	--
50-75%	31.0	29.0	27.5	--	28.5	26.0	24.0	--
25-50%	32.0	30.0	29.0	28.0	29.5	27.0	25.5	24.5
0-25%	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

Notes:

- Assumes 8-hour workdays in a 5-day workweek with conventional breaks.
- TLVs assume that workers exposed to these conditions are adequately hydrated, are not taking medication, are wearing lightweight clothing, and are in generally good health.

10.7.2 Thermal Work Limit (TWL) Index

Thermal Work Limit (TWL) is defined as the limiting (or maximum) sustainable metabolic rate that hydrated, acclimatized individuals can maintain in a specific thermal environment, within a safe deep body core temperature (<38.2˚C or 100.8˚F) and sweat rate (< 1.2 kg/hr). The index is designed specifically for self-paced workers and does not rely on estimation of actual metabolic rates. Work areas are measured and categorized based on a metabolic heat balance equation, using environmental parameters such as dry bulb, wet bulb and air movement to measure air-cooling power.

With the inclusion of clothing factors it can predict a safe maximum continuously sustainable metabolic rate (W m-2) for the conditions being assessed. At high values of TWL, (220 Wm-2) the thermal conditions impose no limits on work with some adjustment of work rate required, as the values increase above 115 Wm-2, adequately hydrated self-paced workers will be able to manage the thermal stress with varying levels of controls. As the TWL gets progressively lower, heat storage is likely to occur and TWL can then be used to predict safe work rest-cycle schedules. At very low values (<115 Wm-2), no useful work rate may be sustained and hence work should cease. These limits are provided in more detail in Table 10.6 below.

Table 10.6. TWL Limit

TWL limit ($W.m^{-2}$)	Name of Limit/Zone	Interventions
<115 (or DB > 44^0 C or WB > 32^0 C)	Withdrawal	• No ordinary work allowed. • Work only allowed in a safety emergency or to rectify environmental conditions. • Permit to Work in Heat must be completed and authorised by manager *beforehand*. • Dehydration test at end of shift. • Personal water bottle (4 litre capacity) must be on the job at all times
115 to 140	Buffer	• Rectify ventilation or redeploy workers if possible. • No person to work alone. • No unacclimatised person to work. • If work does continue, a Corrective Action Request must be completed and signed by the manager within 48 hrs. • Wind speed must be increased to at least 0.5 $m.s^{-1}$. • Dehydration test at end of shift. • Personal water bottle (4 litre capacity) must be on the job at all times
140 to 220	Acclimatis-ation	• Acclimatised persons allowed to work, but not alone • Personal water bottle (4 litre capacity) must be on the job at all times
>220	Unrestricted	• No limits on work due to thermal stress

Source: Brake, D., Bates, GP (2002), Limiting Metabolic Rate (Thermal Work Limit) as an Index of Thermal Stress. App. Occ. & Env. Hyg, 1521-0898, 17(3): Pages 176 – 186.

Work Rest Cycle

When the continuous workload exceeds the TWL, even with adequate fluid replacement, heat storage will limit work time because heat balance cannot be achieved. This means that workers who continuously work in these environments will raise their core body temperature above 38ºC requiring the work-rest cycling schedules to be instigated. Using the TWLs for an individual's work and rest areas it can be determined how long they can safely work in a given environment before their core temperature will begin to rise, and how long they need to rest in order to restore their heat balance.

Data have been calculated for the "average individual" that provide a physiological way of determining the period of time until an individual's core temperature will begin to increase. The duration of rest breaks assumes no work is undertaken during the rest period and unrestricted self-paced work assumes usual work/rest practices are maintained. The data are given in Table 10.6 below.

Table 10.6. Work-rest cycling for given work and rest environments.

TWL in work area	Work levels permitted	Maximum work time before rest is required (minutes)	Rest period (mins) in rest area with TWLs of:			
			115	140	180	220
55	1	42	50	35	23	17
	2	26				
85	1	78				
	2	36				
115	1	543				
	2	60				
	3	32				
130	1	No work limit				
	2	90	50	35	23	17
	3	39				
160	1	No work limit				
	2	No work limit				
	3	68	50	35	23	17
200	1	No work limit				
	2	No work limit				
	3	No work limit				
>220	1, 2, 3, 4	No work limit				

Note that when using the WBGT and TWL indices as limiting values, the limits are only appropriate for workers who:

- Have been screened for intolerance to heat, are in good health and are fit for the activity being considered (see 'Controlling Exposure' section);
- Have been properly instructed in the details of their work tasks and the potential effects and signs and symptoms of heat stress;
- Are able to self-pace their work;
- Are under some degree of supervision (minimally a buddy system); and
- Are not wearing special clothing that restricts sweat evaporation or heat loss.

10.8 Heat stress risk assessment

The workplace air temperature conditions should be measured at regular intervals and whenever there are changes in engineering controls and production methods. The nature and degree of exposure to high temperature can be determined by conducting both workplace and/or personal monitoring. Although the latter is preferred, the former is often the more practical. Fixed-place climatic monitoring should be conducted where workers are most often working. A structured assessment protocol is the best approach, with the flexibility to meet the occasion. A recommended method would be as follows:

1) A walk-through survey carrying out a basic heat stress risk assessment (ask workers what the hottest jobs are), and possibly incorporating a simple index (e.g. WBGT, TWL, etc.). Note that work / rest regimes should not be considered at this point – the aim is simply to determine if there is a potential problem. If there is, implement general heat stress exposure controls (see Section 10.9);
2) If a potential problem is indicated from the initial step, then progress to a second level of assessment (e.g. Thermal Work Limit (TWL) or Wet Bulb Globe Temperature (WBGT)), to enable a more comprehensive investigation of the situation and general environment. Ensure to take into account factors such as air velocity, humidity, clothing, metabolic load, posture and acclimatization. A rational index is recommended. The aim is to determine the practicability of job-specific heat stress exposure controls (see Section 10.9); and
3) Where the allowable exposure time is determined to be less than 30 minutes or there is an involvement of high level PPE, some form of physiological monitoring should be employed, and rational indices used (WBGT or TWL) on an iterative basis to determine the most appropriate control method. The indices should be used as a 'comparative' tool only.

The WBGT has in the past been used as an industry standard metric for assessing the level of heat stress within a given environment, and is detailed by ACGIH documentation, or by ISO 7243. It has been a common measure of exposure. The WBGT index was developed to provide a method that could be easily used in an industrial setting to allow for a simple calculation and quick result, providing a compromise between a precise index and the need for a fast diagnosis. It is therefore best used to estimate whether or not a problem exists by identifying whether reference values are exceeded. If this occurs, the more advanced Standard (ISO 7933) should be used to provide a more accurate estimation of stress.

The TWL index is intended to predict the risk of heat disorders from climate characteristics, the clothing of the workers and their average metabolic work rate, using predicted responses of the body such as sweating and elevated core temperature. To extend the usefulness of the indices, the thermal characteristics (i.e. insulation effect) of a variety of protective clothing combinations has been included in the calculation. The index assumes light clothing is worn (e.g. cotton clothing or cotton/polyester blends), and assumes the body responds similarly in all persons working under the same conditions.

