Principles of Occupational Hygiene Measuring

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QCTO: Occupational Health, Safety Quality Practitioner Qualification – NQF Level 5

ISO NET (Pty) Ltd

Learner Guide

Course Content:

HEALTH EFFECTS
ROUTES OF ENTRY INTO THE BODY
Identify the typical occupational hygiene measurements that is taken within industry
The Practice of Occupational Hygiene
Recognition of hazards
Occupational hygiene evaluations
Exposure assessment
Interpretation of results
Measurements for control
Hazard prevention and control
Examples of Instruments used for hygiene measurements to airborne pollutants

Inhalable and Respirable Dust
Purpose
Principle
Inhalable and Respirable Dust
Methodology
Dust Sampling Equipment
Inhalable Dust
Respirable Dust
Personal Sampling
Apparatus Required
Description of Apparatus
Preparation Before Use Preparation of
filter holders
Calibration of Pump
Personal Sampling Procedure
NOTES:
Fixed Point Air Sampling
Laboratory Analysis
Calculating Concentrations
Real-time Area and Personal Dust Monitors
Peak Dust Concentrations
State of the Art Real-time Airborne Dust Monitors
SKC Dust Detective
Personal Dust Monitor (PDM)

Welding Fumes and Gases
Purpose
Occupational Exposure Limits (OELs)
Verification of compliance with OELs
Air Monitoring
Principle
Filters
Sampling pumps
Analytical balance
Sampling position
Sampling head attached to a separate headband
Analytical techniques

Part 2 (2000): Sampling of gases
General
Personal Exposure Measurements
Instruments used for hygiene measurements to Biological agents
Classification of biological agents
Information and training
Duties of persons who may be exposed to hazardous biological agents
Risk Assessment by the employer or self-employed person
Monitoring exposure at the workplace
Control of exposure to HBA
Personal protective equipment and facilities
Maintenance of control measures
Prohibitions
Labelling, packaging, transporting and storage
Special measures for health and veterinary isolation facilities
Special measures for laboratories, animal rooms and industrial processes
Disposal of HBA
Instruments used for hygiene measurements to dermal exposure and surface contamination
Dermal Exposure Assessment
The Importance of Dermal Exposure Assessment
The Current Dermal Exposure Measurement Methods
Direct methods
Interception methods
Removal methods
Visualization techniques
Indirect methods
Surface sampling methods (non-human)
Biomonitoring
Dermal exposure modeling
Instruments used for hygiene measurements to physical agents
Occupational heat exposure
The measurement of heat exposure (stress and strain) in the occupational environment
INTRODUCTION
WET BULB TEMPERATURE INDEX (WBGT)
Thermal Work Limit (TWL)
PHYSIOLOGICAL MEASUREMENT OF HEAT STRAIN
Urine specific gravity for hydration status
CONCLUSION
Instruments used for hygiene measurements to Ergonomics
Ergonomics
Purpose
Background
Legislation
Methodology
Principles
Identification of Ergonomics-Related Hazards
Factors Influencing Data Acquisition

HEALTH EFFECTS:

Exposure to many of the harmful health hazards may produce either an immediate response (acute health effect) due to intensity of the hazard; or the response may result from exposure over a long period at a relatively lower intensity (chronic health effect).

Acute health effects develop soon after exposure, rapidly reach maximum effect (climax) Acute effects generally develop in response to a high dose or exposure to a high concentration of a substance.

The effect may be temporary (skin irritation, nausea or sickness) or it may be permanent (blindness, scars from acid burns, death). If a worker is removed from a source of exposure, acute health effect may be reversible.

Chronic toxic effects develop gradually over a prolonged period of exposure, many years after initial exposure. Once an effect develops it is normally irreversible or recovery tends to be slow when compared to acute effects. Because of the long latency period between exposure and onset of disease, it is often difficult to make a link.

ROUTES OF ENTRY INTO THE BODY:

For a chemical to exert its harmful effect, it must first come into contact with or enter the body.

The three main routes of exposure in the workplace are *inhalation, absorption*, and *ingestion*.

- **Inhalation** is the most common route of entry of health hazards. Gases and vapours are easily inhaled but inhalation of solid particles depend on their size and shape. The smaller sizes penetrate deeper and have a greater effect.
- **Skin absorption** is the second major route of exposure. Those areas of the skin that come into contact with contaminants are the most impacted. The face or hands are the areas of the skin surface that usually come into contact with potentially toxic materials. Dermal absorption may also be enhanced by scratched, roughened, broken or abraded surfaces of the skin.
- **Ingestion** is generally not a major route of exposure although there are important exceptions. Workers who mouth breathe or chew gum or tobacco can absorb appreciable amounts of airborne contaminants. If areas used to eat, drink or smoke are contaminated by hazardous substances, or if workers do not wash their hands or remove gloves before eating or smoking, chemicals can enter the body through ingestion.

Identify the typical occupational hygiene measurements that is taken within industry

The Practice of Occupational Hygiene

The classical steps in occupational hygiene practice are:

- the recognition of the possible health hazards in the work environment
- the evaluation of hazards, which is the process of assessing exposure and reaching conclusions as to the level of risk to human health

- prevention and control of hazards, which is the process of developing and implementing strategies to eliminate, or reduce to acceptable levels, the occurrence of harmful agents and factors in the workplace, while also accounting for environmental protection.

The ideal approach to hazard prevention is “anticipated and integrated preventive action”, which should include:

- occupational health and environmental impact assessments, prior to the design and installation of any new workplace
- selection of the safest, least hazardous and least polluting technology (“cleaner production”)
- environmentally appropriate location
- proper design, with adequate layout and appropriate control technology, including for the safe handling and disposal of the resulting effluents and waste
- elaboration of guidelines and regulations for training on the correct operation of processes, including on safe work practices, maintenance and emergency procedures.

The importance of anticipating and preventing all types of environmental pollution cannot be overemphasized. There is, fortunately, an increasing tendency to consider new technologies from the point of view of the possible negative impacts and their prevention, from the design and installation of the process to the handling of the resulting effluents and waste, in the so-called cradle-to-grave approach.

Environmental disasters, which have occurred in both developed and developing countries, could have been avoided by the application of appropriate control strategies and emergency procedures in the workplace.

Economic aspects should be viewed in broader terms than the usual initial cost consideration; more expensive options that offer good health and environmental protection may prove to be more economical in the long run. The protection of workers’ health and of the environment must start much earlier than it usually does.

Technical information and advice on occupational and environmental hygiene should always be available to those designing new processes, machinery, equipment and workplaces. Unfortunately such information is often made available much too late, when the only solution is costly and difficult retrofitting, or worse, when consequences have already been disastrous.

Recognition of hazards

Recognition of hazards is a fundamental step in the practice of occupational hygiene, indispensable for the adequate planning of hazard evaluation and control strategies, as well as for the establishment of priorities for action. For the adequate design of control measures, it is also necessary to physically characterize contaminant sources and contaminant propagation paths.

The recognition of hazards leads to the determination of:

- which agents may be present and under which circumstances
- the nature and possible extent of associated adverse effects on health and well-being.

The identification of hazardous agents, their sources and the conditions of exposure requires extensive knowledge and careful study of work processes and operations, raw materials and

chemicals used or generated, final products and eventual by-products, as well as of possibilities for the accidental formation of chemicals, decomposition of materials, combustion of fuels or the presence of impurities.

The recognition of the nature and potential magnitude of the biological effects that such agents may cause if overexposure occurs, requires knowledge on and access to toxicological information. International sources of information in this respect include International Agents which pose health hazards in the work environment include airborne contaminants; non-airborne chemicals; physical agents, such as heat and noise; biological agents; ergonomic factors, such as inadequate lifting procedures and working postures; and psychosocial stresses.

Occupational hygiene evaluations

Occupational hygiene evaluations are carried out to assess workers' exposure, as well as to provide information for the design, or to test the efficiency, of control measures.

Evaluation of workers' exposure to occupational hazards, such as airborne contaminants, physical and biological agents, is covered elsewhere in this chapter. Nevertheless, some general considerations are provided here for a better understanding of the field of occupational hygiene.

It is important to keep in mind that hazard evaluation is not an end in itself, but must be considered as part of a much broader procedure that starts with the realization that a certain agent, capable of causing health impairment, may be present in the work environment, and concludes with the control of this agent so that it will be prevented from causing harm. Hazard evaluation paves the way to, but does not replace, hazard prevention.

Exposure assessment

Exposure assessment aims at determining how much of an agent workers have been exposed to, how often and for how long. Guidelines in this respect have been established both at the national and international level.

In the evaluation of exposure to airborne contaminants, the most usual procedure is the assessment of inhalation exposure, which requires the determination of the air concentration of the agent to which workers are exposed (or, in the case of airborne particles, the air concentration of the relevant fraction, e.g., the "respirable fraction") and the duration of the exposure.

However, if routes other than inhalation contribute appreciably to the uptake of a chemical, an erroneous judgement may be made by looking only at the inhalation exposure. In such cases, total exposure has to be assessed, and a very useful tool for this is biological monitoring.

The practice of occupational hygiene is concerned with three kinds of situations:

- initial studies to assess workers' exposure
- follow-up monitoring/surveillance
- exposure assessment for epidemiological studies.

A primary reason for determining whether there is overexposure to a hazardous agent in the work environment, is to decide whether interventions are required. This often, but not

necessarily, means establishing whether there is compliance with an adopted standard, which is usually expressed in terms of an occupational exposure limit.

The determination of the "worst exposure" situation may be enough to fulfil this purpose. Indeed, if exposures are expected to be either very high or very low in relation to accepted limit values, the accuracy and precision of quantitative evaluations can be lower than when the exposures are expected to be closer to the limit values.

In fact, when hazards are obvious, it may be wiser to invest resources initially on controls and to carry out more precise environmental evaluations after controls have been implemented.

Follow-up evaluations are often necessary, particularly if the need existed to install or improve control measures or if changes in the processes or materials utilized were foreseen. In these cases, quantitative evaluations have an important surveillance role in:

- evaluating the adequacy, testing the efficiency or disclosing possible failures in the control systems
- detecting whether alterations in the processes, such as operating temperature, or in the raw materials, have altered the exposure situation.

Whenever an occupational hygiene survey is carried out in connection with an epidemiological study in order to obtain quantitative data on relationships between exposure and health effects, the exposure must be characterized with a high level of accuracy and precision.

In this case, all exposure levels must be adequately characterized, since it would not be enough, for example, to characterize only the worst case exposure situation. It would be ideal, although difficult in practice, to always keep precise and accurate exposure assessment records since there may be a future need to have historical exposure data.

In order to ensure that evaluation data is representative of workers' exposure, and that resources are not wasted, an adequate sampling strategy, accounting for all possible sources of variability, must be designed and followed. Sampling strategies, as well as measurement techniques, are covered in "Evaluation of the work environment".

Interpretation of results

The degree of uncertainty in the estimation of an exposure parameter, for example, the true average concentration of an airborne contaminant, is determined through statistical treatment of the results from measurements (e.g., sampling and analysis).

The level of confidence on the results will depend on the coefficient of variation of the "measuring system" and on the number of measurements.

Once there is an acceptable confidence, the next step is to consider the health implications of the exposure:

- what does it mean for the health of the exposed workers: now?
- in the near future?
- in their working life?
- will there be an impact on future generations?

The evaluation process is only completed when results from measurements are interpreted in view of data (sometimes referred to as “risk assessment data”) derived from experimental toxicology, epidemiological and clinical studies and, in certain cases, clinical trials.

It should be clarified that the term risk assessment has been used in connection with two types of assessments—the assessment of the nature and extent of risk resulting from exposure to chemicals or other agents, in general, and the assessment of risk for a particular worker or group of workers, in a specific workplace situation.

In the practice of occupational hygiene, exposure assessment results are often compared with adopted occupational exposure limits which are intended to provide guidance for hazard evaluation and for setting target levels for control.

Exposure in excess of these limits requires immediate remedial action by the improvement of existing control measures or implementation of new ones. In fact, preventive interventions should be made at the “action level”, which varies with the country (e.g., one-half or one-fifth of the occupational exposure limit). A low action level is the best assurance of avoiding future problems.

Comparison of exposure assessment results with occupational exposure limits is a simplification, since, among other limitations, many factors which influence the uptake of chemicals (e.g., individual susceptibilities, physical activity and body build) are not accounted for by this procedure.

Furthermore, in most workplaces there is simultaneous exposure to many agents; hence a very important issue is that of combined exposures and agent interactions, because the health consequences of exposure to a certain agent alone may differ considerably from the consequences of exposure to this same agent in combination with others, particularly if there is synergism or potentiation of effects.

Measurements for control

Measurements with the purpose of investigating the presence of agents and the patterns of exposure parameters in the work environment can be extremely useful for the planning and design of control measures and work practices.

The objectives of such measurements include:

- source identification and characterization
- spotting of critical points in closed systems or enclosures (e.g., leaks)
- determination of propagation paths in the work environment
- comparison of different control interventions
- verification that respirable dust has settled together with the coarse visible dust, when using water sprays
- checking that contaminated air is not coming from an adjacent area.

Direct-reading instruments are extremely useful for control purposes, particularly those which can be used for continuous sampling and reflect what is happening in real time, thus disclosing exposure situations which might not otherwise be detected and which need to be controlled.

Examples of such instruments include: photo-ionization detectors, infrared analysers, aerosol meters and detector tubes. When sampling to obtain a picture of the behaviour of

contaminants, from the source throughout the work environment, accuracy and precision are not as critical as they would be for exposure assessment.

Measurements are also needed to assess the efficiency of control measures. In this case, source sampling or area sampling are convenient, alone or in addition to personal sampling, for the assessment of workers' exposure. In order to assure validity, the locations for "before" and "after" sampling (or measurements) and the techniques used should be the same, or equivalent, in sensitivity, accuracy and precision.

Hazard prevention and control

The primary goal of occupational hygiene is the implementation of appropriate hazard prevention and control measures in the work environment. Standards and regulations, if not enforced, are meaningless for the protection of workers' health, and enforcement usually requires both monitoring and control strategies.

The absence of legally established standards should not be an obstacle to the implementation of the necessary measures to prevent harmful exposures or control them to the lowest level feasible. When serious hazards are obvious, control should be recommended, even before quantitative evaluations are carried out. It may sometimes be necessary to change the classical concept of "recognition-evaluation-control" to "recognition-control-evaluation", or even to "recognition-control", if capabilities for evaluation of hazards do not exist.

Some examples of hazards in obvious need of action without the necessity of prior environmental sampling are electroplating carried out in an unventilated, small room, or using a jackhammer or sand-blasting equipment with no environmental controls or protective equipment. For such recognized health hazards, the immediate need is control, not quantitative evaluation.

Preventive action should in some way interrupt the chain by which the hazardous agent—a chemical, dust, a source of energy—is transmitted from the source to the worker. There are three major groups of control measures: engineering controls, work practices and personal measures.

The most efficient hazard prevention approach is the application of engineering control measures which prevent occupational exposures by managing the work environment, thus decreasing the need for initiatives on the part of workers or potentially exposed persons.

Engineering measures usually require some process modifications or mechanical structures, and involve technical measures that eliminate or reduce the use, generation or release of hazardous agents at their source, or, when source elimination is not possible, engineering measures should be designed to prevent or reduce the spread of hazardous agents into the work environment by:

- containing them
- removing them immediately beyond the source
- interfering with their propagation
- reducing their concentration or intensity.

Control interventions which involve some modification of the source are the best approach because the harmful agent can be eliminated or reduced in concentration or intensity. Source

reduction measures include substitution of materials, substitution/modification of processes or equipment and better maintenance of equipment.

When source modifications are not feasible, or are not sufficient to attain the desired level of control, then the release and dissemination of hazardous agents in the work environment should be prevented by interrupting their transmission path through measures such as isolation (e.g., closed systems, enclosures), local exhaust ventilation, barriers and shields, isolation of workers.

Other measures aiming at reducing exposures in the work environment include adequate workplace design, dilution or displacement ventilation, good housekeeping and adequate storage. Labelling and warning signs can assist workers in safe work practices. Monitoring and alarm systems may be required in a control programme.

Monitors for carbon monoxide around furnaces, for hydrogen sulphide in sewage work, and for oxygen deficiency in closed spaces are some examples.

Work practices are an important part of control—for example, jobs in which a worker's work posture can affect exposure, such as whether a worker bends over his or her work. The position of the worker may affect the conditions of exposure (e.g., breathing zone in relation to contaminant source, possibility of skin absorption).