WBGT is a direct index whereas TWL is so called rational index. Direct indices are similar to empirical indices in that they are measurements originating from an instrument with a similar response to humans. The rational indices are normally based on the human heat balance equation and attempt to model various important physiological parameters that indicate heat strain.

Note that there are many different monitoring methods for heat stress, and that they are continually being refined. HSE has developed a basic risk assessment for heat stress, which is provided in **Appendix 5 – Heat Stress Assessment.**

It is important to note that no single index can accurately account for the numerous variables associated with heat stress assessment and for that reason they should only be used as guidelines, not safe/unsafe limits. Different thermal indices are suitable for different thermal and work conditions, and all have some limitations in terms of their ability to predict human response to the environment. The most appropriate method of addressing heat stress issues is by directing most effort to controlling and managing the high-risk issues.

10.9 Management of Heat Stress

Self-awareness is one of the key steps to reducing heat-related disorders. Employees and supervisors should terminate exposure to heat stress at the onset of the first symptoms. Supervisors should consider a worker's physical condition when determining heat stress conditions. Obesity, lack of conditioning, medical conditions, use of medications, pregnancy, and inadequate rest can increase susceptibility to heat stress even in indoor office environments.

10.9.1 Hydration

Dehydration is a major factor in reducing an effective work limit and is the most important control measure.

The worker must be adequately hydrated to work. If the worker is not adequately hydrated the risk assessment cannot continue. People who are moderately dehydrated (USG <1.027) are allowed to continue working but with the condition that they rehydrate themselves and get tested after 2 hours to ensure the hydration management is working.

Required fluid intake to maintain hydration during work

Once an individual is hydrated they must remain so by drinking sufficient and the correct fluids. At high workloads and /or high thermal stress, sweat rates exceed 1.2L/hr. Increasing fluid intake at this level and above is not practical because of gastric discomfort (the upper limit for gastric emptying and fluid absorption is approximately 1.5L/hr). Therefore to aid successful re-hydration, fluid replacement is required to be little and often.

The hydration management tool also uses TWL and an individual's continuous workload to determine specific fluid replacement to manage the thermal stress risk. Reduced hydration is a major factor in reducing this safe work rate and has been estimated to reduce the effective work limit by up to 20%.

If using TWL results, individuals can ascertain how much fluid they should be drinking to replace what they are losing through sweat. The data are given in Table 5.6 below.

Table 10.7. Required Fluid Intake to Maintain Hydration during Work

Work area TWL	Fluid replacement per 30 minutes (in mL)			
	Continuous work level			
	Level 1	Level 2	Level 3	Level 4
≤115	600*	600*	600*	600*
116-140	500-600	600*	600*	600*
141-180	400-500	500-600	600*	600*
181-220	250-400	400-600	500-600	600*
≥200	150-250	250-400	400-500	500-600

* Maximum absorption rate

What to drink

Water is the best choice as individuals will normally get sufficient salt intake from the food they eat. When people work hard they lose little magnesium in sweat, although they do loose sodium, potassium and iron (note that iron can be a problem when women menstruating, they can become anemic) and with excessive work it is possible that an individual may become depleted in some ions.

When someone is severely dehydrated and not getting enough sodium from their diet they become hyponatremia. The lack of sodium in the blood means that the potassium is instead leached from the cells leading to hyperkalemia. In addition to this, because potassium comes out of the cells it has to be replaced by another ion, so H+ goes into the cells, causing acidosis. Hence it is important that if individuals are carrying out heavy work that electrolytes lost in sweat are ingested.

To rebalance the bodies' electrolytes it is recommended that individuals who are at risk of hyponatremia alternate consumption of water with an electrolyte replacement drink.

It is recommended that for every 1 L of water 1 L of Aqualyte is consumed.

Aqualyte is recommended over any other electrolyte replacement drink do to:

- Hypotonic, that is, the water in the drink enters the body rapidly through osmosis (more rapidly than water). Some drinks are isotonic, this means that the electrolytes are in equilibrium with the body, which in turn means that there is no osmotic effect to push the water from the drink into the body: while the drink will be absorbed fairly rapidly it absorbs at a slower rate than hypotonic drinks. Other drinks are hypertonic, this means that they have higher electrolyte concentrations than the body, hence when they enter the gut they will actually remove water from the body, causing further dehydration (examples are cola, coffee and alcohol). These products are diuretics.
- Contain those electrolytes that are lost through sweating. Other electrolytes, vitamins and minerals are not required as the fluid only needs to rehydrate and replace what is being lost through sweating. Individuals need to be responsible for eating nutritionally balanced meals themselves, and not relying on drinks.
- Very low in sugar, only containing enough to make it hypotonic (without some sugar it becomes slower to absorb).

Higher calorie drinks, such as cordials and some electrolyte replacements, can result in excessive calorie intakes when large fluid volumes are required per day; in some instances calorie in-take from these drinks alone could be as much as 10,000 calories (daily intake should be approximately 2500 to 3000).

10.9.2 Engineering controls

Engineering controls are the most effective means of reducing excessive heat exposure. The examples which follow illustrate some engineering approaches to reducing heat exposure.

- Reducing metabolic heat production (heat produced by the body): Automation and mechanization of tasks minimize the need for heavy physical work and the resulting buildup of body heat.
- Reducing the radiant heat emission from hot surfaces: Covering hot surfaces with sheets of low emissivity material such as aluminum or paint that reduces the amount of heat radiated from this hot surface into the workplace.
- Insulating hot surfaces: Insulation reduces the heat exchange between the source of heat and the work environment.

- Shielding: Shields stop radiated heat from reaching work stations. Two types of shields can be used. Stainless steel, aluminum or other bright metal surfaces reflect heat back towards the source. Absorbent shields, such as a water-cooled jackets made of black-surfaced aluminum, can effectively absorb and carry away heat.
- Ventilation and air conditioning: Ventilation, localized air conditioning, and cooled observation booths are commonly used to provide cool work stations. Cooled observation booths allow workers to cool down after brief periods of intense heat exposure while still allowing them to monitor equipment.
- Reducing the humidity: Air conditioning, dehumidification, and elimination of open hot water baths, drains, and leaky steam valves help reduce humidity.

10.9.3 Administrative controls

Administrative controls are also effective means of reducing excessive heat exposure. The examples which follow illustrate some administrative approaches to reducing heat exposure.

- Acclimatization: Allow sufficient acclimatization period before full workload.
- Duration of work: Managing working time in risk area by the use of breaks, manipulation of working hours, personnel rotation where possible and ease of work load.
- Hydration testing before, during and after work for high-risk outdoor work activities.
- Buddy system: Ensure that no work is carried out alone.
- Training: Adequate training and induction including on the signs and symptoms of heat stress, preventative measures and emergency procedures should be regularly given.
- Pace of work: Requirement for self-paced working and encourage co-worker observation to detect signs and symptoms in others. Encourage regular breaks in cool rest areas.
- Supervision: Regular supervision to monitor for signs and symptoms of individuals exposed to hazardous thermal conditions.
- Water: Provision of cool drinking water close to the working site and encouragement to drink water approximately every 15 minutes. If electrolytes are to be added to the water they should be done so sparingly and decreased as acclimatization is reached.
- Self-reporting system: Encourage self-reporting of illness, medication and alcohol/caffeine intake that may influence susceptibility to heat stress.
- Wellbeing: Encourage healthy lifestyles including diet and healthy body weight.
- First aid and medical care: Define emergency procedures. Assign one person trained in first aid to each work shift. Train workers in recognition of symptoms of heat exposure.

10.9.4 Personal Protective Equipment (PPE)

PPE is always the last line of defense, however, it is certainly recommended that employees are “sun smart” by wearing wide brimmed hats, sun cream and long-sleeved, light-weight shirts that still allow heat to dissipate. The use of ice vests or other PPE such as may also be utilized in certain situations after a review has been completed.

It is noted that wearing of PPE for other hazards (respirators, disposable Tyvek suits, etc.) could also contribute to heat load and risk assessment may be warranted.

11 Vibration Assessment

11.1 Purpose of a vibration assessment

The purpose of a vibration assessment is to protect the health of people at work by ensuring that vibration exposure is limited to the lowest practicable level. This is achieved by monitoring worker's potential exposure and controlling vibration to levels that won't adversely affect their health.

The level of vibration of equipment used in the workplace should be measured or assessed at regular intervals and whenever there are changes in equipment used or production methods. The various standards mentioned above provide methods for measuring the various forms of vibration. Note that most countries have based their method of monitoring on ISO 2631 and ISO 5349.

11.2 Types of vibration for assessment

Vibration is a term used to describe oscillatory movement in one or more planes around a static position. It commonly involves 'hand-transmitted vibration' and 'whole body vibration' (via a seat or the floor). Assessments are, therefore, based upon these two exposures.

11.2.1 Hand-arm vibration

Hand-arm vibrations (HAV) are mechanical vibrations transmitted via the hands and affect only or mainly the hand-arm system. Hand-arm vibrations are for instance caused by hand-held electrical or pneumatic tools including hedge trimmers and the like.

Health hazards depend on the site of impact, the intensity of exposure and daily recurrence of exposure over years.

Hand-arm vibrations impair subjective perception, fine motor skills and performance, and may, after years of exposure, cause:

- Circulation disorders;
- Nerve function disorders;
- Muscular tissue changes; or
- Bone and joint damage.

Exposure to high-frequency vibrations over years may lead to circulation disorders in the fingers: workers may suffer periodic attacks in which the fingers become white and numb (white finger or hand-arm vibration syndrome). The condition is also known as vibration-induced vasospastic syndrome. Intense low-frequency hand-arm vibrations may also cause degenerative changes of the hand bones, finger joints and wrists as well as the elbow and shoulder regions. The condition is painful and may impair mobility.

In addition, lunate necrosis and/or fatigue fractures may occur in the region of the carpal bones.

Working in a cold environment increases the risk for these conditions.

11.2.2 Whole-body vibration

Exposure to whole-body vibration (WBV), particularly to large shocks and jolts, is a back-pain health risk for employees who work on machine platforms, drive mobile machines or other work vehicles over poor surfaces as a main part of their job.

Risks may also exist where industrial trucks are used to transport materials, e.g. in factories, depots, warehouses and docks, particularly where the surfaces the trucks travel on are in poor condition or the drivers use poor driving techniques. Vehicles such as vans, lorries and buses, which are normally driven on well-maintained public roads, may also expose their drivers to some WBV, but the levels are likely to be relatively low and therefore the likelihood of related health risks is low.

Exceedance of the action level by operators exposes them to a significant risk of long-term health impairment including:

- Impair the senses and may lead to balance disorders, kinetoses or visual disturbances;
- Impair fine motor skills or reduce performance;
- Cause stomach troubles; or
- Affect the spine.

11.3 Instrumentation – Accelerometer

An accelerometer is the most common instrument for measuring vibration. It is an electromechanical transducer that produces a voltage signal that is proportional to the acceleration that it is subjected to.

11.3.1 Triaxial accelerometer

For whole body measurements, a triaxial accelerometer is used to evaluate vibration in different directions and at different frequencies. The triaxial accelerometer is molded into a rubber pad that can be positioned at the point of excitement, whether that means that a worker sits on the pad or puts it behind his back or it is placed on the floor with a brick over it to ensure good contact of the triaxial accelerometer with the floor. Figure 11.1 below is an example of triaxial accelerometer for whole body and hand vibration measurements.

11.4 Instrumentation – Dosimeters

Dosimeters are new to the market place, with their development being very recent.

11.4.1 Whole-body vibration Dosimeter

The whole body vibration (WBV) dosimeter will continuously measure, evaluate and log workers' exposure to whole body vibration in the field. A whole fleet of vehicles can easily be scanned very quickly. A whole body vibration dosimeter can assess the following parameters:

- Weighted acceleration levels in m/s², usually expressed as weighted rms values. This provides for a number representing an average acceleration integrated over a certain time period (most commonly measured);
- Weighted Maximum Peak Acceleration levels, which provide information on shock loads that would otherwise be lost in the rms acceleration levels. This is particularly significant with equipment that often encounters rough conditions, and usually has inadequate suspension or poor seating;
- Crest Factor (CF), which helps to define the roughness of a particular ride. This is the ratio of the weighted peak acceleration level to its corresponding weighted rms value;
- Vibration Dose Value (VDV) in m/s1.75, defined as the relation between vibration magnitude and duration. It has the advantages that it is not limited to low crest factor motions and it may be applied to intermittent vibration exposures, to repeated shocks and also to those exposures consisting of periods of vibration at different magnitudes; and
- Spinal Response Dose (acceleration peaks to the power of 6), which is converted to an equivalent static stress in the spine. Results are compared to a Caution Stress (0.5Mpa; <0.5 is low probability of health effects from lifetime exposure) and a Limit Stress (0.8Mpa; >0.8 is high probability of health effects from lifetime exposure).

11.4.2 Hand-arm vibration Dosimeter

A hand-arm vibration dosimeter will measure vibration dosage in accordance with current standards. It is wireless, and is worn between the fingers while operating power machinery. It can be worn inside a work glove without problems.

11.5 Conducting a vibration assessment

The European Parliament and Council Directive for vibration states that the "level of exposure to mechanical vibration may be assessed by means of observation of specific working practices and reference to relevant information on the probable magnitude of the vibration corresponding to the equipment or the types of equipment used in the particular conditions of use, including such information provided by the manufacturer of the equipment."

Therefore, it is often more practical to conduct assessments using known vibration levels of equipment or tools.

11.5.1 Identifying sources of vibration

When commencing an assessment you must first identify what will produce vibrations that may be harmful to workers. A generic list of equipment that was perceived to cause high levels of vibration, was compiled and prioritized through a subjective evaluation is provided in Table 11.1 below.