Lastly, occupational exposure can be avoided or reduced by placing a protective barrier on the worker, at the critical entry point for the harmful agent in question (mouth, nose, skin, ear)—that is, the use of personal protective devices. It should be pointed out that all other possibilities of control should be explored before considering the use of personal protective equipment, as this is the least satisfactory means for routine control of exposures, particularly to airborne contaminants.

Other personal preventive measures include education and training, personal hygiene and limitation of exposure time.

Continuous evaluations, through environmental monitoring and health surveillance, should be part of any hazard prevention and control strategy.

Appropriate control technology for the work environment must also encompass measures for the prevention of environmental pollution (air, water, soil), including adequate management of hazardous waste.

Although most of the control principles hereby mentioned apply to airborne contaminants, many are also applicable to other types of hazards. For example, a process can be modified to produce less air contaminants or to produce less noise or less heat. An isolating barrier can isolate workers from a source of noise, heat or radiation.

Far too often prevention dwells on the most widely known measures, such as local exhaust ventilation and personal protective equipment, without proper consideration of other valuable control options, such as alternative cleaner technologies, substitution of materials, modification of processes, and good work practices.

It often happens that work processes are regarded as unchangeable when, in reality, changes can be made which effectively prevent or at least reduce the associated hazards.

Hazard prevention and control in the work environment requires knowledge and ingenuity. Effective control does not necessarily require very costly and complicated measures. In many cases, hazard control can be achieved through appropriate technology, which can be as simple as a piece of impervious material between the naked shoulder of a dock worker and a bag of toxic material that can be absorbed through the skin.

It can also consist of simple improvements such as placing a movable barrier between an ultraviolet source and a worker, or training workers in safe work practices.

Aspects to be considered when selecting appropriate control strategies and technology, include the type of hazardous agent (nature, physical state, health effects, routes of entry into the body), type of source(s), magnitude and conditions of exposure, characteristics of the workplace and relative location of workstations.

The required skills and resources for the correct design, implementation, operation, evaluation and maintenance of control systems must be ensured. Systems such as local exhaust ventilation must be evaluated after installation and routinely checked thereafter.

Only regular monitoring and maintenance can ensure continued efficiency, since even well-designed systems may lose their initial performance if neglected.

Control measures should be integrated into hazard prevention and control programmes, with clear objectives and efficient management, involving multidisciplinary teams made up of occupational hygienists and other occupational health and safety staff, production engineers, management and workers.

Programmes must also include aspects such as hazard communication, education and training covering safe work practices and emergency procedures.

Health promotion aspects should also be included, since the workplace is an ideal setting for promoting healthy life-styles in general and for alerting as to the dangers of hazardous non-occupational exposures caused, for example, by shooting without adequate protection, or smoking.

Examples of Instruments used for hygiene measurements to airborne pollutants

Inhalable and Respirable Dust
Purpose

The primary purpose of airborne dust sampling is to protect worker health by measuring personal dust exposures to ensure they are in compliance with occupational exposure limits. Other reasons include evaluating the effectiveness of engineering controls and changes in dust levels as a result of process changes, and as a measure of dose in epidemiological studies.

Principle

The air to be sampled is drawn by means of a mechanical pump through a filter contained in a filter holder. The dust present in the sampled air is deposited on the filter and can be weighed to determine the mass concentration of airborne dust and/or sent to a laboratory for analysis to determine the airborne concentration of a particular element or compound present in

the dust e.g. lead, quartz, or vanadium pentoxide.

Inhalable and Respirable Dust

Suspensions of solid or liquid particles in air are often referred to as aerosols or particulates. Dust is generally considered an aerosol of solid particles mechanically produced, with individual particle diameters of 0.1 µm upwards (Figure 3.1).

Fume is an aerosol of solid particles generated by condensation from the vapour state usually following the volatilisation of molten metals. The individual particle diameters of fume are typically less than 1 µm, though the existence of multi-particle aggregates is common.

The behaviour, deposition and fate of particles after entry into the human respiratory system, and the response that they elicit, depends on the nature and size of the particles.

Thus the mass concentrations of airborne particles for occupational hygiene purposes are generally measured in terms of different size fractions (Figure 3.2) such as the inhalable fraction (particles < 100 µm) or respirable fraction (particles < 10 µ). In the case of inhalable dust this approximates to the fraction of airborne material that enters the nose and mouth during breathing, and is therefore available for deposition in the respiratory tract. Examples of dusts for which the inhalable fraction would be sampled includes certain hardwood dusts (which may cause nasal cancer) and dusts from grinding lead-containing alloys (which can be absorbed and cause systemic poisoning).

Respirable dust approximates to the fraction of airborne material that penetrates to the gas exchange region of the lung. Examples of dusts for which the respirable fraction would be sampled includes dusts containing the various forms of free crystalline silica such as Cristobalite, Quartz and Tridymite. Coal dust is also measured as the respirable fraction.

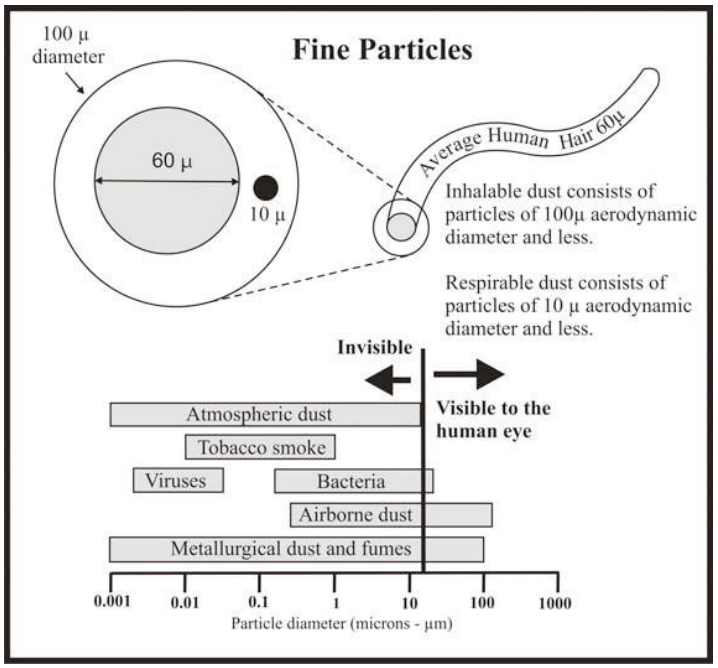


Figure 3.1 Fine Particles

Methodology

Dust Sampling Equipment

Different sampling instruments are utilised according to whether inhalable or respirable dust fractions are to be measured (Figures 3.2 and 3.3). The essential features of all systems are a collection substrate such as a filter and a pump for pulling the air through it; the collection substrate may be held within a cassette system placed within the respirable or inhalable sampler.

In personal sampling the sampler is attached to the wearer within his or her breathing zone, and the pump is connected to it by a length of flexible tubing and worn on a belt, harness, or in a pocket.

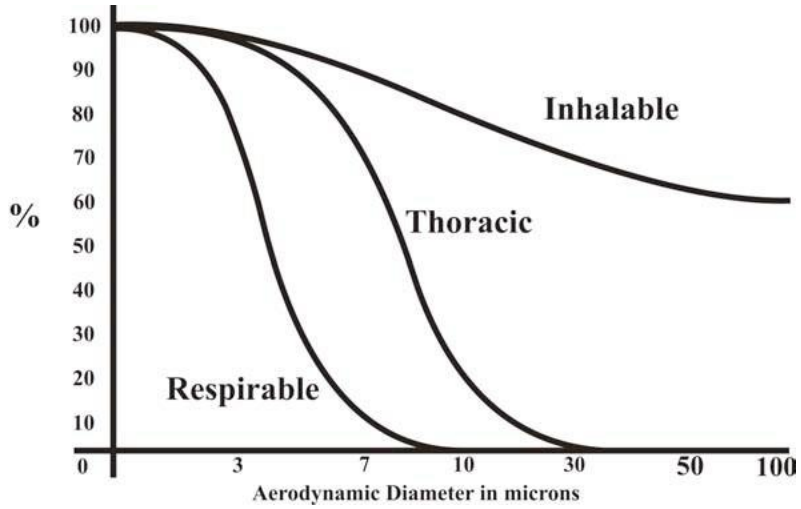


Figure 3.2 ISO/CEN/ACGIH Sampling Convention for Aerosols[1]

Inhalable Dust

Two examples of personal samplers for inhalable dust are the multi-orifice sampler (Figure 3.4) and the Institute of Occupational Medicine (IOM) sampler (Figure 3.5). The multi orifice and IOM-sampler require a pump capable of maintaining a smooth flowrate of 2.0 ± 0.1 litre/ min throughout the sampling period.

The IOM sampler utilises an internal cassette made of plastic or metal that is weighed together with the filter it contains as dust is collected on the walls of the cassette as well as on the filter. The IOM sampler can be used for Inhalable and Thoracic dust sampling by inserting the appropriate foam plug into the entry or front part of the cassette (A longer version of the IOM cassette must be used when sampling with foam plugs).

The foam size selects the dust that passes through it and allows the correct type of dust to be collected on the filter.

NOTES: For many years the closed-face plastic cassette has been widely used for monitoring "total dust" in working atmospheres (Figure 3.3). Studies have shown, however, that these may underestimate inhalable dust exposures compared to the IOM sampler depending on the

particle size distribution of the dust. The terms “total dust” or “total inhalable dust” have now generally been replaced by the term “inhalable dust”.

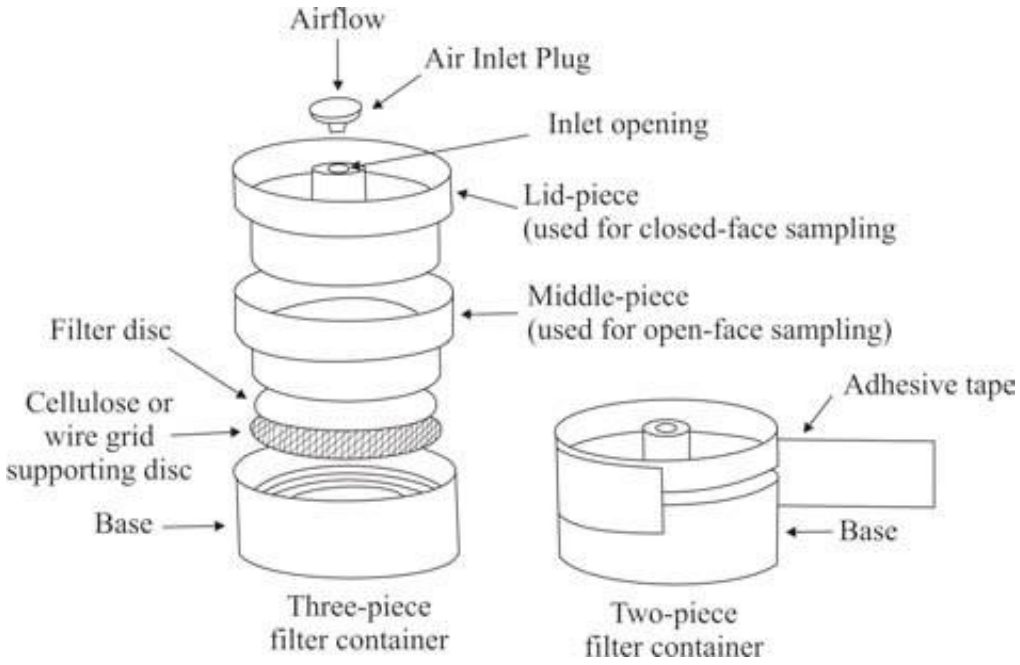


Figure 3.3 Filter Cassette Assembly

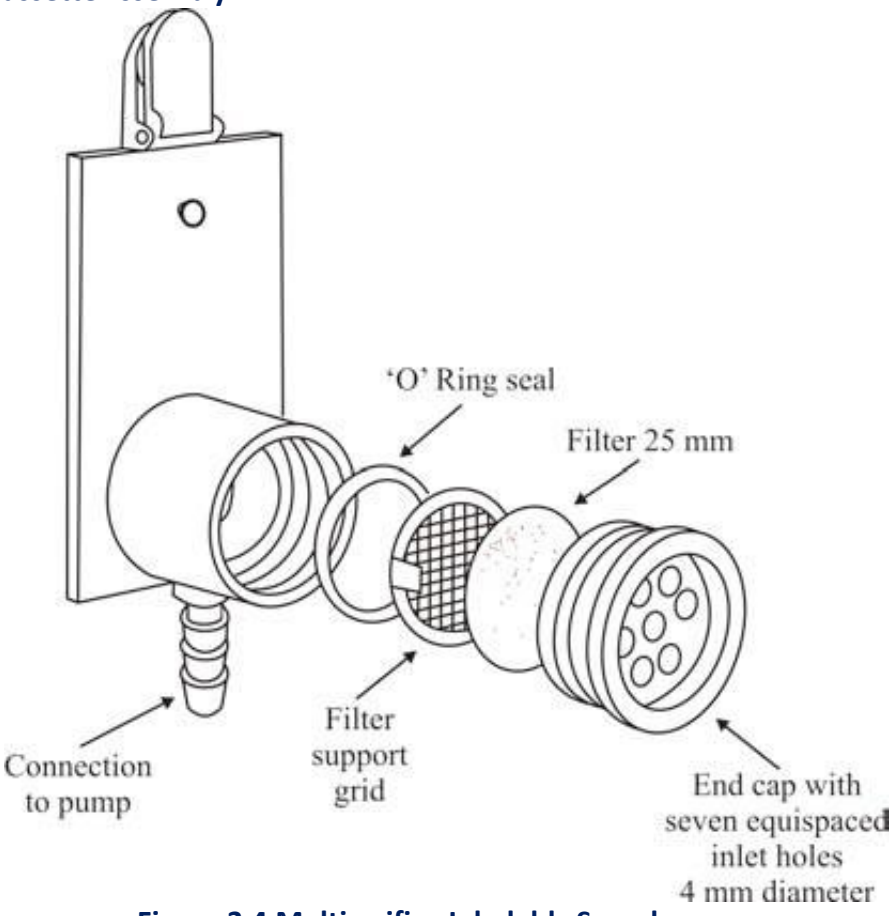


Figure 3.4 Multi-orifice Inhalable Sampler

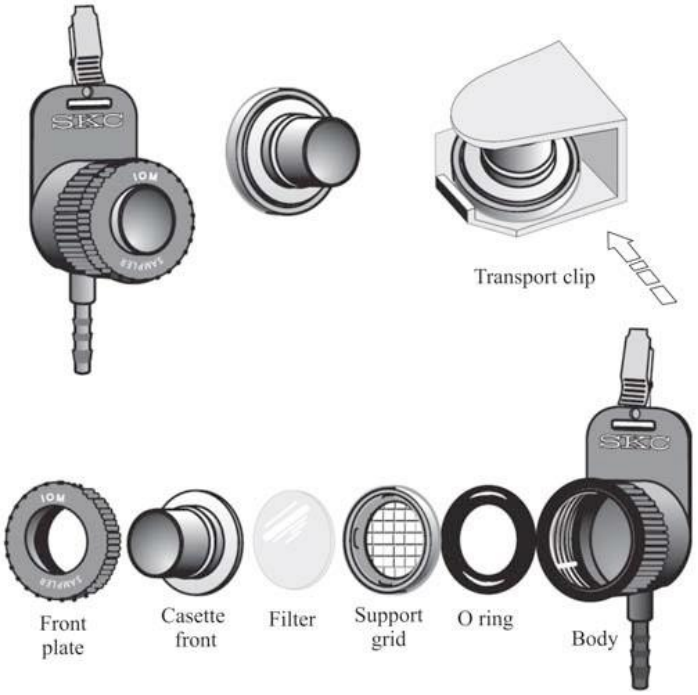


Figure 3.5 Institute of Occupational Medicine (IOM) Inhalable Sampler[2]

Respirable Dust

The respirable fraction is generally collected on a filter substrate using a cyclone to remove the coarse or non-respirable dust from the sampled air (Figures 3.6). The cyclone type typically used in South Africa is the generic Higgins-Dewell design, which should operate at a flowrate of 2,2 litre/min for optimal agreement with the ISO/CEN/ACGIH respirable convention (Figure 3.6).