Table 11.1. Generic HAV and WBV Levels

Hand-arm Vibration (HAV)	
Dominant axis frequency weighted vibration acceleration	
Hand tool	**$A_{h,w}$ m/s²**
Rock drill	32

Concrete breaker (jack hammer)	19
Needle gun	16
Pedestal grinder	12
Chipping hammer	12
Hammer drill	11
Chain saw	10
Pneumatic wrench	10
Hand-held compactor	10
Nut runner	3.5-6.1
Hand-held sander	6.0
Hand-held portable grinder	5.3
Impact wrench	5.0
Metal saw	4.9
Jig saw	4.2
Impact screwdriver	4.0
Drill re-collaring machine	3.7
Metal drill	3.0
Roof bolter	2.8
Drill sharpening machine	2.5
Router	2.1
Floor polisher	2.0
Whole-body Vibration (WBV)	
Frequency weighted vibration accelerations for vertical vibration on seat	
Vehicles	**$A_{h,w}$ m/s^2**
Off-road vehicle	1.5
High-speed boat	1.5
Loader	1.2
Road roller	1.0
Forklift truck	0.9
Bulldozer	0.75-2.0
Grader	0.75
Dump truck	0.75

Van	0.7
Mower	0.65
Excavator	0.6
Bus	0.6
Vibratory road compactor	0.55
Car	0.5
Mobile crane	0.3

Note: Representative frequency weighted vibration accelerations ($a_{h,w}$ values; in meters per second squared (m/s^2), root-mean squared (rms)).

11.5.2 Vibration databases

Manufacturers should be able to supply such information on vibration levels for specific equipment or tools, or some information is held by the National Institute for Working Life (NIWL). For older equipment a database of generic vibration levels could be used for a risk assessment. The NIWL, in Sweden, hosts a hand-arm vibration database and a whole-body vibration database.

Hand-arm vibration database

http://umetech.niwl.se/eng/havhome.lasso

The database contains vibration data for more than 2000 hand-held power tools, either CE-declared values (i.e., vibration measured in accordance with corresponding parts of the ISO 8662 standard) or measured according to ISO 5349 during normal operation at a work site. As little or as much information can be inserted into the search to specifically or generically identify a hand tool. An example of the information obtained from the database is given below.

Whole-body vibration database

http://umetech.niwl.se/eng/wbvhome.lasso

The database contains vibration levels measured during working conditions in accordance with ISO 2631. The number of vehicles in the database is about 60. The database will later be complemented with vibration levels measured in other categories of vehicles (e.g., busses, lorries, fork-lift trucks, forestry machines, etc.). As little or as much information can be inserted into the search to specifically or generically identify a vehicle. An example of the information obtained from the database is given below.

11.6 Assessing the risk from vibration

KAUST has adopted the ACGIH TLVs for the hand-transmitted and whole-body vibration exposure limits. Based on the advice given by Rio Tinto regarding vibration doses (see Section 1.9), the assigned vibration level can be compared to an action level of 2.5 m/s^2 (8-hr) for hand-transmitted vibration and 0.5 m/s^2 (8-hr) for whole-body vibration. If values are above these action levels then vibration and health surveillance is recommended.

Table 11.2. ACGIH TLVs – Hand-transmitted Vibration Limits

ACGIH Threshold Limit Values (TLVs)	
Total Daily Exposure Duration	Maximum value of the frequency weighted acceleration
4 to less than 8 hours	4 m/s^2
2 to less than 4 hours	6 m/s^2
1 to less than 2 hours	8 m/s^2
Less than 1 hour	12 m/s^2

Table 11.3 ACGIH TLVs – Whole-body Vibration Limits

Standard	Limit Values (likely health risk)	Action Values (caution)
ACGIH	A(8) = 0.9 m/s^2	A(8) = 0.5 m/s^2
ISO 2631-1	VDV = 17 $m/s^{1.75}$	VDV = 8.5 $m/s^{1.75}$

11.7 Vibration Controls

11.7.1 Anti-Vibration Tools

Tools can be designed or mounted in ways that help reduce the vibration level. For example, using anti-vibration chain saws reduces acceleration levels by a factor of about 10. These types of chain saws must be well maintained. Maintenance must include periodic replacement of shock absorbers. Some pneumatic tool companies manufacture anti-vibration tools such as anti-vibration pneumatic chipping hammers, pavement breakers and vibration-damped pneumatic riveting guns.

11.7.2 Anti-Vibration Gloves

Conventional protective gloves (e.g., cotton, leather), commonly used by workers, do not reduce the vibration that is transferred to workers' hands when they are using vibrating tools or equipment. Anti-vibration gloves are made using a layer of viscoelastic material. Actual measurements have shown that such gloves have limited effectiveness. When the vibration hazard cannot be removed or controlled adequately, Personal Protective Equipment (PPE) such as anti-vibration gloves may be used.

11.7.3 Safe Work Practices

Along with using anti-vibration tools and gloves, workers can reduce the risk of hand-arm vibration syndrome (HAVS) by following work practices:

- Use a minimum strength hand grip that still allows the safe operation of the tool or process.
- Wear sufficient clothing, including gloves, to keep warm.
- Avoid continuous exposure by taking rest periods.
- Rest the tool on the work piece whenever practical.
- Do not use faulty tools.
- Maintain tools properly. Tools that are worn, blunt or out of alignment will vibrate more.

- Consult a doctor at the first sign of vibration disease and ask about the possibility of changing to a job with less exposure.

11.7.4 Education and Training

Training programs are an effective means of heightening the awareness of HAVS in the workplace. Training should include proper use and maintain vibrating tools to avoid unnecessary exposure to vibration. Vibrating machines and equipment often produce loud noise as well. Therefore, training and education in controlling vibration should also address concerns about noise control.

11.7.5 Whole-Body Vibration

The following precautions help to reduce whole-body vibration exposure:

- Limit the time spent by workers on a vibrating surface.
- Mechanically isolate the vibrating source or surface to reduce exposure.
- Ensure that equipment is well maintained to avoid excessive vibration.
- Install vibration damping seats.

The vibration control design is an intricate engineering problem and must be set up by qualified professionals. Many factors specific to the individual work station govern the choice of the vibration isolation material and the machine mounting methods.

11.8 Reporting Results

The results of the vibration assessment need to be forwarded to the site/ area safety manager detailing the risks associated with the hand tool or vehicle in use. If generic vibration levels are determined as being above the action levels then the recommendation must be that a more detailed vibration assessment must be carried out using accelerometers and health surveillance must be conducted for those employees potentially at risk.

11.9 Health Surveillance

11.9.1 Hand-Arm Vibration

According to ISO 5349-1, health surveillance has an important preventative function. Qualified health professionals should conduct the following for those with regular exposure to hand-transmitted vibration:

- Prior physical examination, with records of any previous harm;
- Advise on the risk of exposure to hand-transmitted vibration to those who use vibrating equipment;
- Raynaud's disease or phenomenon (if present, person should not be exposed to hand-transmitted vibration);
- Disease caused by impairment of blood circulation to the hands;
- Past injuries to the hand causing circulatory defects or deformity of bones and joints;
- Disorders of the peripheral nervous system;
- Disorders of the musculoskeletal system.

Regular medical check-ups of those at risk. The use of the 'Stockholm Workshop' scales is recommended. Guidelines for medical examination are provided in the UK HSE publication 'Hand-Arm Vibration' while there is an ISO standard for measurement of vibrotactile perception at the fingertips.

11.9.2 Whole-Body Vibration

For whole-body vibration exposure, it may be useful for qualified health professionals to question workers as to whether they have experienced vibration-related health complaints such as:

- Headaches;
- Motion sickness;
- Stomach complaints;
- Spinal disorders;
- Numbness and clumsiness of the fingers; and/or
- Traces of blood in the urine.

12 Portable Gas Detection Instrument Calibration

This Section has been compiled for the purpose of ensuring uniformity of approach to calibrating personal, portable continuous and tube-type gas detectors. Fixed gas detection equipment is not included in the scope of this document and is contained within the KAUST TGM System Guidelines.

12.1 Scope

Gas detectors are designed to alert workers to toxic gases, as well as oxygen-deficient and combustible atmospheres that may exist in their workplace environments, such as permit-required confined spaces, manholes, and other enclosed spaces.

Instrument inaccuracy due to improper or irregular maintenance and calibration can lead to exposure to hazardous levels of toxic gases or to an oxygen-deficient atmosphere. This exposure can cause workers to suffer serious injuries or illness, and even death. Flammable gas explosions are often catastrophic, resulting in worker injuries and death, or destruction of property.

The best way to verify that a portable gas meter detects gas accurately and reliably is to test it with a known concentration of gas. This guideline will verify whether the sensors in the instrument respond accurately and whether the alarms function properly.

12.2 Roles and Responsibilities

12.2.1 Managers/Supervisors

- Ensure adequate gas detection equipment is available at the worksite.
- Provide employees with training in the use and maintenance of gas detection equipment.
- Regularly review function test (bump test) and calibration records to verify compliance with this process.
- Ensure calibration check or full calibration is performed per manufacturer’s instructions.

12.2.2 Employees/Workers

- Properly select and use gas detection equipment according to the task hazards.
- Always conduct a function test (‘bump test’) prior to use.
- Use and maintain the gas detection equipment in accordance with this process and the applicable manufacturer’s instructions.

12.3 Calibration Drift and Causes

When an instrument's reference point shifts, the reading will shift accordingly and be unreliable. This is called "calibration drift," and it happens to all sensors over time. An instrument that experiences calibration drift can still measure the quantity of gas present, but it cannot convert this information into an accurate numerical reading. Calibration checks or full calibration with a traceable gas concentration will verify or update the instrument's reference point. Operators should conduct these procedures daily, or more frequently if needed, to ensure that the instrument will continue to produce accurate readings.

Calibration drift occurs most often because of:

- Degradation caused by exposure to phosphates

- Degradation of phosphorus-containing components
- Degradation of lead-containing components
- Gradual chemical degradation of sensors and drift in electronic components that occur normally over time.
- Use in extreme environmental conditions, such as high/low temperature and humidity, and high levels of airborne particulates.
- Exposure to high concentrations of the target gases and vapors.
- Exposure of catalytic hot-bead LEL sensors in the instruments to volatile silicones, hydride gases, halogenated hydrocarbons, and sulfide gases.
- Exposure of electrochemical toxic gas sensors to solvent vapors and highly corrosive gases.
- Handling/jostling of the equipment causing enough vibration or shock over time to affect electronic components and circuitry.

Operators must validate a portable gas detector's operability when any of these conditions occurs, or is suspected, during use. When attempting to calibrate an instrument after exposure to these conditions, the sensor often will either display a failure message or will not allow the operator to fully adjust the display reading. Harsh operating and storage conditions can affect instrument performance, leading to inaccurate readings or even failure. While a gas detector may appear undamaged during visual inspection, it actually could be damaged internally. At this point, the operator should replace the damaged sensor or have qualified personnel service the sensor. Be sure to follow the manufacturer's instructions regarding sensor replacement and servicing.

12.4 Portable Gas Detectors Alarms

The primary reason for proper, regular instrument calibration is to provide accurate gas-concentration readings that could prevent worker illness, injury, or death. Correctly calibrating an instrument helps to ensure that the gas detectors will respond accurately to the gases it is designed to detect, thereby warning users of hazardous conditions before the conditions reach dangerous levels. Most gas detectors have two levels of alarms – warning and danger. The warning alarm alerts the operator and workers that the work environment has a detectable elevated concentration of toxic gas and is, therefore, potentially hazardous. The danger alarm indicates that the toxic-gas concentration exceeds the programmed hazard threshold, and that the toxic gas in the work area is above the warning level and approaching a hazardous level. Whether a gas detector provides a warning or danger alarm at the proper concentration depends on its detection capabilities, its ability to translate its findings into an accurate reading, and the presence of interfering gases (see "Calibration Drift and Causes" above).

12.5 Safe Operating Practices

12.5.1 Approved Portable Gas Detectors

- Approved gas detection devices include personal gas detectors, portable continuous gas detectors and tube-type detectors.
- Personal gas detection devices must not be used for operations requiring portable continuous gas detection devices.
- Equipment designed and engineered to be attached to a personal monitor converting the detector to an aspirated, continuous detector will be deemed acceptable if used in accordance with the manufacturer’s directions.

- The attachment must be used with a separate personal gas detection device from those being used by the workers.
- Portable continuous gas detection devices must be able to provide continuous atmospheric readings and are mandatory in the following circumstances at a minimum:
  - Confined space entry
  - Hot work
  - Purging
  - Other situations as determined by site-specific operating procedures or hazard assessments
- Tube-type detectors may only be used for confirming gas concentrations and not for ongoing monitoring.
- Detector tubes only provide an approximate measure of gas concentrations.
- Readings may take up to one minute to register.
- Accuracy of tubes is ± 25% of the indicated reading.

12.6 Sensors and Set Points

Personal gas detectors, also known as 4-gas meter, must be equipped with the following sensors:

- Combustible gases - Lower Explosive Limit (LEL);
- Oxygen (O_2);
- Hydrogen sulfide (H_2S); and
- Carbon monoxide (CO)

Portable continuous gas detection devices must be equipped with the appropriate sensors for the activities being completed.

Personal gas detectors alarm settings must be set according to local regulations or KAUST requirements. Please contact HSE or an Industrial Hygienist (IH) for consultation. Table 12.1 below provides a default alarm settings for common chemical contaminants.