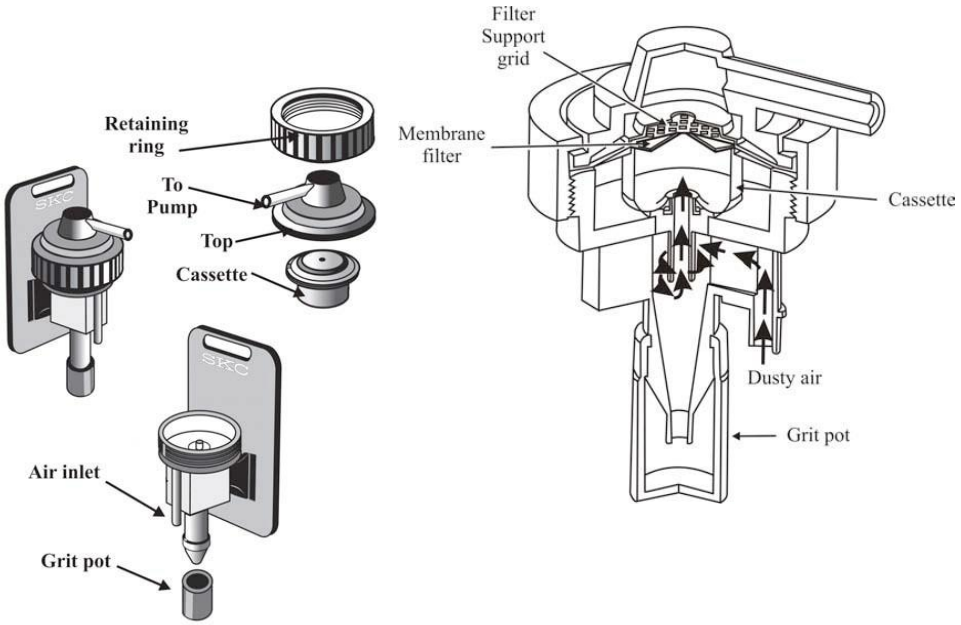


Figure 3.6 Cyclone and Airflow in Cyclone Respirable Dust Sampler

Alternative cyclone types that also agree with the respirable convention at specified flowrates

can also be used. An example is the 10-mm Dorr-Oliver cyclone which is used at 1,7 litre/ min.

Personal Sampling

Apparatus Required

- A battery powered personal sampling pump capable of maintaining a sustained flow rate of at least 2,2 L/min over a full working shift.
- A clean filter holder capable of holding a 25 mm or 37 mm diameter filter.
- One metre of 5 mm or 6 mm internal diameter thick walled tubing suitable for connecting the personal sampling pump to the sampling head.
- 25 mm or 37 mm diameter filter media. The pore size should be selected to suit the specific application (e.g. 0,8 m for respirable dust.)
- Where respirable dust is to be sampled a cyclone separator to remove coarse dust is also required.
- A clip-on holder, which allows the filter holder to be attached to the worker's clothing.
- Belts or harnesses to which the sampling pumps can be conveniently fixed, unless they are small enough to fit inside worker's pockets.
- A calibrated rotameter or electronic air flow calibrator for the measurement of the flow rate through the sampling pump.
- Flat-tipped Tweezers.
- Micro-balance.
- Petri dishes.
- A charging system to charge the air sampler batteries.
- A stopwatch.
- A means to transport the filter samples from the workplace to the laboratory, which minimises the possibility of accidental transfers of collected dust to or from the filter media.

Figure 3.7 Early Model Personal Respirable Dust Sampler Attached via a Harness

Description of Apparatus

Pump: Several types of positive displacement personal air sampling pumps with built-in flow rate compensation for varying filter pressure drop conditions are available. The pump should be capable of maintaining a constant air-flow rate to within 5% of the calibrated airflow rate over a full sampling shift.

NOTE: Sampling instruments should be intrinsically safe for use in fiery mines and flammable atmospheres.

Filter Holder: The filter holder usually consists of a two part case, a filter disk and a filter support pad. The assembled unit in some instances requires the unit to be sealed with an adhesive cellulose band before use.

Cyclone Separator: The cyclone separator is used where respirable dust is to be sampled. The cyclone is attached to the filter holder and acts as a pre-separator to remove the coarse or non-respirable dust which is collected in a grit pot.

Clip-on Holder: The clip-on holder is designed to hold the filter holder in position, and is usually attached to the worker's lapel as close to the breathing zone as possible. It allows the filter/cyclone assembly to be suspended in a vertical position in which the cyclone operates most efficiently.

Filter Media: The filter disks utilised are generally either 25 mm or 37 mm in diameter, depending on the type of filter holder being used. If sampling is carried out solely for the measurement of the gravimetric concentration, without analysis, glass fibre filters may be used. Fibre loss from such filters may occur during handling and may be significant if less than 1 mg of dust is collected.

At such concentrations silver, teflon or membrane filters should be used. Some types of filter (e.g. cellulose nitrate) can show excessive weight change due to moisture absorption, and other types (e.g. PVC, teflon) can show excessive static build-up.

Filters made up of mixed esters of cellulose do not have these drawbacks to the same degree. If analysis of the collected material is required, this is likely to determine the choice of filter and the appropriate sampling and analytical method should be consulted.

Electronic Air Flow Calibrator: This can be used to calibrate rotameters, or to determine the flow rate of air sampling pumps, sampling trains, or virtually any device that involves air flow through tubing. It is based on the use of infrared sensors to measure the flow of a liquid film between two points in a precision tube.

As the soap film passes two infrared sensors, the time spent between the sensors is fed to a microprocessor, which uses this data to calculate the flow rate.

Rotameter: Rotameters are variable area flowmeters that provide field accuracy in an easy- to-

read instrument. The rotameter is a secondary standard and should be calibrated by a primary standard calibrator such as a laboratory film flowmeter or electronic air flow calibrator to ensure the correct pump flowrate is set when using a rotameter.

It should be noted the calibration is for a given density and that the performance of the rotameter will be affected significantly by changes in elevation (and hence air density).

Preparation Before Use

Preparation of filter holders

- Assemble the filter holders in a clean environment.
- Only clean filter holders must be used. Use flat-tipped tweezers to handle the filter and filter support pad or grid.
- Place the filter and the filter support pad or grid in the filter holder, with the filter on the air intake side.
- Close the inlet and outlet ports of the filter holder with the plugs or covers provided with the filter holder.
- Seal the filter holder joints with shrinkable cellulose band or tape to prevent leakage where applicable.

Calibration of Pump

Before a pump and filter holder assembly is used to measure the dust level, it is necessary that the pump is correctly adjusted (Figure 3.8).

- Take a filter holder which is fitted with a clean filter and attach it to the pump tubing in the correct way, (i.e. "outlet" side connected to the pump tubing).
- Connect a calibrated rotameter or electronic air flow calibrator to the intake side of the filter holder.
- Switch the pump on and note the rotameter or electronic air flow calibrator reading.
- If required, adjust the pump flow rate to the required rate.
- Once the pump has been calibrated, a filter holder which has been prepared for actual sampling is connected to the pump and the assembly used to measure dust levels as required.

Figure 3.8 Sampling Train for Pump Calibration[2]

Personal Sampling Procedure

(a) Assemble the sampling train by fixing one end of the flexible tubing to the inlet port of the pump and the other end to the outlet port of the filter holder.

(b) Check for air leaks in the sampling train. This is usually done by turning on the pump and inserting a clean plastic plug into the inlet port of the filter holder. The air flow indicator on pumps with a flow meter must drop to the zero flow position and oscillate slightly. If this does not occur, find and either repair the leak if possible, or re-place the faulty component.

(c) Where respirable dust is to be measured, fit the cyclone separator to the inlet side of the filter holder where required, or use a filter holder specifically designed for this purpose.

NOTE: Care should be taken to ensure that the correct flowrate for the cyclone separator is utilised. Where the flow rate through the cyclone differs from the correct or rated flow rate, the efficiency of the cyclone is affected.

(d) Label the filter holder and the filter media with an appropriate sample number.
(e) Attach the pump, preferably to the worker's belt or place it in his pocket; place the flexible tubing over his shoulder and clip the filter holder to the clothing with the inlet port facing downwards, as near as possible to the breathing zone. Ensure that the equipment will not interfere with the worker's movements.
(f) Check again that all equipment is properly assembled, remove the plastic plug from the filter holder's inlet port where applicable and switch on the pump.
(g) Note the following information for each sample:
    (i) date of sampling;
    (ii) company name;
    (iii) model and serial number of pump;

(iv) calibration date of the sampling pump;

(v) name of employee;

(vi) job title;

(vii) work performed including any abnormal activities such as stone dusting;

(viii) filter holder or sample number;

(ix) air flow rate; and

(x) time of initiation and termination of sampling.

(h) The ambient air temperature and pressure in the sampling area must be recorded at least once.

(i) To terminate sampling, perform the following sequence of steps:

(i) Check that the pump is operating prior to termination of air sampling;

(ii) Record the time of termination of sampling;

(iii) Switch off the pump and carefully remove the entire sampling train from the worker;

(iv) Check that the assembly still handles the pre-set flowrate with a maximum allowable variation of 5%;

(v) Remove the filter holder and seal with the protective cover or plugs to prevent contamination.

For samplers that use an internal cassette (e.g. the IOM sampler) remove the cassette from each sampler and fasten with the transport clip supplied by the manufacturer.

NOTES:

Where the cyclone pre-selector is used, particular care should be taken that the cyclone unit is not turned upside-down or handled in such a way that the dust is dislodged from the grit pot and falls onto the filter.

Sampling may be carried out for a total duration of six to eight hours, if feasible, to obtain a time-weighted average concentration. Where necessary, sequential air samples may be taken as opposed to single air samples. The total sampling duration may or may not include lunch breaks, depending on the nature of the work exposure to be measured.

Total sampling duration may be shorter than six hours, provided that the individual air samples taken during the selected periods are representative of the employee's exposure over the entire work shift. In practice a minimum sampling period of 5 hours is advised for an 8-hour shift.

For determination of risk assessment on mines and works the current requirement is that full working shifts have to be sampled.

During the sampling interval, the sampling train must be checked periodically to ensure that it is functioning properly. The airflow rate must not be re-adjusted after the flow rate is set.

Fixed Point Air Sampling

Fixed point or static air sampling may be used to determine background levels of airborne dust in the workplace. For the purpose of fixed point air sampling personal sampling equipment may be used.

The sampling heads should be sited at about head height and as near as possible to the job locations, or failing this as near as is possible to major sources of airborne dust to which employees in that workplace are exposed.

Due consideration should be given to the direction of air currents in the workplace in relation to sources of dust and to job locations when siting the static samplers.

The number and location of sampling points in each workplace should be such that the results as a whole would provide a good description of the background airborne dust concentration in the workplace. In general it is not appropriate to compare dust concentrations determined by fixed point (background) sampling with occupational exposure limits.

Laboratory Analysis

The procedure for determining the amount of dust sampled for gravimetric mass determination is described in the chapter on the electronic microbalance. For analysis of the filter deposit, the filter is generally sent to an accredited laboratory.

Techniques used for laboratory analysis to determine dust composition include atomic absorption techniques, ion selective electrode or ion chromatography, infra-red analysis, inductively coupled plasma- mass spectrometry, X-ray diffraction, X-ray fluorescence spectrometry and scanning electron microscopy.

Calculating Concentrations

The airborne dust concentration is expressed as mass (mg) per cubic meter (m^3) of air or number of particles per cubic meter of air (m^3) and generally referred to as "dust concentration or dust count" in the air. For example, coal dust concentration is expressed in mg/m^3; mineral fibre concentrations in f/ml. Using the sampling period, flow rate and mass of sample collected on the filters, the sample concentration is obtained as follows:

$$\text{Sample Concentration (DC)} = \frac{(C_f - C_i)}{Fl \times T_S}$$

Where,

DC = dust concentration measured in mg/m3 Ci = corrected initial filter mass in mg

Cf = corrected final filter mass containing dust in mg
Fl = sample flow rate in m3/min
TS = sampling time in minutes

If the sampling period is not an 8-hour period, a calculated 8-hour time-weighted average dust concentration (TWA-8h) is obtained as follows:

$$\text{TWA - 8h} = \frac{(DC \times T_S)}{480}$$

Where,

DC = dust concentration measured in mg/m^3 TS = sampling time in minutes

The above assumes that minimal dust exposure occurs during the unsampled portion of the shift.

Real-time Area and Personal Dust Monitors

Assessment of workplace exposures is important to help minimize dust-related occupational illness and diseases. Real-time airborne particulate monitoring can effectively locate areas where dust controls are needed and determine how well they are working.

Currently, there are a wide variety of direct reading real-time monitoring instruments available commercially specifically for area and personal sampling purposes. However, it is difficult to compare the manufacturers' specifications.

Also, currently there is no consensus standard on the selection of a suitable instrument. Real-time hand held dust-monitoring instruments based on the light scattering principle include the: Microdust pro (Casella CEL) , TM-data respirable dust measuring instrument (Helmut Hund GmbH) and the TSI Dust track. The PersonalDataRam (Thermo Electron Corporation) was designed for personal and area dust sampling.

Real time monitors include a built-in data logger to store individual dust readings and will, depending on the sampling time, store averaged individual readings ranging from 1-60 seconds. The real-time monitoring system consists of a computer program into which measured data are entered and time-related concentrations can be displayed and printed.

The program also allows for captured data to be manipulated in spreadsheet programs for statistical analyses.

Most of the available real-time instruments are not yet fully portable or applicable for underground operations. Instruments are calibrated using “mono-disperse” particles (e.g. Arizona road dust) in the laboratory.

However, each instrument requires a user-determined “correction factor” obtained from a side-by-side gravimetric size-selective sampler, evaluated with “poly-disperse” dust having wide size-distribution curves appropriate to the specific mine.

There is no “absolute correction factor” available for individual sampling instruments. The “correction factor” changes with the history of the sampling data obtained in side-by-side comparisons of the real-time monitoring instrument and the type of gravimetric size-selective sampler used.

Finally, in order to determine the quartz content of the exposed dust, the real time monitoring instruments must be used in conjunction with respirable dust samplers in active sampling mode.

Peak Dust Concentrations

The average dust concentration levels to which workers are exposed provides an important measure of dustiness in relation to pneumoconiosis, but should be supplemented by information on the variability of dust exposures where possible.

There is a growing awareness of the importance of peak concentrations and their effects on the human body. Any information on peak dust levels and their frequency in relation to average dust levels will assist in quicker reactive measures to improve the dust control systems and their effectiveness in ultimately reducing worker exposures. Figure 3.9 illustrates peak dust levels measured with a direct reading instrument.

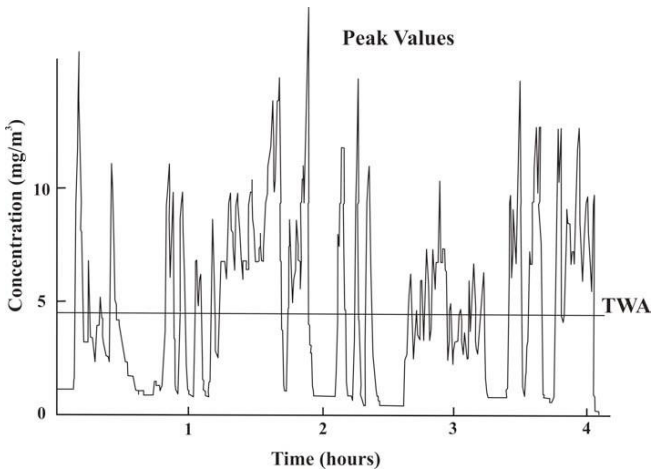


Figure 3.9 Real-time measurement of airborne dust

State of the Art Real-time Airborne Dust Monitors

A number of new instruments for real-time monitoring of airborne dust should be available commercially following development under the NIOSH mining research program (USA).

SKC Dust Detective

An affordable, person-wearable, real-time dust monitor called the SKC, Inc., Dust Detective (SKCDD) has been developed through a Cooperative Research and Development Agreement between NIOSH and SKC, Inc. (USA).

The SKCDD consists of a disposable sampling tube (Figure 3.10) connected to a small handheld sampling pump and provides short-term measurement of the cumulative personal

dust exposure of a worker during a shift. The dust detector tube models itself after the concept of a radiation dosimeter or, more precisely, after sorbent detector tubes used to measure exposure to various gases.

The device measures the increasing back pressure across a glass fibre filter as the respirable fraction of dust is collected on the filter. This equipment has been evaluated in South Africa under SIMRAC Project Health 704.

A version of the SKCDD has been developed for diesel particulate measurements in raw diesel exhaust and is called the SKC Diesel Detective.

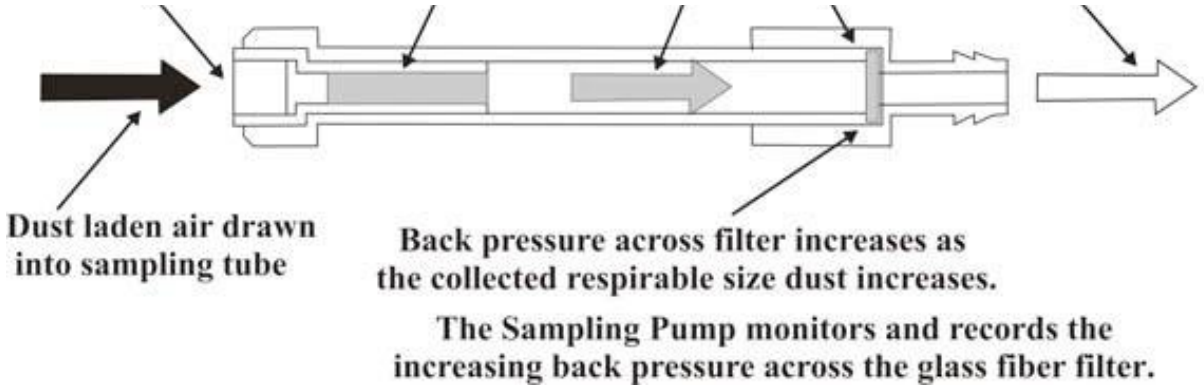


Figure 3.10 Dust Detective Sampling Tube[3]

Personal Dust Monitor (PDM)

The PDM was developed by Rupprecht & Patashnick Co., Inc. (R&P - now Thermo Electron Corporation) under contract to NIOSH for personal exposure measurements of respirable coal dust. It has as its mass sensor, a Tapered Element Oscillating Microbalance (TEOM), which continuously measures the mass of particles from the mine atmosphere collected on a sample filter.

The main components of the device include a cap lamp and sample inlet located on the end of an umbilical cable, a belt-mounted enclosure containing the respirable dust cyclone, sampling, and mass measurement system, and a charging and communication module used to transmit data between the monitor and a PC while charging its lithium ion batteries for the next shift. Figures 3.11 and 3.12 illustrates the components typically carried by the miner. Figure 3.12 also shows a version of the PDM for general occupational hygiene monitoring.

The PDM calculates the shift exposure and allows exposure data continually to be displayed during the shift to enable workers and management to react to changes in dust exposure.

The instrument is designed to withstand the harsh conditions found in the mine environment, and to meet intrinsic safety type approval requirements.

A 2.2 liter per minute flow of particle-laden air from the mine atmosphere enters an inlet mounted on the bill of the miner's hard hat, and passes through conductive tubing before reaching the Higgins and Dewell (HD) cyclone at the entrance of the PDM.

The sample stream with respirable particles that exits from the cyclone is then conditioned in a heated section of tubing to remove excess moisture. As the air stream subsequently passes through the mass sensor, an exchangeable filter cartridge collects the respirable particles. The mass

sensor can be removed from the PDM by a mine's dust technician who changes its particle collection filter and cleans the unit after the end of each work shift.

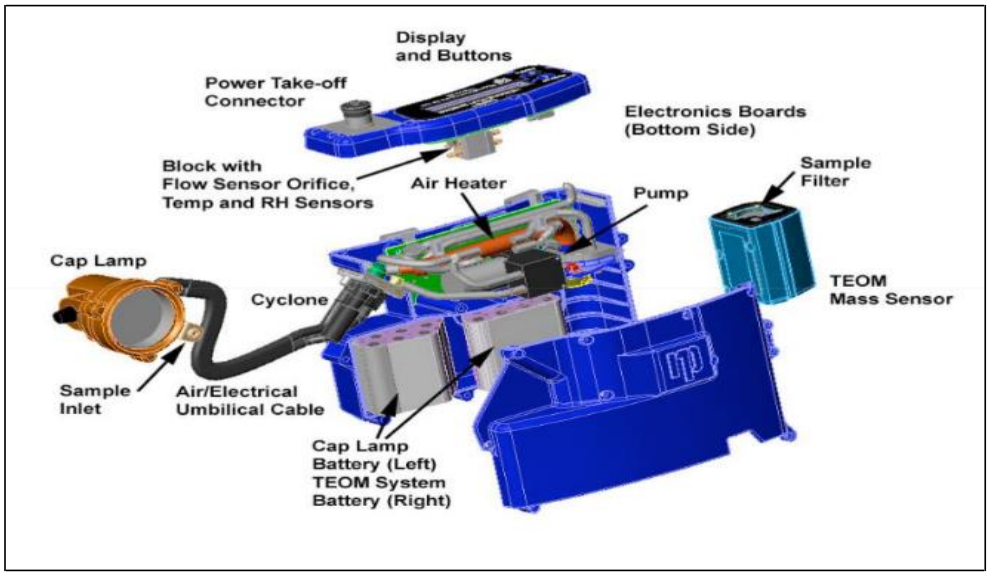


Figure 3.11 Major components of the PDM[4]

Downstream of the mass sensor, the filtered air sample flows through an orifice used in conjunction with a differential pressure measurement to determine the volumetric flow rate. The system computer uses this information to maintain a constant volumetric sample flow by varying the speed of a DC pump.

Figure 3.12 Series 3600 monitor with integrated cap-lamp for mining and Series 3700 monitor for general occupational hygiene monitoring

Welding Fumes and Gases

Purpose

To measure worker exposure to welding fumes and gases to assess compliance with occupational exposure limits.

Occupational Exposure Limits (OELs)

Most open arc or oxy-fuel processes give off both particulate fume and gases. Under the Mine Health and Safety Act (No. 29 of 1996), employers have to carry out a risk assessment to identify any potential exposure to hazardous substances in the work place, and devise and hazards from any fumes and gases that can arise from welding and cutting.

In a number of countries, including South Africa, exposure to welding fume must not exceed 5 mg/m^3 when averaged over an eight hour reference period, but with the proviso that none of the fume constituents exceeds its own exposure limit.

Thus, if fume contains substances with exposure limits less than 5 mg/m^3, e.g. nickel, chromium, cobalt, manganese etc., it is possible that the total fume will require control to levels significantly less than 5 mg/m^3 to maintain control of these more toxic elements.

Thus, fume of different compositions will require control to different levels and the requirements for extraction will vary accordingly, e.g. fume from stainless steel welding will require control to lower levels than fume from carbon steel welding. Gases present in the fume will require control to their respective exposure limits.

A listing of OELs for airborne pollutants likely to be encountered in welding and allied processes are given in Table 6.1.

Verification of compliance with OELs

A visual assessment of exposure to welding fume may be all that is needed to establish a requirement for extraction. For MMA welding of stainless steel or nickel alloys, then extraction will be required in almost all situations.

Additional protection in the form of respiratory protection may be required in some cases. Only when the duration of exposure is very low, will extraction not be required.

The assessment of exposure, and therefore the requirement for extraction, will often be difficult. This is particularly the case with toxic gases where visual assessments are impossible and guidance or experience is required.

Measurement may be necessary to establish whether extraction is required, or indeed, if extraction is already installed, whether additional control methods are necessary. In such cases, measurement should be performed by breathing zone (BZ) sampling (inside the welder's face shield, when one is worn) according to the International Standards Organization ISO 10882 (2000/ 2001).

Table 6.1 Relevant DME 2006 OELs for Welding and Associated Processes

Substance	Formula	OEL ppm	OEL mg/m^3	STEL ppm	STEL mg/m^3
Aluminum metal: Inhalable particulate Respirable particulate	Al	- -	 10 5	- -	- -
Aluminium Welding Fumes	-	-	5	-	-
Barium compounds, soluble	-	-	0.05	-	-
*Beryllium and beryllium compounds [as Be]	Be	-	0.002	-	-
Boron oxide	B_2O_3	-	10	-	20
Cadmium oxide fume [as Cd]	CdO	-	0.01	-	0.050
Calcium oxide	CaO	-	2	-	-
Chromium, metal and inorganic compounds [as Cr] Cr (II) compounds, Metal and Cr(III) compounds *Cr(VI) compounds	Cr	 - - -	 0.5 0.5 0.05	 - - -	 - - -
Cobalt & cobalt compound [as Co]	Co	-	0.05	-	-
Copper fume	Cu	-	0.2	-	-
Fluorides [as F]	F	-	2.5	-	-
Iron oxide , dust & fume [as Fe]	Fe_2O_3	-	5	-	10

*Lead, elemental, and inorganic compounds [as Pb]	Pb	-	0.1	-	-
Manganese fume [as Mn]	Mn	-	1	-	3
Manganese, elemental, and inorganic compounds [as Mn]	Mn	-	1	-	-
Molybdenum compounds [as Mo] soluble compounds insoluble compounds	Mo	 - -	 5 10	 - -	 10 20
*Nickel Nickel, organic compounds [as Ni] *Nickel, inorganic compounds [as Ni] soluble compounds insoluble compounds	Ni	- - - - -	0.5 1 - 0.1 0.5	- - - - -	- - - - -
Nitric oxide	NO	25	30	35	45
Nitrogen dioxide	NO_2	3	5	5	9
Ozone	O_3	-	-	0.2	0.4

Substance	**Formula**	**OEL ppm**	**OEL mg/m^3**	**STEL ppm**	**STEL mg/m^3**
Selenium & compounds, except hydrogen selenide [as Se]	Se	-	0.1	-	-
Silica, amorphous Inhalable particulate Respirable particulate *Silica, crystalline respirable particulate Cristobalite Quartz Tridymite Tripoli Silica fume respirable particulate Silica, fused respirable particulate	SiO_2	- - - - - - - - -	- 6 3 0.1 0.1 0.1 0.1 2 0.1	- - - - - - - - -	- - - - - - - - -
Tin compounds, inorganic except SnH_4 [as	-	-	2	-	4
Titanium dioxide Inhalable compounds Respirable compounds	TiO_2	 - -	 10 5	 - -	 - -
Vanadium pentoxide Inhalable particulate Fume & Respirable particulate	V_2O_5	 - -	 0.5 0.05	 - -	 - -
Welding Fumes	-	-	5	-	-
Zinc oxide fume	ZnO	-	5	-	10

Notes - the OEL for welding fumes is without prejudice to any occupational exposure limits for individual components in the fume. Some welding processes generate fume that contains components, which have specific OELs, these limits should be applied to control exposure if these substances are present in the fume.

Exposure to a substance demarcated with an asterix (*) must be kept as far below the OEL as is reasonably practicable.

Air Monitoring

Routine air monitoring should be conducted to determine the levels of hazardous materials in the atmosphere of the welding area.

Gases are invisible. However, in general, the highest concentration will be found in the vicinity of the visible plume of particulate fume (if there is one).

The exception is ozone, which can form remote from the arc and is less likely to be affected by convection currents arising above the arc. NOx and the inert shielding gases are usually heavier than air, and therefore can sink into low level pockets, compartments, recesses etc, creating dangerous concentrations there.

Sampling for the common pollutant gases can be carried out quickly and cheaply using a chemical indicator method and a simple bellows pump, for example as those sold by Dräger, SKC etc.

The actual readings obtained are only representative of the concentration at the sampling point and the instant of sampling, and as such do not give a true measure of the time weighted average (TWA) concentrations. As a compromise, it is usual to take the average of at least three measurements made with the chemical indicator tube method during consecutive operations of the process.

More accurate measurements for gases require longer sampling times, and more expensive equipment and expertise.

Particulate fume exposure is generally measured using a battery powered air sampling pump to draw air through a filter located inside the helmet. Shift exposure studies on arc welders were performed in this way by the Laboratory of the Danish Labour Inspectorate in the 1960's. Examples of in-helmet sampling are given in Figures 6.1 and on the Air Monitoring page of the SIMRAC Welding OHS Resources CD.

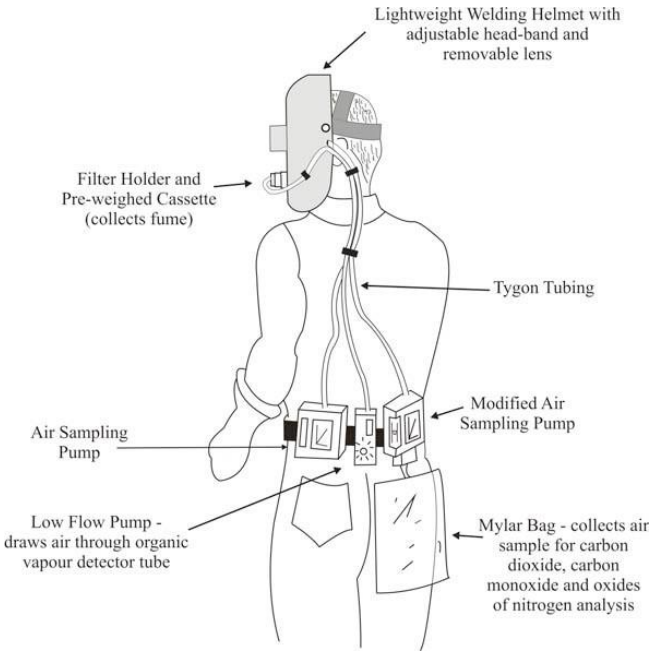


Figure 6.1 Example In-Helmet Sampling for Gases, Vapours and Fume Conducted by NIOSH in the 1970s

ISO 10882 Part 1 (2001): Sampling of airborne particles

Principle

This ISO standard is based on the common occupational hygiene practice to assess welding fume exposure e.g. BZ sampling. Welding fume is collected by drawing a known volume of air through a preweighed filter or filter cassette, mounted in a sampler designed to collect the inhalable fraction of airborne particles.

For personal sampling, the sampler is positioned in the operator's BZ, which is inside the welder's face shield, when one is worn. At the end of the sampling period, the mass of welding fume collected is determined by reweighing the filter or filter cassette.

The mass concentration of welding fume in air is calculated by dividing this by the volume of air sampled.

Exposure to specific chemical agents in welding fume may be determined by chemical analysis of the sample. Alternatively, it may be estimated from the mass concentration of the welding fume in air using fume analysis data for filler materials, e.g. from fume analysis data sheets.

Filters

They must be compatible with the analytical technique, have good collection efficiency, be sufficiently resistant to moisture retention and not be excessively friable.

Sampling pumps

They must give a pulsation free flow, have adjustable flow rate, incorporate a flow meter or a flow fault indicator, and be capable of maintaining the required flow rate to within ± 5% of the nominal value throughout the sampling period.

For personal sampling, the pumps shall be capable of being worn without impeding the operator's normal work activity. The sampling pump can be conveniently fitted to a waist belt, unless it is small enough to fit in the operator's pocket.

Analytical balance

It should be capable of weighing to an accuracy of ± 0,01 mg, able to accommodate the filter used, and calibrated with weights traceable to national standards.

Sampling position

The highest concentration of fume usually occurs in the immediate vicinity of the operator and it is therefore essential that measurement of personal exposure is performed in the operator's BZ. Welders' face shields can provide some degree of protection from exposure by physically deflecting the welding plume away from the BZ.

It will usually be necessary for the operator to wear apparatus that enables the sampler to be maintained in the BZ throughout the sampling period without impeding normal work activity. The BZ is considered to be preferably adjacent to the operator's nose and mouth, at mouth level, a maximum of 50 mm to the right or left of the mouth and in a horizontal position with the sampler inlet facing forwards.

Sampling head attached to the welder's face shield by means of a removable clip A specially designed, removable clip may be used to attach the sampler inside the welder's face shield.