Table 12.1. Default Portable Gas Detection Instrument Alarm Settings

	Safety/Evacuation		OELs	
Gas	**Low**	**High**	**8-hr TWA**	**STEL (15-minute)**
LEL	10% LEL	20% LEL	N/A	N/A
O_2	19.5% vol.	23.5% vol.	N/A	N/A
CO	25 ppm	50 ppm	35 ppm	200 ppm
H_2S	10 ppm	20 ppm	10 ppm	15 ppm
SO_2	2 ppm	4 ppm	2 ppm	5 ppm
NO_2	3 ppm	6 ppm	3 ppm	5 ppm
Cl_2	5 ppm	1 ppm	0.5 ppm	1 ppm
ClO_2	0.1 ppm	0.2 ppm	0.1 ppm	0.3 ppm
CO_2	2500 ppm	5000 ppm	5000 ppm	30,000 ppm
PH_3	0.15 ppm	0.3 ppm	0.3 ppm	1 ppm

NH_3	25 ppm	50 ppm	25 ppm	35 ppm
HCN	5 ppm	10 ppm	10 ppm	4.7 ppm
NO	12.5 ppm	25 ppm	25 ppm	25 ppm
HCl	2.5 ppm	5 ppm	2.5 ppm	2.5 ppm
H_2	4000 ppm	10,000 ppm	N/A	N/A
CH_4	5000 ppm	12,500 ppm	N/A	N/A
SIH_4	2.5 ppm	5 ppm	5 ppm	5 ppm
C_3H_8	2000 ppm	5000 ppm	1000 ppm	1000 ppm
B_2H_6	0.05 ppm	0.1 ppm	0.1 ppm	0.1 ppm

Note: Personal gas detectors must not be utilized to determine or measure personnel exposure. Time weighted average (TWA) and short-term exposure limit (STEL) settings and alarms, if available on instruments, should not be utilized.

12.7 Bump Testing (Function Testing)

This is a qualitative function check in which a challenge gas is passed over the sensor(s) at a concentration and exposure time sufficient to activate all alarm settings. The purpose of this check is to confirm that gas can get to the sensor(s) and that all the instrument's alarms are functional. The bump test or function check does not provide a measure of the instrument's accuracy. When performing a bump test, the challenge gas concentration should trigger the gas detector's alarm(s). Users of personal/portable gas detector must complete the following:

- To assure functionality, personal and portable continuous gas detectors must be bump tested (function tested) prior to each day's use in accordance with the manufacturer instructions.
- Retain all bump test records in accordance with the record retention guidelines. Records may be kept in electronic or paper formats.
- Personal and portable continuous gas detectors must also be bump tested as soon as is reasonably practicable in the following circumstances:
    - An exposure causes the detector to alarm; or
    - The detector is dropped or exposed to a physical shock.

12.8 Calibration Check and Full Calibration

There are two methods for verifying gas detector accuracy: a calibration check and a full calibration. Each method is appropriate under certain conditions.

12.8.1 Calibration Check

A calibration check verifies that the sensor(s) and alarms respond within the manufacturer's acceptable limits by exposing the instrument to a test gas. The user compares the reading to the test-gas concentration (as indicated on the cylinder containing the test gas). If the instrument's response is within the acceptable range of the test-gas concentration (typically ± 10-20% of the test-gas concentration), then the calibration check verified the instrument's accuracy. The user should "zero" an instrument (reset the reference point, in some cases "zero air" gas may be needed) before conducting the calibration check to ensure that the calibration check results are accurate. When performing a calibration check, the test-gas concentration should be high enough to trigger the instrument's alarm(s).

12.8.2 Full Calibration

If the calibration-check results are not within the acceptable range, the operator should perform a full calibration. A full calibration adjusts the instrument's reading to coincide with a known concentration (i.e., certified standard) of test gas. Test gas used for calibration gas should always be certified using a standard traceable to the National Institute of Standards and Technology (NIST) or any recognized organizations.

Users of personal/portable gas detector must complete the following:

- Calibrate gas detectors as per manufacturer's specifications.
- Retain all calibration records in accordance with the record retention guidelines. Records may be kept in electronic or paper formats.
- Personal and portable continuous gas detectors must also be calibrated in the following circumstances:
    - An over-range occurs on a sensor;
    - The detector fails a bump test; or
    - The monitor is exposed to liquids or condensation.
- Any gas detection device that fails a calibration test or is found to be otherwise defective is to be tagged as out of service and repaired prior to being returned to service.

12.9 When to Perform a Bump Test and When to Perform a Full Calibration

Follow the International Safety Equipment Association (ISEA) position statement on instrument calibration, which states "A bump test . . . or calibration check of portable gas monitors should be conducted before each day's use in accordance with the manufacturer's instructions." If an instrument fails a bump test or a calibration check, the user should perform a full calibration on it before using it. If the instrument fails the full calibration, the employer should remove it from service. Contact the manufacturer for assistance or service.

12.9.1 General Calibration Rules

The following are a few basic calibration rules for personal/portable gas detectors:

- Follow the manufacturer's guidelines for proper calibration. Users cannot perform any job, including gas detector calibration, properly or safely without the right tools. The type and concentration of calibration test gas, sample tubing, flow regulators, and calibration adapters are key links in the calibration chain. Users should conduct any testing to verify the operation of the gas monitor in an environment that is the same as (or similar to) the working conditions (e.g., temperature, humidity, atmospheric pressure).
- Only use a certified traceable test gas, and do so before its expiration date. The instrument can only be as accurate as the test gas used to calibrate it. Be certain that the supplier can provide a certificate of analysis for every test-gas cylinder. The concentration of the test gas, particularly reactive gases such as hydrogen sulfide and chlorine, will only remain stable for a limited period. Never use a test gas after its expiration date.
- Train users on the proper method to perform bump test. Most instruments have detailed instructions provided in the manufacturer's user manual, training videos, or computer-based

training modules. Employers should train and test everyone responsible for performing bump test.

- It is highly recommended that a full calibration be performed by an experienced calibration technician complying with manufacturer's procedures.

12.10 Gas Detection Equipment Usage

- Where personal gas detector are required, the employee/worker must wear the gas detector at all times.
- Wear personal gas detectors near the worker's breathing zone on the outer layer of clothing with the sensors facing outwards. Detectors may be worn within mesh pockets if they are within the breathing zone and do not hinder airflow to the monitor sensors.
- Prior to proceeding with work or building entry, verify non-hazardous atmospheric conditions by following work site entry procedures.
- Under normal operating conditions, it is not expected that combustible or toxic gases are present in detectable concentrations. In these conditions, one may use a personal gas detector to verify the absence of combustible or toxic gas (LEL, H2S, CO, and O2).
- Where portable continuous gas monitoring is required, the necessary equipment and atmospheric testing requirements (i.e., interval or continuous) must be identified on the hazard assessment. Prior to starting work and at the identified frequencies, the readings must be recorded on the hazard assessment.
- Record all atmospheric readings on the file copy of the hazard assessment for audit purposes.
- When a monitor goes into alarm, it is indicating there may be a dangerous environment present.
- The wearer must ensure the work area is evacuated immediately and in a safe manner.
- Work must not continue in the area until the source of the alarm has been identified and controlled.
- Any chemical gas/vapor exposure incident must be reported in Report It System.
- Several cleaners, solvents and lubricants can contaminate and potentially cause permanent damage to the sensors. Make sure to follow manufacturer's procedures for cleaning sensors.