Sampling head attached to the headband of the welder's face shield harness
A specially designed mounting may be used to attach the sampler to the headband of the welder's face shield harness (Figure 6.2)

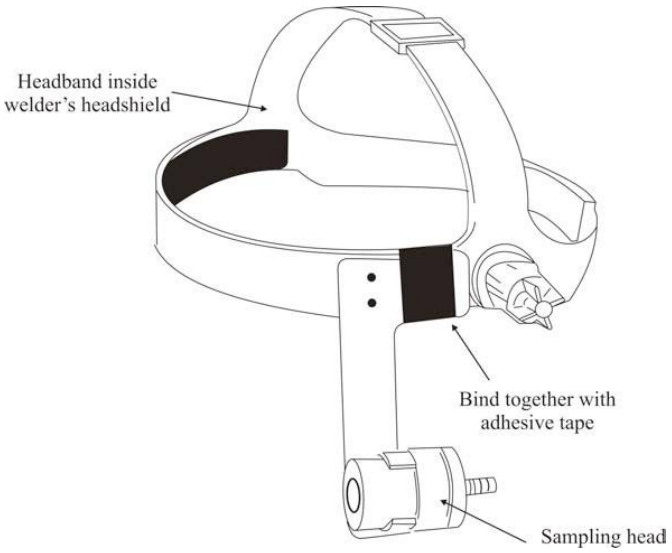


Figure 6.2 Sampling Head Attached to Welders Headband

Sampling head attached to a separate headband

A specially designed mounting may be used attached to a separate headband that is worn in addition to the headband of the welder's face shield harness e.g. a sports person's headband (sweatband).

Analytical techniques

For elemental analysis (e.g. Ag, Al, Ba, Be, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pb, V, Zn), a variety of analytical techniques are available and include:

- Inductively coupled plasma – Atomic emission spectrometry (ICP-AES)
- Inductively coupled plasma – Mass spectrometry (ICP-MS)
- Atomic absorption spectrometry (AAS)
- Atomic fluorescence spectrometry (AFS)
- X-ray fluorescence spectrometry (XRFS)

For Fluoride (F-) analysis, Ion chromatography (IC) and Ion selective electrode (ISE) are used. In the case of Hexavalent chromium (CrVI), two analytical techniques are Ion chromatography (IC) and Spectrophotometry.

It is essential that the filters used are suitable for collection of hexavalent chromium. Many filter materials (e.g. mixed cellulose ester membrane filters) react with hexavalent chromium, resulting in its reduction to the trivalent state and poor analytical recoveries. Quartz fibre filters, glass fibre filters and PVC filters have been found to be satisfactory and are widely used.

Part 2 (2000): Sampling of gases

General

Gases and vapours covered in this standard include ozone (O_3), carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO) and nitrogen dioxide (NO_2), and vapours produced in the welding or cutting of metals having paint or other surface coatings. Fuels, oxidant and shielding gases used in welding and allied processes are not covered.

Personal exposure to gases and vapours in welding and allied processes is generally determined using:

- Direct reading electrical instruments (O_3, CO, CO_2, NO, NO_2)
- Detector tubes (short term or long term) (CO, CO_2, NO, NO_2); or
- Indirect methods involving laboratory analysis (vapours)

Direct reading electrical apparatus or detector tubes are generally most applicable for the measurement of gases. Indirect methods, which involve laboratory analysis of samples collected using a suitable solid or liquid sorbent, are most applicable for the determination of vapours which can be produced in the welding or cutting of metal having paint or other coating.

A complex mixture of particulates and gases is produced in welding and allied processes, and, whatever method of analysis is selected, it is necessary to confirm that techniques, which might have been successful in other applications, are suitable for the welding situation.

In selecting any of the methods described, due regard should be paid to the possibility of interference with the determinations of one gas or vapour by the presence of another, which could result in either enhancement or reduction of the result.

Personal Exposure Measurements

Measurements of very short duration, e.g. for screening purposes, can be made by directly positioning the sampling line or sampler in the BZ and maintaining it in position by hand.

However, to obtain time weighted average concentrations of gases and vapours, e.g. for comparison with OEL values, it will usually be necessary for the operator to wear apparatus that enables the sampler to be maintained in position in the BZ throughout the sampling period, without impeding normal work activity.

Instruments used for hygiene measurements to Biological agents

Classification of biological agents

The chief inspector may publish in the Government Gazette for the purpose of these regulations a document, which may be revised or reissued from time to time, entitled "Categorisation of biological agents according to hazard and categories of containment" (Annexure V) containing a list of biological agents together with the classification of each agent.

Where a biological agent has not been assigned a classification, the employer and self-employed person shall provisionally classify that agent in accordance with subregulation (3) below, having regard to the nature of the agent and the properties of which he or she may reasonably be expected to be aware.

When provisionally classifying biological agent the employer and self-employed person shall assign that agent to one of the groups according to its level of risk of infection and if there is doubt as to which of two alternative groups is the most appropriate, the HBA shall be assigned to the higher of the two.

Information and training

Every employer shall, before any employee is exposed or may be exposed, after consultation with the health and safety committee established for that section of the workplace, ensure that the employee is adequately and comprehensively informed and trained, and is thereafter informed and trained at intervals as may be recommended by that health and safety committee with regard to –

(a) the contents and scope of these regulations;
(b) the potential risks to health caused by the exposure;
(c) the measures to be taken by the employer to protect an employee against any risk from exposure;
(d) the importance of good housekeeping at the workplace and personal hygiene requirements;
(e) the precautions to be taken by an employee to protect himself or herself against the health risks associated with the exposure, including the wearing and use of protective clothing and respiratory protective equipment;
(f) the necessity, correct use, maintenance and potential of safety equipment, facilities and engineering control measures provided;
(g) the necessity of medical surveillance;
(h) the safe working procedures regarding the use, handling, storage, labelling, and disposal of HBA at the workplace;
(i) the procedure to be followed in the event of exposure, spillage, leakage, injury or any similar emergency situation; and decontamination or disinfection of contaminated areas; and
(j) the potential detrimental effect of exposure on the human reproductive process.

- An employer or a self-employed person shall give written instructions of the procedures contemplated in subregulation (1)(i) to the drivers of vehicles carrying the HBA.
- Every employer and every self-employed person shall ensure that he or she or any person who in any manner assists him or her in the carrying out or conducting of his or her business has the necessary information and has undergone sufficient training in order for him or her to identify the potential risks and the precautions that should be taken.

Duties of persons who may be exposed to hazardous biological agents

Every person who is or may be exposed to HBA shall obey any lawful instruction given by or on behalf of the employer or a self-employed person regarding

(a) the prevention of an uncontrolled release of HBA;
(b) the adherence to instructions regarding environmental and health practices, personal hygiene and good housekeeping;
(c) the wearing of personal protective equipment and clothing as prescribed by these or any other regulations;
(d) the wearing of personal samplers, when necessary, to measure personal exposure to airborne hazardous biological substances;
(e) the disposal of materials containing HBA and the disinfection and decontamination of any site contaminated by HBA;
(f) the reporting during normal working hours for such medical examination or test as contemplated in regulation 8(1); and
(g) information and training as contemplated in regulation 4.

Any person shall immediately report to the employer, the health and safety representative or self-employed person any possible accidental exposure to HBA at the workplace, and the employer or self-employed person shall ensure that such incident is investigated and recorded in accordance with regulation 8 of the General Administrative Regulations.

Risk Assessment by the employer or self-employed person

Every employer or self-employed person contemplated in regulation 2 shall, after consultation with the relevant health and safety representative or relevant health and safety committee, cause a risk assessment to be made and thereafter at intervals not exceeding two years, to determine if any person may be exposed to HBA.

The employer shall inform the relevant health and safety representative or health and safety committee in writing of the arrangements made for the assessment contemplated in subregulation (1), give them reasonable time to comment thereon and ensure that the results of the assessment are made available to the relevant health and safety representative or health and safety committee, which may comment thereon.

When making the assessment, the employer or self-employed person shall keep a record of the assessment and take into account such matters as

a) the nature and dose of the HBA to which an employee may be exposed and the suspected route of exposure;
b) where the HBA may be present and in what physical form it is likely to be;
c) the nature of the work or process and any reasonable deterioration in, or failure of, any control measures; what effects the HBA can have on an employee; and the period of exposure.

The employer or self-employed person shall cause the risk assessment to be conducted on

the basis of all available information as far as is reasonably practicable, including

a) classification of the HBA into the relevant risk group, according to its level of risk of infection;
b) recommendations from the manufacturer, supplier or a competent person regarding the control measures necessary in order to protect the health of persons against such agents as a result of their work;
c) information on diseases that may be contracted as a result of the activities at the workplace;
d) potential allergenic or toxic effects that may result from the activities at the workplace; and
e) knowledge of diseases from which an employee may be suffering and which may be aggravated by conditions at the workplace.

An employer shall forthwith review the assessment required by subregulation (1) if -

a) there is any reason to suspect that the previous assessment is no longer valid; or
b) there has been a change in a process involving HBA or in the methods, equipment or procedures in the use, handling, control or processing of the HBA, and the provisions of subregulations (2), (3) and (4) shall apply.

Monitoring exposure at the workplace

The employer shall ensure that the exposure of employees to HBA is monitored in accordance with a suitable procedure that is standardised, sufficiently sensitive and of proven effectiveness in any case which

a) it is requisite for ensuring the maintenance of adequate control of the exposure of employees to HBA; or
b) it is otherwise requisite for protecting the health of employees.
c) Medical surveillance

8.(1) An employer shall ensure that an employee is under medical surveillance if -

(a) the results of the assessment referred to in regulation 6 indicate that an employee may be exposed to HBA; or
(b) the exposure of the employee to any HBA hazardous to his or her health is such that an identifiable disease or adverse effect to his or her health may be related to the exposure, there is a reasonable likelihood that the disease or effect may occur under the particular conditions of his or her work and there are techniques to diagnose indications of the disease or the effect as far as is reasonably practicable such as pre-clinical biomarkers where appropriate for detecting sensitisation to allergens or an inflammatory response associated with exposure; or an occupational health practitioner recommends that the employee concerned should be under medical surveillance, in which case the employer may call on an occupational medicine practitioner to ratify the appropriateness of such recommendation.

(2) In order to comply with the provisions of subregulation (1), the employer shall after extensive counselling and education offer the employee the opportunity to have -

(a) an initial health evaluation, which should be carried out by an occupational health practitioner immediately before or within 14 days after a person commences employment, where any exposure exists or may exist, which comprises an evaluation of the employee's medical and occupational history;
   (i) a physical examination; and
   (ii) any biological tests and other appropriate medical tests or any other essential examination that in the opinion of the occupational health practitioner is desirable in order to enable the practitioner to do a proper evaluation;
(b) periodic medical examinations and tests in cases where HBA are known to be capable of causing persistent or latent infections which in the light of present knowledge, are undiagnosable until signs or symptoms develop;
   (i) can have particularly long incubation periods;
   (ii) can result in an illness which is recurrent in spite of treatment; or
   (iii) are known to have serious long-term effects.
(c) All tests and examinations contemplated in paragraphs (a) and (b) shall be conducted according to a written medical protocol.

(3) The employer shall, in accordance with regulation 8 of the General Administrative Regulations, investigate and record all incidents that result or may result in infections or death of an employee.

(4) All occupational health practitioners shall submit to the health and safety committee for approval a written protocol for procedures to follow when dealing with abnormal results.

Control of exposure to HBA

10.(1) Every employer and self-employed person shall ensure that -
(a) the exposure of persons to HBA in the working environment is either prevented or, where this is not reasonably practicable, adequately controlled; and
(b) standard precautions as explained in Annexure VI are implemented to reduce the risk of transmission of HBA from recognised and unrecognised sources of infection in a workplace.

(2) Where reasonably practicable, the employer or self-employed person shall control the exposure of persons to HBA in the working environment by applying the following measures where appropriate:
(a) Limit the amount of HBA used that may contaminate the working environment;
(b) limit the number of employees who will be exposed or may be exposed;
(c) introduce engineering control measures for the control of exposure, which may include the following:
   (i) Process separation, automation or enclosure;
   (ii) the installation of local extraction ventilation systems to processes, equipment and tools for the control of emissions of airborne HBA;
   (iii) separate workplaces for different processes;
   (iv) proper access control to prevent unauthorized access; and
   (v) immediate personal/environmental disinfection.

(d) introduce appropriate work procedures that employees must follow where materials are used, processes are carried out, or incidents may occur that could give rise to the exposure of an employee to HBA, and such procedures shall include written instructions to ensure-
  (i) the safe handling, use and disposal of HBA;
  (ii) the proper use and maintenance of process machinery, installations, equipment, tools and local extraction and general ventilation systems;
  (iii) the regular cleaning of machinery and work areas by vacuum cleaners fitted with a suitable filter that prevents contamination of the environment; and
  (iv) that a system whereby changes in work procedures and processes that indicate the need for early corrective action can be readily identified;
(e) ensure that emissions to the atmosphere comply with the provisions of the Atmospheric Pollution Prevention Act, 1965 (Act No. 45 of 1965);
(f) display the biohazard sign shown in Annexure 1 and other relevant warning signs; and
(g) specify procedures for taking, handling and processing samples that may contain HBA.

Personal protective equipment and facilities

11.(1) If it is not reasonably practicable to ensure that the exposure of an employee is adequately controlled as contemplated in regulation 10, the employer shall
(a) in the case of airborne HBA, provide the employee with suitable respiratory protective equipment and protective clothing; and
(b) in the case of HBA that can be absorbed through the skin, provide the employee with suitable impermeable personal protective equipment.

(2) Where respiratory protective equipment is provided, the employer shall ensure -
(a) that the relevant equipment is capable of preventing exposure to the HBA concerned;
(b) that the relevant equipment is correctly selected and properly used;
(c) that information, instructions, training and supervision that are necessary with regard to the use of the equipment are known to the employees; and
(d) that the equipment is kept in good condition and efficient working order.

(3) An employer shall -
(a) not issue used personal protective equipment to an employee unless it is capable of being decontaminated and sterilised prior to use;
(b) provide separate containers or storage facilities for personal protective equipment and protective clothing when not in use; and
(c) take steps to ensure that all protective equipment and protective clothing not in use are stored in a demarcated area with proper access control

(4) An employer shall as far as is reasonably practicable ensure that all contaminated personal protective clothing issued is cleaned and handled in accordance with the following procedures:
(a) Where such clothing is cleaned on the premises of the employer, care shall be taken to prevent contamination during handling, transporting and cleaning;
(b) where the clothing is sent off the premises to a contractor for cleaning purposes,

the clothing shall be placed in impermeable, tightly sealed colour coded containers, and such containers shall be clearly identified as contaminated with a biohazard label as depicted in Annexure 1; and

(c) ensure that the contractor contemplated in paragraph (b) is fully informed of the requirements of these regulations and the precautions to be taken for the handling of the contaminated clothing.

(5) Subject to the provisions of subregulation (4)(b), an employer shall ensure that no person removes dirty or contaminated personal protective equipment and personal protective clothing from the premises: Provided that where contaminated personal protective equipment has to be disposed of, it shall be treated as HBA waste as contemplated in regulation 17.

(6) Subject to the provisions of the Facilities Regulations, an employer shall provide employees using personal protective equipment and clothing as contemplated in subregulation (1) with –

(a) adequate washing facilities that are readily accessible and located in an area where the facilities will not become contaminated, in order to enable the employees to meet the standard of personal hygiene consistent with the adequate control of exposure, and to avoid the spread of HBA;

(b) two separate lockers labelled “protective clothing” and “personal clothing”, respectively, and ensure that the clothing is kept separately in the locker concerned; and

(c) separate “clean” and “dirty” change rooms if the employer uses or processes HBA to the extent that the HBA could endanger the health of persons outside the workplace.

Maintenance of control measures

12. An employer shall ensure that –

(a) all control equipment and facilities provided in terms of regulations 10 and 11 are maintained in good working order; and

(b) thorough examinations and tests of engineering control measures are carried out at intervals not exceeding 24 months by an approved inspection authority or by a person whose ability to do the measurements, analysis and tests is verified by an approved inspection authority.

Prohibitions

13.(1) No person shall –

(a) use compressed air to remove HBA from any surface or person; or

(b) eat, drink, smoke, keep food or beverages or apply cosmetics in an HBA workplace or require or permit any other person to eat, drink, smoke, keep food or beverages or apply cosmetics in such a workplace; or

(c) leave a controlled area without prior removal of protective or contaminated clothing.

(2)Every employer or self-employed person shall cause a notice to be posted at a conspicuous place prohibiting the provisions of paragraphs (a) and (b).

Labelling, packaging, transporting and storage

14. Every employer or self-employed person shall, as far as is reasonably practicable, take steps to ensure that
(a) all HBA under his or her control in storage, in transit or being distributed are properly contained and are controlled to prevent the spread of contamination from the workplace;
(b) the colour coded containers in which HBA are transported are clearly marked with a biohazard sign as depicted in Annexure 1 and other relevant warning signs that identify the contents; and
(c) the driver is trained in and equipped with a certificate in emergency procedures.

Special measures for health and veterinary isolation facilities

15.(1) Subject to the provisions of regulation 6, every employer and self-employed person shall, in the case of health and veterinary isolation facilities, take into account
(a) uncertainties about the presence of HBA in a patient or animal and the materials and specimens taken from them;
(b) the hazard represented by HBA known or suspected to be present in a patient or animal and materials and specimens taken from them; and
(c) the risks posed by the nature of the work.

(2) The employer or self-employed person contemplated in subregulation (1) shall ensure that the correct containment measures indicated in Annexures III and VI are selected for persons and animals in isolation facilities that are suspected of being infected with Group 3 or Group 4 HBA in order to minimise the risk of infecting others.

Special measures for laboratories, animal rooms and industrial processes

16. In the case of laboratories, animal rooms and industrial processes the employer or self-employed person contemplated in regulation 2 shall ensure that -
(a) the containment measures required in Annexures III and VI are implemented in laboratories and in rooms for laboratory animals, including diagnostic laboratories, and in rooms for laboratory animals that have been deliberately infected with Groups 2, 3 and 4 HBA or where laboratory animals are suspected of carrying such agents;
(b) the containment measures required in Annexures III and VI are implemented in laboratories handling materials in respect of which uncertainty prevails about the presence of HBA that may cause human disease, but that do not have as their aim working with HBA as such: Provided that the containment measures that are required for Group 3 or 4 are implemented where it is known or suspected that it is necessary; and
(c) the containment measures required in Annexures IV and VI are implemented where Group 2, 3 or 4 HBA are used in industrial processes: Provided that where it has not been possible to carry out a conclusive assessment of HBA, but where the use envisaged might involve a serious health risk for persons, such activities may be carried out only in workplaces where the containment measures correspond to requirement for Group 3 HBA.

Disposal of HBA

17.(1) An employer or self-employed person contemplated in regulation 2 shall

(a) lay down written procedures for appropriate decontamination and disinfection;

(b) implement written procedures enabling infectious waste to be handled and disposed of without risk;

(c) ensure that all fixtures and equipment including vehicles, reusable containers and covers that have been in contact with HBA waste are disinfected and decontaminated after use in such a manner that it does not cause a hazard inside or outside the premises concerned;

(d) ensure that all HBA waste that can cause exposure is disposed of only on sites specifically designated for this purpose in terms of the Environmental Conservation Act, 1989 (Act No. 73 of 1989), in such a manner that it does not cause a hazard inside or outside the site concerned;

(e) ensure that all employees engaged in the collection, transport and disposal of HBA waste who may be exposed to that waste are provided with suitable personal protective equipment; and

(f) ensure that if the services of a waste disposal contractor is used, a provision is incorporated in the contract stating that the contractor shall comply with the provisions of these regulations.

Instruments used for hygiene measurements to dermal exposure and surface contamination

Dermal Exposure Assessment

Hazardous chemicals may enter the body by inhalation, ingestion, injection or dermal absorption. These exposure routes constitute the overall exposure burden on the body. Most occupational exposure studies have focused on measurement of the concentration of air-borne contaminants and other possible routes of exposure are often overlooked.

Several studies have already highlighted the importance of dermal absorption. However, less development occurred in the assessment of dermal exposures to occupational and environmental contaminants compared to air sampling techniques.

This paper intends to highlight the importance of dermal exposure and looks at the methods currently used for its assessment. Advantages and disadvantages of each method in the context of occupational dermal exposure assessment are also outlined. Dermal exposure models, as an easy-to-use and low-cost tool to predict dermal uptake, especially when few or no actual data are available, are also included in this review.

Keywords: Skin absorption; Workplace; Environmental monitoring; Hazardous substances; Humans; Occupational exposure

The Importance of Dermal Exposure Assessment

Health risks from occupational dermal exposure to hazardous substances may occur at many workplaces. In addition to the local effects that chemicals can directly have on the skin, the skin also acts as a pathway for hazardous chemicals to be absorbed into the body.1 Exposures to soot, tar, and mineral oils, for example, have been known to cause skin cancer since decades ago.

Dermal exposure is the process of contact between an agent and human skin at an exposure surface over an exposure period.

Dermal exposure is the direct contact of the skin with liquids, solids and splashes on the skin, or contact with contaminated working clothes or surfaces. It may also occur with aerosols, gases and vapors.

New exposure levels are likely to be less than those seen previously, and they are therefore, more difficult to detect.6 In addition, over the last few years, the emphasis in epidemiology has shifted from qualitative risk identification to quantitative risk assessment, which incorporates exposure-response relationships into the overall exposure assessment process and requires all exposures through multiple routes (i.e., inhalation, dermal and oral) and from various sources (i.e., occupational, environmental and dietary) be accurately assessed.

Therefore, valid and reliable exposure assessment methods are crucial in order to gain the right picture of a worker's overall exposure.

The Current Dermal Exposure Measurement Methods

Similar to the assessment of inhalational exposure, a number of exposure parameters need to be measured for characterization of dermal uptake. The exposure intensity, exposed surface area, duration of skin contact, and the frequency of skin cleaning or repeated exposure should be measured to know the mass of substance likely to be entered the body.8

Proper dermal exposure assessment strategies depend on the study design and the health outcome under consideration. These two factors determine the locations where the measurements should be made.

In the case of local effects like hand dermatitis, dermal exposure is important at the body location of interest, while for systemic effects, the total dermal exposure through all exposed areas is the key for estimating the absorbed dose.

Several dermal exposure evaluation methods have been developed in the past few decades. These methods broadly grouped into direct and indirect methods.

Direct methods

These methods basically assess what is deposited on the skin. Direct methods can be categorized into three subgroups including interception (or surrogate), removal, and visualization techniques.2,9

Interception methods

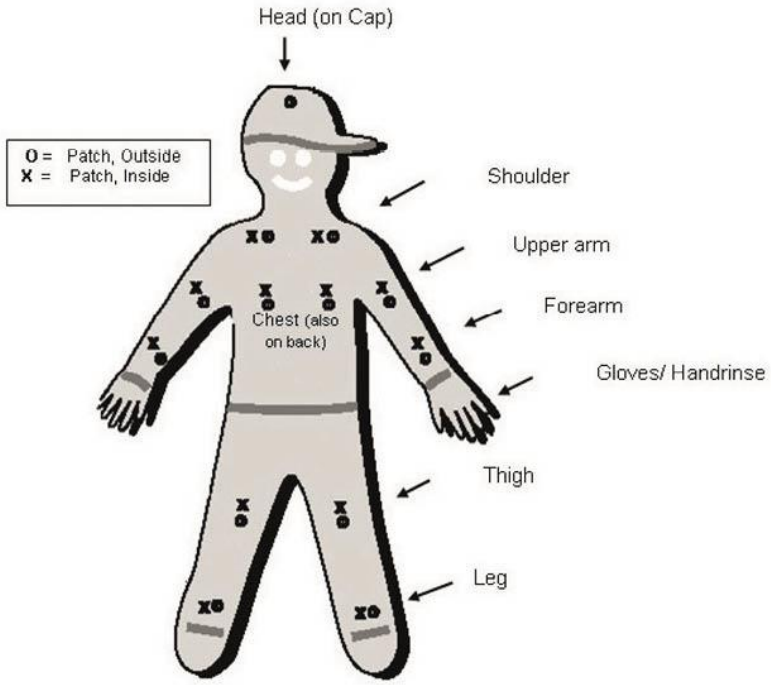
Interception techniques refer to placing dermal dosimeters in the form of patches/pads, gloves and whole body suits against the exposed skin or clothing to collect contaminants. When an interception sampler is worn or attached to the skin sampling zone, it receives the chemicals depositing on the skin of that part.

Selection of the body parts for placing the dosimeters depends on the study design and the exposure scenario. For hand sampling, the cotton gloves may be used instead of patches. For whole-body sampling, a coverall may be used. If we need to sample the head as well, a coverall with a hood or a hat is used.

All surrogate techniques assume that the collection medium captures and retains the chemicals in the same way as the skin does. These methods can be grouped into three categories including patch, glove and whole body methods.

Patch method: Absorbent patches or dosimeters are attached to the different representative parts of body, either inside or outside the clothing (Fig 1). Patches with predetermined size are used to collect chemicals and surrogate for measuring the amount of contaminants coming into contact with the clothing or skin.

The quantities of contaminants on patches are then determined using suitable analytical techniques. The rate of clothing penetration may be determined using the difference between the amounts of chemicals deposited on the inside and outside clothing patches. The composition and size of the patches used in dermal sampling studies are important and need to be based on the physical and chemical properties of the contaminant and exposure conditions.



Body parts for dermal exposure measurement by absorbent patch

Patches are usually made from surgical gauze, cotton gauze, clothing material, polyester-cotton cloth, absorbent paper, and polyurethane foam. These patches should be backed by an impervious material such as aluminum or plastic foil to reduce the potential of contamination of the patches by materials on the skin or clothing, and to prevent seepage of the contamination through the patch to the skin or clothing.

The typical thickness for the patches is approximately 1 mm. The most commonly used patch size is 10×10 cm2.9 Using smaller patches generally fails to provide representative exposure data and should be avoided. A complete set of patches for each exposure period usually consists of 10–12 patches on the locations depicted in Figure 1.

The number of patches used per worker varies from protocol to protocol. Organization for Economic Cooperation and Development (OECD) recommends the use of 13 patches covering 8% of body surface,10 whereas the protocol of the World Health Organization (WHO) relies on six patches covering 3% of body area.

Glove method: Gloves provide a technique for monitoring dermal hand exposure. Several light absorbent cloth gloves are commercially available. They can be used in place of, underneath or on top of the protective gloves.

Physical durability of the sampling gloves is important; they should be capable of withstanding the mechanical forces exerted during the routine activities of the worker. Gloves should not become saturated, and they should be replaced if soaked.

Participants are required to wash their hands in an appropriate solvent to remove background contaminants before wearing the sampling gloves. In the case of using protective gloves in work, sampling gloves should be worn underneath. Considerations should be given to avoid cross contamination.

For example subjects should turn inside out from both hands, and then place the gloves into storage container. As with all dosimeters, gloves need to be pretested to ensure that they do not contain materials that might interfere with the contaminant under study.

Whole body method: A whole body dosimeter, which is usually a type of clothing (including socks) is used for monitoring total dermal exposure. It should be made of suitable absorbent materials such as cotton or cotton/polyester.

Standard whole body dosimeters that are commercially available include white cotton socks, long-sleeved cotton T-shirts, and thermal underwear bottoms and tops. After exposure, dosimeters should be removed and sectioned for storage, extraction, and analysis.

This procedure may be more suitable for liquids than dry contaminants, since powders may be lost in handling. Workers are required to wear whole body dosimeters underneath their normal work clothing to simulate the absorptive surfaces of bare skin protected by normal work clothing.

As a result, work clothing may have the role of a potential source of cross contamination.

Depending on the amount of contamination, whole body dosimeters are at least sectioned into arms, torso and legs. Whole-body suits seem to give more reliable data than patches.

However, both techniques have their advantages and disadvantages.

Advantages and disadvantages of dermal exposure measurement methods		
Method	**Advantages**	**Disadvantages**
Patch method	Easy to use, low cost Cab be used to assess local effects and the effectiveness of personal protective equipment (PPE). The dosimeter is backed with a protective impermeable layer.	Extrapolation from patch to body area needs to be made. Assumption of uniform distribution for contaminant Adherence of the contaminant to the patch and real skin may differ.
Glove method	More applicable Simple to use	It measures the loading available at the time of sampling. Its application is limited to the hands.

Whole body suits	It overcomes the problem posed by the assumption of uniform deposition in patch method. There is no need to extrapolate from patches to larger body regions. It can be used concurrently with biological monitoring to measure absorbed dose. It is less likely to miss areas of body where exposure may occur.	Expensive analysis. It requires large volume of solvent for extraction of the chemical. Due to the lack of an impermeable backing layer chemicals may penetrate through.
Hand washing	Simple to use Low cost	Some solutions may be hazardous to the hands. It is limited for repeated sampling. It does not recover residues absorbed into the skin. Limited use when the substance is highly volatile or rapidly absorbed by the skin. Removal efficiency varies depending on loading, time of sampling, number and duration of hand washings. It is not applicable for whole body measurement. There are uncertainties in the removal efficiency.
Wiping	It can be used to take samples from the skin, work surfaces and work tools.	There is no standard protocol for the number of wipes and the amount of force.
Tape stripping	It measures percutaneous absorption rather than exposure. Simple to use	It is subject to operator variation.
Visualization	There is no need for chemical analysis. It provides instant results. It measures actual skin loading.	A tracer needs to be added whose behavior may differ from the chemical substance under study. It needs skilled operator and it is expensive. Tracer may bind to skin and limits the application of this method.
Biological monitoring	This method measures actual internal dose.	Exposure routes and causes cannot be distinguished.

	It integrates all routes of exposure. It is useful in assessing the effectiveness of PPE.	Human pharmacokinetic studies are required for validation. Not relevant to local skin effects. Only a few biological exposure limits are available. More interference is required to collect samples. Potential problems in using invasive techniques to collect specimens.

For lack of an impermeable barrier compared to patches, there is the potential for chemicals to penetrate through, which could result in underestimating exposure. Any measurements of dermal exposure that use surrogate skin sampling media such as patches, oversuits or gloves, raises the question of sampling efficiency and retention relative to the skin.

Removal methods

Removal techniques including washing, wiping, tape-stripping and suction remove chemicals from the skin (or surfaces). Collecting media are then analyzed by suitable techniques. Removal methods are particularly suitable for substances remaining on the skin for a long time, such as dusts and sticky low volatile substances.

These techniques are often used to sample substances imposing local effects on the skin. Skin and surface sampling should be made before any hand washing or cleaning. These methods should not increase the risk by damaging the skin barrier or enhancing the penetration rate of the substance, e.g., washing with solvents or using wipes soaked in solvents. These techniques, however, are not easily applicable to assess the total body exposure.

Washing: Washing method is usually applied to the hands where a significant proportion of total dermal exposure occurs. For this purpose, the hand is placed in a sealable bag containing a known volume of a suitable solvent.

Vigorous shaking then applied for a given period to wash out the chemicals from the surface of the skin. The resulting mixture subsequently analyzed by a suitable analytical method.

Several types of solutions including various types of aqueous surfactant solutions like water, water with surfactant, and water-alcohol mixture to neat isopropanol or ethanol may be used to collect hand rinse samples. Selection of the solvent depends on the physical and chemical properties of the contaminant being studied.

For example, if a chemical is water soluble, then an aqueous surfactant solution should be used instead of a neat alcohol.

Water used for preparing aqueous solutions should be distilled and deionized. Two consecutive washings can be used to achieve better removal; however, washing may affect the integrity of the skin, and make it more penetrable. The handwashing procedure has been standardized to ensure operator independency in pesticide applications.

Wiping: This method can be carried out dry or using absorbent materials soaked in an appropriate solvent like water, alcohol or other solvents, providing these solvents do not damage the skin, or increase penetration of the chemicals.

For water-soluble chemicals, a wipe pad moistened with deionized water can be used to wipe the skin. The best procedure is generally to allow employees to use a wipe pad to clean their skin surface, and then putting the wipe pad into a clean container.

This sampling method may be used to take samples from the skin, work surfaces and work tools. By taking samples from predetermined areas (Fig 2), it is possible to make comparisons between samples taken at different times or from different surfaces. Several wipes such as cotton balls, cotton pads, filter papers and wet wipes are currently used for this purpose.

There is currently no standard protocol describing the number of wipes and the amount of force needed to be applied in collecting samples.