Appendix 1 - Chemical Health Risk Assessment Database

Appendix 2 – IAQ Investigation Form

IAQ Building Occupant Report of Concerns, Page 1 of 3

Use this form to assist in documenting concerns related to indoor air quality and the general indoor environment. Indoor air quality problems include concerns with temperature, humidity, ventilation, odors, or air pollutants that may be causing health or discomfort symptoms. Collect this information via in-person interview, email, or phone interview.

Date:
Facility/Building name:
Address:
Room number/Location:
Name of building occupant: Phone:

Nature of the concern
What is the nature and location of the problem?

Symptoms
What kind of symptoms or discomfort are you experiencing?

Location
Where are you when you experience symptoms or discomfort? How long have you worked in this location?

Where else in the building do you frequent, where do you spend most of your time? Any changes or introduction of new materials/equipment in work environment? If so, collect and review product information and/or safety data sheets (SDS).

Time
When was the problem first experienced?

When does it occur or when is it the worse (time of day, day of week, related to certain activities/events, seasons)?

When do the symptoms go away?

Additional information
Do you have any observations about the building conditions that might need attention or might help explain your symptoms? Do you have any other observations or comments?

Interior Building Walk-Through and Assessment, Page 2 of 3

Building history and information **Date of construction:** **Size of building:** **Type of construction:** **Type of ventilation:**			
Inspection observations	**OK**	**Not OK**	**Notes**
Air quality (odors, stuffiness)			
Signs of occupant discomfort (e.g. heaters, fans)			
Thermal conditions (excessively warm/cold)			
Thermostat setting appropriate for season			
Exhaust fans working and clean			
Air plenums, grills, and ducts (ducts connected, no excessive dirt, odors, no evidence of pests)			
Supply and return air diffusers, present, working, and clean (not blocked or dirty)			
Work area clean and meets housekeeping standards (e.g., minimal dust buildup, no overflowing trash)			
Evidence of pests, pets, stored food in desks, plants			
No moisture damage or visible mold growth			
Floors and carpet (wet, damaged, odors)			
Doors and windows (no leaks or gaps in weather stripping)			
Ceiling tiles (no stains, leaks)			
Drains clear and no standing water			
Chemicals, cleaning, and building material containers stored properly (not leaking, no odors)			
Recent changes in cleaning products			
New paint or other finishes, equipment, carpet of other materials in area			
The following areas are **clean, with no odors, leaks, condensation, moisture buildup on surfaces, visible mold growth, evidence of pests or unprotected openings to the outside.**			
Storage rooms			
Stairwells (e.g. no evidence of smoking, spills, leaks)			
Mechanical and equipment rooms (no leaks or odors; all equipment functioning)			
Other areas:			

List major thermal or contaminant sources in this space (e.g. outdoor sources, equipment, occupant activities, operation and maintenance activities, and housekeeping):

Exterior Building Walk-Through and Assessment, Page 3 of 3

Building/Location: **Date:**

Exterior building and components	OK	Not OK	Notes
Roofs: Leaks, damage			
Walls: Excessive moisture, cracks, signs of damage			
Doors: Condition of weather stripping			
Windows: Good condition			
Rooftop and air handling units: Operating properly, appropriate filters in good condition, outdoor air mix working, fans and belts in good condition, no excessive dirt buildup or condensate pan leaks/biological growth			
Cooling tower: Water treated and no visible color or biological growth Leaks or excessive moisture from overspray on adjacent walls or vents			
Emergency generator: Stack not adjacent to building air intakes, leaks			
Odors: Noticeable odors from outdoors (e.g. roof tar, vehicle exhaust)			
Air intake: Obstructed, bird droppings, or nests			
Pollutant sources: No sources within 25 ft. of air intake (e.g. sanitary vents, loading dock, trash collection area)			
Bird screen(s): Obstructed; nests			

Appendix 3 - Lighting Survey

Ref. no.	Date

MRU	Conducted by
Work area	Approved by
Weather conditions	

Instrument type	Make/model	Serial no.
Calibrated *Yes* *No*	If calibrated, date of calibration	

Location	Accepted lux level AS ……	Lux level reading		Deviation		Action taken or required	Action target date	Action completion date	New lux reading after Action	
		Day	Night*	Day	Night*				Day	Night

*Night readings required if a work area is ocupied during night shift.

Appendix 4 - Noise screening survey

Ref. no.	Date

Survey area		MRU
SPL meter make	Make type	No.
Microphone no.	OBA no.	Calibration no.
Cal readings Start dB	Finish dB	

Item no.	Noise source (Make, model and description)	Operating conditions and processes	Measurement position	L_{Aeq}, T (dB(A))	Peak noise level dB(lin)	Extent of affected area

Appendix 4 - Noise survey

Ref. no.		Date
Survey area		MRU
SPL meter make	Make type	No.
Microphone no.	OBA no.	Calibration no.
Cal readings Start dB	Finish dB	

Item no.	Operating conditions	Sound pressure levels				8 h $L_{eq(A)}$/Time (min)	Sound pressure levels (Octave band Centre frequency (Hz) (dB(lin) L_{eq})										Noise character
		$L_{Aeq}T$	SPL (dB(A))	dB(lin)	(dB(lin)) peak		31.5	63	125	250	500	1k	2k	4k	8k	16k	

Plant which is operating or maintenance which is being caried out around the survey area at the time of the survey can influence the survey reading.

Appendix 4 - Personal noise/dosimetry field data sheet

Monitored by	Date

Surname Given name	Given name	Date of birth
Job title		Shift
MRU	Output team	

Hearing protection worn?	Yes	No	Type	Adequate	Yes	No

Dosimeter make	Model	Serial no.
Calibrator make	Model	Serial no.

TIME DETAILS

Setup no.	Clock	Date
Start	End	Run
Pause	Overload	

DOSE DETAILS

Dose %	Dose 8h%	Pa^2h
8h Pa^2h	Daily exposure	
LEP,d	PSEL	

LEVEL

L_{eq}	>140dB	>115dB
Max L	Max P	SEL

STATS

dB(A)	<65	65	70	75	80	85	90	95	100	105	110	115	120	125
Distributution (%)														

COMMENTS

Appendix 5 – Heat Stress Risk Assessment

Heat Stress can be initially assessed with an estimation of several criteria, work rate and measurements of the ambient conditions or WBGT. This can be measured by using the Quest Temp 34 Meter. The WBGT is not the same as air temperature and utilizes the following sensors:

Dry Bulb thermometer – measures ambient air temperature
Natural Wet Bulb – Considers humidity and wind speed to indicate the effects of humidity on an individual by measuring the amount of evaporative cooling taking place at a thermometer covered with a moistened wick
Globe Thermometer – Gives an indication of the radiant heat exposure on an individual due to either direct light or hot objects in the environment.
Relative Humidity Sensor – measures relative humidity
The following factors also contribute to heat stress and shall be considered as part of the risk assessment:

- Acclimatisation – all persons coming to site after more than a 7 day break are required to do dehydration tests
- Clothing – can have a major effect on the amount of heat gained or lost by the body.
- Work rate – high work rates increase heat production which can cause body temperatures to rise if this heat is not dissipated.