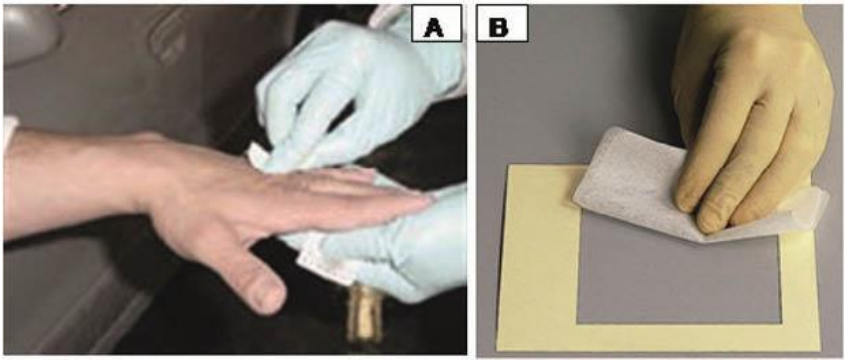


Figure 2: A) Skin wiping; B) Template with a known size for wipe sampling

Tape stripping: Tape stripping removes a thin layer of the outer surface of the skin for determining the amount of the chemicals deposited on the skin.

This method is more invasive than surrogate and other removal methods.

This technique is also used to take samples from surfaces such as tools, work benches and personal protective equipment (Fig 3).

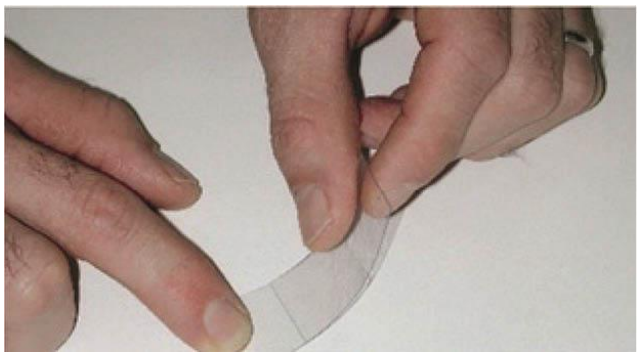


Figure 3: Tape stripping

It is a good method for compounds with low volatility and long retention time on the skin.19 However, it has been argued that tape stripping, as wipe sampling, may not be as accurate as washing method due to the larger variation caused by the operator performing the sampling.20

Visualization techniques

These techniques rely on measuring fluorescent materials deposited or retained on the skin or other surfaces under ultraviolet light by suitable detection or imaging systems.

Fluorescence might be produced by the chemical itself or by a tracer added to the chemical. The most commonly used fluorescent tracers are Uvitex, Tinopal and Calcoflur.

The use of fluorescent compounds is coupled with video imaging measurements to produce exposure estimates.

This requires pre- and post-exposure images of the skin surfaces under long-wave ultraviolet illumination, development of a standard curve relating dermal fluorescence to skin-deposited tracer, and sampling the chemical residue to quantify the relationship between the tracer and the chemical substance deposited on the skin. A portable tracer detection system is shown in Figure 4.

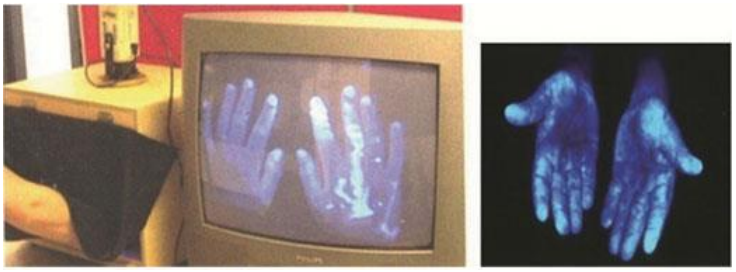


Figure 4: A portable system for detection of the tracers on the skin and surfaces18

Computer analysis of the image can be used to provide a quantitative estimate of the mass of fluorescent compound on the skin and the exposed area. Fenske, et al developed the Video Imaging Technique to Assess Exposure (VITAE), which transformed qualitative observations of the fluorescent skin images into quantitative data by means of a computer software.

Another visualization technique is Fluorescent Interactive Video Exposure System (FIVES). These techniques allow uniform illumination of the body surface and provide information on the area exposed and the amount of substance deposited on the skin.

Indirect methods

Indirect methods primarily refer to measuring a biologic response such as cholinesterase activity in blood or urinary excretion. Measuring contaminants on an accessible surface and dermal exposure modeling also fall into indirect methods group.

The main concern in indirect methods is defining a relationship between biological indices or surface contamination, and dermal exposure levels. The availability of the skin absorption data is crucial for this purpose.

Surface sampling methods (non-human)

The most common method used to assess potential exposure from a contaminated surface is wipe sampling (Fig 2). Materials used as wipe samplers for chemicals include glass fiber, filter paper, cotton swab, surgical gauze, paper tissues and cloth.

While wipe sampling provides information about the mass of the contaminant on a surface, the method suffers from a lack of standardized protocol and fails to relate the mass of contaminant on the surface to the mass transferred into the skin.

The accuracy and precision of wipe sampling depend on surface characteristics, contaminant loading, type of sampling material, and the procedures used.

Suction: Suction method is mainly used to collect particulate matter on surfaces. In this method the contaminant particulates are drawn to the collecting medium using a small vacuum pump (Fig 5). Compared to other removing methods, this technique is more costly, complicated and prone to errors

Figure 5: Collecting particulates from a surface using a suction pump

Biomonitoring

Biological monitoring is the assessment of human exposure through the measurement of internal chemical markers of exposure, such as the chemical agent itself, one of its metabolites, or an exposure-related change in human biological samples, related or unrelated to disease.

This method is useful in determining dermal uptake, especially when dermal exposure is a significant contributor to the employee's overall uptake. Because of the difference between animal and human metabolisms, human pharmacokinetic studies are required to validate the results obtained from biological monitoring. Ideally, surface and dermal sampling should be done concurrently with air and biological monitoring.

By this approach, not only the true dose of an individual is assessed, but also the sources of exposure are identified. Biomarkers of exposure potentially reflect the internal dose and have the advantage that they integrate the exposure through all routes including the skin. However, for most chemicals, no biomarkers of the internal dose are available.

As a result, substances absorbed through the skin will require separate exposure estimates for dermal exposure.

For chronic health outcomes, the cumulative exposure is generally considered as the most appropriate measure of exposure. It is also important to note that biological monitoring has no relevance when local skin effects are being considered.

The advantages and disadvantages of the methods already discussed in this paper are provided in Table 1.

Dermal exposure modeling

Dermal exposure assessment to hazardous substances can be expensive and time-consuming. It also requires a considerable degree of professional expertise and judgment. Furthermore, technical information from a wide range of scientific and professional disciplines is needed.

The great degree of random variability between individuals and workplace situations, and the practical and economic constraints of gathering sufficient data should also be taken into account to make reliable judgments. Therefore, any means to ease the complexity of the exposure assessment process, and making it more structured and formalized is desirable.

With use of a standardized methodology, exposure predictions can be made with some degree of uniformity and reliability. Validating such a method against real exposure data can then lead to refined and more accurate predictive systems called models.

Models are used to assess occupational dermal exposure particularly in cases when few or no actual data are available. They can also serve as tools in epidemiological studies. Some of the currently used models for dermal exposure are described as follows:

Conceptual model for dermal exposure: Dermal contamination may occur from the deposition of aerosols, by direct immersion into a chemical substance (liquid or powder), due to spills and splashes, through vapor penetration, or by direct contact with contaminated surfaces.

Dermal exposure can be considered as an interactive process between a source of contamination and the body with several compartments and processes. A conceptual model of the processes leading to exposure from the source of a hazardous substance to the surface of the skin, and the intermediate compartments has been proposed by Schneider, et al.

Pathways between six compartments and two barriers are described along with eight mass transport processes (Fig 6). The identified compartments are source, air, surface contaminant layer, outer and inner clothing contaminant layers separated by the clothing fabric barrier having a buffer capacity, and the skin contaminant layer, which is separated from the perfused tissue by the stratum corneum that acts as a rate-limiting barrier.

The mass transfer processes include emission (E), deposition (Dp), resuspension/evaporation (L), transfer (T), removal (R), redistribution (Rd), decontamination (D), and penetration/permeation (P).

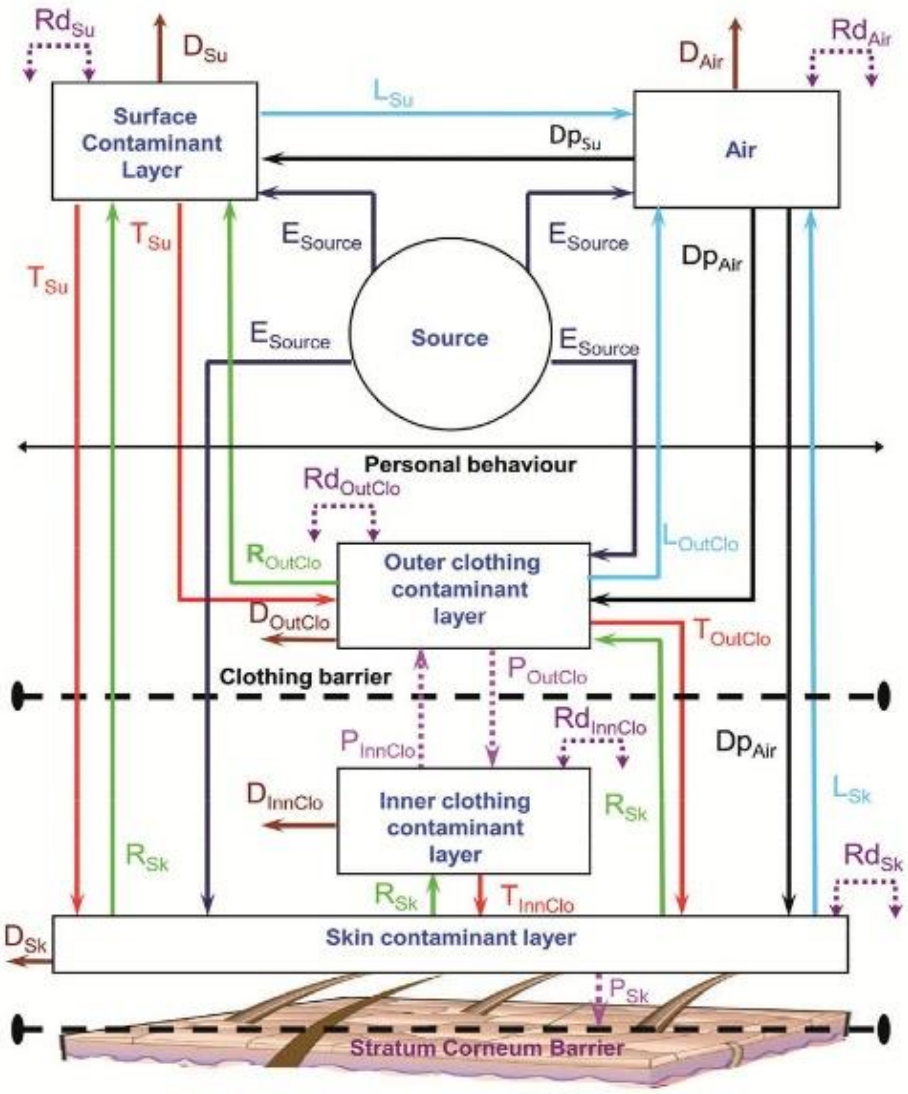


Figure 6: The conceptual model of dermal exposure showing 6 compartments and 8 mass transfer processes. The 6 compartments include source, air, surface contaminant layer (Su), skin contaminant layer (Sk), outer clothing contaminant layer (OutClo) and inner clothing contaminant layer (InnClo). The 8 mass transfer processes are E: Emission, Dp: Deposition, Rd: Redistribution, D: Decontamination, P: Penetration/Permeation, L: Resuspension/Evaporation, R: Removal, and T: Transfer (adapted with permission from Schneider, et al. 199926)

Once a chemical has been assigned to a particular hazard group, it is necessary to consider the assessment of the potential exposure in the workplace.

The combination of the hazard classification of the chemical and assessment of the exposure potential will allow understanding of the level of risk, which leading to the selection of an appropriate control method.

Table 2 shows R phrases for dermal exposure. The relative rankings for systemic toxicity (through the skin) are consistent with the rationale for inhalation hazard ranking and include all health hazards.

Table 2: Relevant risk phrases for the skin exposure	
Risk No.	Phrase
Exposure via the skin	
R 21	Harmful in contact with the skin
R 24	Toxic in contact with the skin
R 27	Very toxic in contact with the skin
Exposure of the skin	
R 34	Causes burns
R 35	Causes severe burns
R 38	Irritating to the skin
R 43	May cause sensitization by skin contact
R 66	Repeated exposure may cause skin dryness or cracking
Exposure of the eyes	
R 36	Irritating to the eyes
R 41	Risk of serious damage to eyes

This toolkit is based on a large number of measurements of dermal exposure in real work situations and is considered a valid tool for assessing dermal exposure.

The tool combines hazard information of a substance or product with an inhalation and/or dermal exposure assessment to calculate a risk score. These risk scores are assigned to exposure bands.

The comparison of exposure bands and hazard bands leads to a risk band or priority band (Table 3). Relevant control measures can be subsequently put into an action plan.

The tool has several other functionalities regarding registration and storage of products.

Stoffen manager generally estimates exposure well and is sufficiently conservative, but it needs more adaptations for specific scenarios.33

Table 3: Priority bands in the stoffenmanager. Hazard band from A: lowest to E: highest and exposure band from 1: lowest exposure to 4: highest exposure level. Overall result, from 1: highest priority to 3: lowest priority (adapted with permission from Marquart, et al, 200833).

Exposure band	Hazard band				
	A	B	C	D	E
1	3	3	3	2	1
2	3	3	2	2	1
3	3	2	2	1	1
4	2	1	1	1	1

Instruments used for hygiene measurements to physical agents

Occupational heat exposure

The measurement of heat exposure (stress and strain) in the occupational environment

Over the years many attempts have been made to equate the level of heat stress with a measurable level of physi- ological heat strain (consequences) with over 90 different heat stress indices being developed up to the early 1980s.

This has led to some confusion as to what may be the best way to assess heat stress and strain and made collection, analysis and comparison of environmental and physiological heat stress data, difficult to interpret.

A robust easy to use heat stress index that can be standardised across industries is thus vital in progressing research in this area, and should help ensure protection of workers' health by assessing all required environmental variables.

Heat stress indices can be classified as either empirical or analytical. An empirical index is based upon the assess- ment of two or more environmental heat parameters and the associated expected response in humans.

An analytical index is based on the heat balance equation, clothing and physiological response of the body and either predicts ther- mal strain based on environmental conditions or monitors physiological indicators of heat strain.

Environmental parameters incorporated in many of the heat stress indices have included various combinations of ambient air temperature, relative humidity, evaporative cool- ing, radiant heat, conductive heat (from sources such as the rock face), and air movement (direction and velocity).

Due to the many variables in calculations and different environ- mental parameters used, the different indices generally do not agree and have widely divergent results when compared in the same environment.[1,2]

This paper will present the most commonly used heat stress index, the Wet Bulb Globe Temperature index (WBGT) and then present a recently developed index from Australia the Thermal Work Limit (TWL) which is presently used in the mining industry.

A short discussion will follow on some practical physiological measurements of heat strain and hydration levels that can be used in the field.

WET BULB TEMPERATURE INDEX (WBGT)

The WBGT index is one of the most commonly used heat stress indices, and the standard in South Africa in industrial settings and is mentioned in Occupational Health and Safety legislation.

Interestingly, the use of the WBGT index is not mandatory in the mining environment where a mix of indi- vidual environmental parameters are used in the proposed occupational hygiene regulations of >25°C wet bulb and/or >32°C dry bulb and/or >32°C mean radiant temperature.

The index was developed in the 1950s for the protection of military personnel, and it combines the dry bulb, wet bulb and globe temperatures into a single figure based upon the formula:

Indoor WBGT = 0.7 NWB + 0.3 GT and the modification for Outdoor WBGT (with solar load) represented as Outdoor WBGT = 0.7 NWB + 0.2 GT + 0.1 DB.

Where:
NWB = Naturally ventilated wet bulb temperature
GT = Globe temperature inside a "Vernon (6″ black) Globe"
DB = Dry bulb temperature (air temperature)

Screening criteria for heat stress exposure and recom- mended work-rest regimes have been developed and set by the American Conference of Governmental Industrial Hygienists (ACGIH) for varying WBGT indices where work demands at different metabolic rates are considered against varying WBGT indices and acclimatisation levels and the recommended work-rest cycle is then given.

The objective of the work-rest regimen is to maintain a balance between work rate (metabolic heat production) and rest rate in accordance with the environmental thermal conditions so as to ensure the core temperature of a worker does not exceed 38°C[6] (see Table 1).