To conduct a Heat Stress Probability Risk Assessment proceed through the following steps utilizing the risk assessment table on the next page:

Step 1: Prior to mobilizing and at the workplace progress through the form and assess the level of risk for each hazard. Ensure this is carried out with personnel working in the area. Add up the points and get a total for 'A'.

Step 2: Assess the level of work rate that you observe. Use the following examples of work rate table to assess the work rates as being low, moderate or high. This will give you the number for 'B'.

Light work	Sitting or standing to control machines; hand and arm work assembly or sorting of light materials
Moderate work	Sustained hand and arm work such as hammering, handling of moderately heavy materials
Heavy work	Pick and shovel work, continuous axe work, and carrying loads up stairs

Step 3: Using a heat stress monitor to establish a WBGT for the area. If you do not have access to this meter then it is still useful to assess the main criteria and utilize the current air temperature. The heat stress index in Appendix 1 can also provide an assessment of risk exposure for the day.
If access is possible the world weather web site gives up to date measurements of temperature for Saudi Arabia and the world which may be of use: https://worldweather.wmo.int/en/home.html

Step 4: List the types of control measures in the area provided under the risk assessment tool you are going to use to reduce the incidence of heat stress. Ensure these control measures are clearly communicated to at-risk employees and implemented at site.

Heat Stress Risk Assessment Form

Task, Environmental and Personal Factors	Task/Program being assessed:		
Section A – Hazard Type	**Assessment Point Value**		
	1	**2**	**3**
Hot surfaces	Contact neutral ☐	Hot on contact ☐	Burn on contact ☐
Exposure period	< 30 min ☐	30 min - 2 hours ☐	> 2 hrs ☐
Task complexity	Simple ☐	Moderate ☐	Complex ☐
Climbing, ascending, descending	None ☐	Moderate ☐	Significant ☐
Distance from cool rest area i.e.: A/C vehicle, caravan	<100 Metres ☐	100 – 1km ☐	>1km ☐
Distance from drinking water	At hand (within 50m) ☐	Close By 50-100 Metres ☐	>100m ☐
Clothing (permeable)	Single layer (light) ☐	Single layer (mod) ☐	Multiple layer or single layer heavy ☐
Humidity	<40% ☐	40-70% ☐	>70% ☐
Air movement	Windy ☐	Some wind ☐	No wind ☐
Fitness	High ☐	Moderate ☐	Low ☐
Acclimatization	Acclimatised ☐	Partly ☐	Un-acclimatised ☐
Understanding of heat strain risk/ experience in conditions	Experienced ☐	Training given/some experience ☐	No training given/ no experience in conditions ☐
SUB-TOTAL A			
Section B -Metabolic work rate* (see below for examples)	**2**	**4**	**6**
	Light ☐	Moderate ☐	Heavy ☐
SUB-TOTAL B			

Section C - WBGT	**1**	**2**	**3**	**4**
	< 24°C ☐	>24°C ≤ 27°C ☐	>27°C ≤ 30°C ☐	> 30°C ☐
Air temp (only if WBGT not available)	< 24°C ☐	>24°C ≤ 30°C ☐	>30°C ≤ 35°C ☐	> 35°C ☐
SUB-TOTAL C				

TOTAL = A + B	˚C	=

Risk result (˚C)	Action
< 28	Risk due to thermal conditions is low to moderate
28 to 60	There is potential of heat induced illnesses occurring if conditions are not addressed. Further work is required.
>60	The onset of heat induced illness is very likely and action should be taken as soon as possible to implement control

Appendix 6 – Air Sampling Field Data Sheet

Client Sample ID	Location/Description	Analyte / Method	Media	Flow (lpm)	Sample Time		Volume / Area	Sample Type	Sample Date	Comments
					On	Off				
								☐ Area ☐ Personal		
								☐ Area ☐ Personal		
								☐ Area ☐ Personal		
								☐ Area ☐ Personal		
								☐ Area ☐ Personal		
								☐ Area ☐ Personal		
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								☐ Area ☐ Personal		
								☐ Area ☐ Personal		

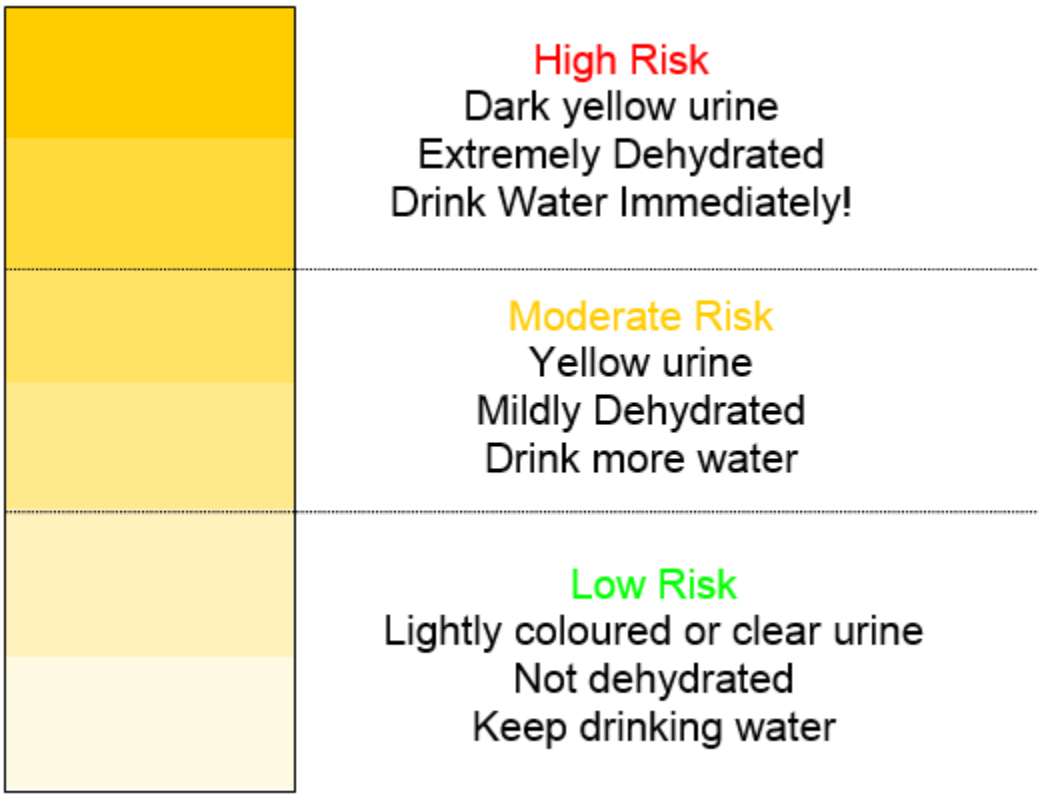
Comments:

Appendix 7 – Urine Color Chart

What color is your Urine?

It's a good indicator of how dehydrated you are!

Dehydration is a major risk and contributes to many health related incidents and illnesses.



Did you pass the test?

1. Urine color is not affected by dehydrating liquids, such as coffee and tea.
2. Urine color will also turn yellow from some colored agents e.g., vitamin B.
3. On hot days with strenuous work you could need 10-15 L of water a day.