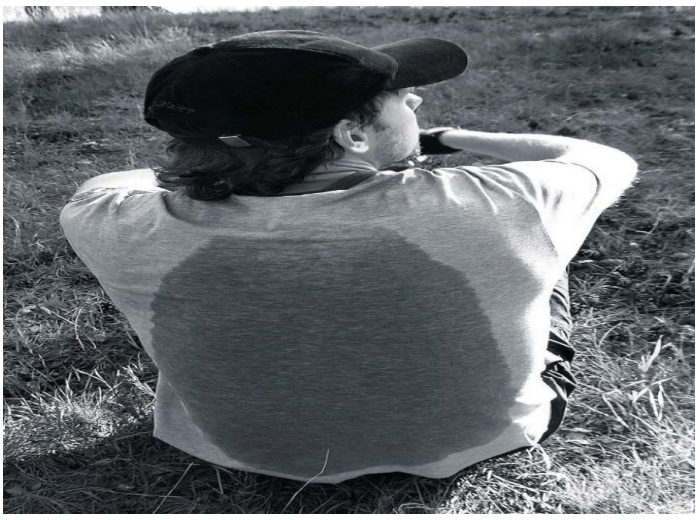
Values are given as WBGT °C. Some of the shortcomings of this method are the observer variability that can be introduced in estimation of the workload into categories set by the ACGIH of light, moderate, heavy or very heavy.

If varying work loads and rest periods in different environments are taken during the work shifts then an estimated hourly time-weighted average (TWA) calculation must be used.

The screening criteria also apply to the normal five-day work week and eight-hour day with conventional breaks, so if extended shifts are under- taken the criteria require recalculation.

In situations where the workload is very heavy with unfit workers the ACGIH recommend detailed analysis and or physiological monitor- ing as an added measure.

Other shortcomings that have been highlighted by various authors are the over-emphasis of the DB reading in the WBGT calculation towards the top end of the scale, an insensitivity to the cooling effects of air movement above 1.5 m/s and high levels of humidity.



Thermal Work Limit (TWL)

A more recent development in Australia of the TWL index has seen its introduction into a variety of industries with an associated reduction in heat illness. The TWL is defined as the maximum sustainable meta- bolic rate that euhydrated (adequately hydrated), clothed, acclimatised individuals can maintain in a specific thermal environment, whilst maintaining a safe deep body core temperature (<38.2°C) and sweat rate (<1.2 kg/hr).

The index is designed specifically for self-paced workers defined as those who can and do regulate their own workload and are not subject to excessive peer, managerial pressure or financial incentives. The index has the advantage that it does not rely on subjective estimation of work rates but does still rely on measurement of specific environmental parameters.

The TWL uses five environmental parameters (dry bulb, wet bulb and globe temperatures, wind speed and atmospheric pressure) and accommodates for clothingfactors and acclimatisation status to arrive at a prediction of a safe maximum work rate for the environmental condi- tions, clothing worn and acclimatisation status of the worker. Information on how the TWL is derived and a simple free software package (Excel format) is available online which can be used to calculate TWL, sweat rates and various other parameters by inserting specific measurement results.

The basic purpose of the TWL index is to calculate the maximum metabolic rate, in W/m^2 of body surface, that can be continually expended in a particular thermal environment within safe physiological limits[8] i.e. the thermal work limit.

The higher the number the higher the sustainable work rate in terms of thermal stress (see Table 2). At high values of TWL the thermal conditions impose no limits on work. See Table 3.

The TWL also has application to engineering sciences, as it allows productivity decrement due to heat (seen as a reduced sustainable metabolic rate) to be linked to cost- benefit calculations of heat control strategies such as improved local ventilation or refrigeration.

This is particularly useful when we consider that 11.4% of the total working cost of an underground goldmine can be attributed to electricity consumption and that in 1999 the mining industry con- sumed 18.4% of the electricity sold in South Africa.

Because the TWL is measured in W/m^2, it can easily be compared to Watts of refrigeration. The impact of localized cooling using various types of refrigeration can therefore be measured directly.

For example, consider a mine being ventilated with 10 m^3/s supplied air at 30°C WB, 40°C DB, 40°C Globe, 100 kPa barometric pressure, and a wind speed of 0.2 m/s. The initial TWL is 110 W/m^2 (which are withdrawal conditions for self paced work, refer to Table 3). If local refrigeration of 100 kW(R) (kilowatts of refrigera- tion effect) is installed it can be calculated using standard psychometric equations that temperatures in the workplace will drop to 28°C WB and 31.4°C DB, which results in an increase in TWL to 158 W/m^2.

The capital and operating costs of this engineering intervention (refrigeration) can be directly evaluated against the cost benefit of improved productivity.

Using the above example, the TWL could have been increased to the same 158 W/m^2 by increasing the wind speed over the skin from 0.2 to 0.7 m/s without any addition of refrigeration, a much cheaper option by instal- lation of a local spot cooling fan or venturi air mover.

This as Brake and Bates[8] indicate is not to say that increasing the wind speed over the skin is able to increase the TWL in all situations; typically, increasing the wind speed beyond 4 m/s provides little further benefit to cooling.

The above example shows how the TWL index has the potential to assess different heat control strategies against cost-benefit implications and can also be extended out to include the heat load implications in various clothing ensembles and personal protective equipment use in regards to thermal insulation and vapour permeability and body cooling and heating.

Table 1. Screening criteria for TLV and action limit for heat stress exposure[6]

	Acclimatised				Unacclimatisd			
Workload demands	**Light**	**Moderate**	**Heavy**	**Very heavy**	**Light**	**Moderate**	**Heavy**	**Very heavy**
Continuous work	**29.5**	**27.5**	**26**		**27.5**	**25**	**22.5**	
75% Work / 25% Rest	30.5	28.5	27.5		29	26.5	24.5	
50% Work / 50% Rest	**31.5**	**29.5**	**28.5**	**27.5**	**30**	**28**	**26.5**	**25**
25% Work / 75% Rest	32.5	31	30	29.5	31	29	28	26.5

Table 2. Some typical metabolic energy production values associated with various mining activities for a South African miner of average size[1]

Task	Energy production W/m^2 (surface area = 1.8 m^2)
Winch operation	66
Sweeping	120
Drilling	178
Loading and pushing ore cars	237
Shovelling rock	260

Table 3. Recommended guidelines for TWL values and control action that should be implemented

Risk	TWL (W/m^2)	Action
Low	>220	Unrestricted work
Medium	141–220	Acclimitisation Zone - Acclimatised workers allowed to work but not alone.
High	116–140	Buffer Zone - Unacclimatised workers must not work at all. - No lone or isolated workers. - Air flow must be increased to greater than 0.5 m/s. - Rectify ventilation if out of service. - Redeploy persons wherever practical. - Workers to be tested for hydration, withdraw if dehydrated. - Work should only continue with authorisation. - Dehydration test to be conducted at end of shift.
Critical	<115	Withdrawal Zone - Persons must not work in this environment unless in emergency conditions or to rectify environmental conditions. - Permit to work in heat to be completed and authorised by manager. - Dehydration test to be conducted at end of shift.

Note: Work can still be undertaken when the TWL is less than 115 W/m^2 however a formal permitting system with management approval should be required.
See Brake and Bates[8] for additional information on requirements and application of the TWL index.

Table 4. An example of Specific Gravity Hydration Level guide

Urine SG level	Risk rating	Hydration rating	Action required
1.000 – 1.021	Low	Adequate hydration	No action.
1.022 – 1.026	Moderate	Hypohydrated	Drink 1 L of water.
1.027 – 1.029	High	Dehydrated	Drink at least 1.5 L of water.
>1.030	Critical	Clinically dehydrated	Unacceptable risk, stop work and drink water until properly hydrated (may take several hours).

PHYSIOLOGICAL MEASUREMENT OF HEAT STRAIN

The measurement of heat strain can also be used to meas- ure the severity of an environment on an individual. The main parameters used for evaluating heat strain are body core temperature, heart rate, sweat loss and urine specific gravity (USG) for hydration status.

Generally, all of these parameters can be evaluated under laboratory conditions, but extension to field measurements makes this far more difficult and sometimes impossible due to the practical constraints of fieldwork. One particular parameter – USG – lends itself to field assessment of individual hydration status and is presented below

Urine specific gravity for hydration status

Sweat loss and fluid intake have a direct influence on hydra- tion status and USG readings can be used as an indication of the hydration status of a person. A urine refractometer is used, a simple instrument that measures the concentration of particles in a solution (grams/ml) by its ability to refract light passing through a small specimen of urine.

Urine is a good marker of hydration, when it is of high osmolarity (resulting in dark colour) it indicates hypohydration (lowered hydration levels) and the conservation of body fluids by the body.[14] These readings are non-invasive, easy and quick to conduct.

Urine specific gravity could be used as an educational tool for workers as to the required fluid intake before and after heat exposure[15] (see Table 4). In some mines in Australia, it is used to assess hydration of miners before a shift as a proactive precautionary measure to avoid increased risk of heat related illness due to inadequate hydration at the start of the shift. Alternatively, colour photographs of urine samples of different specific gravities could be a more practical and simpler on-site educational tool and a reminder to workers to drink adequate fluids (see Figure 1).

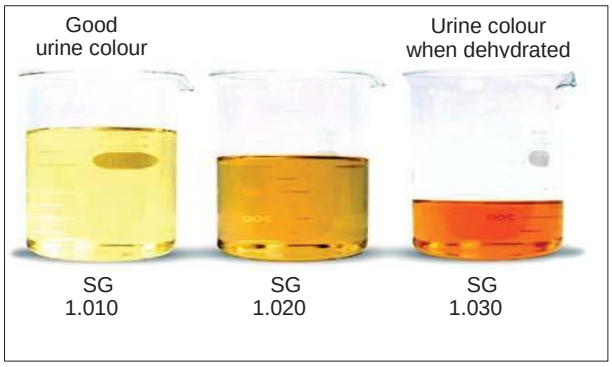


Figure 1. An example of a colour photo indication of urine samples of different specific gravities which relate to hydration status and the requirement for further hydration

CONCLUSION

Many attempts over the years have been made to assess heat stress in the environment using a variety of different environmental and personal parameters and indices derived from these. To date, no single index has managed to incorp- orate all heat stress parameters into an easily applied and calculated index.

The WBGT heat stress index is used in South Africa yet it too has limitations. The recent develop- ment of the TWL index which has been based upon many of the other indices and prior research offers a simple to use index.

Thermal work limit considers all of the required environmental parameters as well as workload, clothing, acclimatisation status and metabolic heat production toderive a single figure output which is easy to interpret.

This indicates the limit of heating and cooling that is sustainable and will avoid heat related disorders. The importance of fluid and electrolyte replacement and physiological moni- toring of this cannot be over-emphasised as an additional personal monitoring measure and should go hand in hand with environmental thermal control efforts and worker education.

Instruments used for hygiene measurements to Ergonomics

Ergonomics

Purpose

Ergonomic surveys are conducted to identify ergonomics-related risk factors in a workplace. The surveys include elementary hazard identification, risk assessment and identification of areas where specialist ergonomics advice is required.

This Chapter provides the reader with basic tools in the form of checklists to identify ergonomics-related risk factors in a workplace. In the present context an ergonomics programme is regarded as a systematic approach to anticipating, identifying, analysing and controlling ergonomics-related hazards. The hazard identification process provides the data needed to identify, control, and prevent work-related injuries and illnesses.

Background

Ergonomics is the science and practice of designing systems to fit people so that the tasks required of the human users are not only within their limitations, but also to ensure that best use is made of their functional capabilities. Unhealthy, unsafe or inefficient situations at work could often be avoided by taking into account the physiological and psychological capabilities and limitations of humans.

Ergonomics is a multi-disciplinary science as specialists from various areas, e.g., engineering, physiology, medicine, psychology, industrial design and occupational hygiene contribute to the body of knowledge. Ergonomics should therefore not be viewed in isolation when applied in the work environment and it is essential to draw on all available skills and experience from the above-mentioned disciplines in a multi-disciplinary team.

Ergonomics differs from other fields by its inter-disciplinary approach and applied nature. As a consequence, the ergonomics approach results in the adaptation of the work environment or workplace to fit people, rather than the other way round.

A large number of factors play a role in ergonomics such as working postures (sitting, standing,

stooping), body movements (pushing, pulling, lifting), the physical nature of the task (energy expenditure), environmental factors (thermal stress, noise, vibration, illumination, air quality), information gained through displays (visually or through other senses), the relation between displays and controls, as well as general work organisation.

These factors largely determine the health, safety, comfort and efficiency of task performance in the workplace.

The ultimate goal of ergonomics is to improve and maintain the well-being of an individual worker. At the same time the well-being of the organisation, reflected by increased productivity, will also be improved and maintained. The application of sound ergonomic principles in a workplace will minimise design-induced human error, and also eliminate significant occupational health and safety risks, especially those related to the musculo-skeletal system.

The identification of ergonomics-related hazards in a workplace should ideally be part of a mine's ergonomics programme, which in turn should form an integral part of the overall occupational health and safety programme.

Most mines have, as a result of the requirements of Section 11 of the MHSA, established risk management elements such as hazard identification, risk quantification, training, audit and feedback within a specific management system but have not yet adequately addressed ergonomics.

Legislation

"Ergonomics" is not a new concept in the South African mining industry. The MHSA makes specific reference to ergonomics. Section 21(1)(c) of the Act states that: any person who designs,

manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during the design, manufacture, erection or installation.

Mine management must ensure that original equipment manufacturers (OEMs) comply with this requirement.

Methodology

Principles

In practice it is essential that the design of workstations and optimal working conditions take the following into consideration:

- The physical sizes of people and the implications for the "fit" of an individual at a workplace and within a facility.
- The cardiovascular system and its limitations on physically-demanding work, as measured by work physiology.
- The major musculo-skeletal system and its limitations on manual materials handling.
- The minor musculo-skeletal systems and their limitations on fine work, manipulation and dexterity.
- Environmental factors such as lighting, noise and thermal comfort, and their impact on worker performance.
- Cognitive capabilities of people and their impact on the processing of information and "human error".

Identification of Ergonomics-Related Hazards

Ergonomics surveys should ideally be conducted on a regular basis to identify any significant changes in a workplace. Effective and regular analysis of the potential hazards in a mine will allow for a greater degree of control of the risks identified.

The selection of a particular task or workplace for further or more detailed investigation should always be done by considering the priority areas of the mine and in consultation with the relevant personnel in a given work area.

Some factors which may indicate the need for intervention include an increase in incidence of musculo-skeletal injury, greater prevalence of absenteeism or significant reductions in worker productivity.

Factors Influencing Data Acquisition

One of the major challenges facing an occupational hygienist or ergonomist is the complexity of human responses. No two workers will respond to a given situation in exactly the same way and various data acquisition techniques are available to address this issue.

The ergonomics experience of an assessor will dictate the level of sophistication of the data acquisition and analysis techniques used for the specific type of work being done. Ergonomics data are useful for health surveillance, assessment of workstation design and selection of tools or equipment, product design, quality aspects, participative aspects and education, training and information.

Due to the inherent complexities it is recommended that simple methods be used (at least initially) to identify potential hazards. It is further recommended that basic checklists be used whenever a work process is changed, when new tasks are introduced, and periodically thereafter (especially after new cases of musculo-skeletal disorders are reported) to detect whether trends exist across jobs that use similar equipment, tools or processes.

Limitations

An effective ergonomics hazard identification and risk assessment process should facilitate the classification of possible high risk jobs in a mining environment. In instances when the risks associated with a job are considered to be extreme when compared with recognised standards, it is strongly recommended that an experienced professional ergonomist be consulted.

Certain jobs may require extensive re-design and this should be done in consultation with the inter-disciplinary team members.

Procedures

When conducting an ergonomics risk assessment the following general steps listed below should be followed [1].

- Identify potential hazards in the workplace
- Estimate the risk for each hazard
- Evaluate the risk
- Prepare risk control action plans

The control of workplace hazards requires regular assessment of working conditions on a mine. Occupational surveillance systems include data collection relating to the specific or general working area, analysis of the data, and some action or response to ensure that surveillance activities are translated into preventive action.

Once areas of priority have been identified it is possible to follow a BASIC ERGONOMICS SURVEY

along the lines suggested by the US Air Force (USAF) School of Aerospace Medicine Ergonomics Program, 2004, as given below [2].

Step 1: Prepare for a workplace ergonomics risk assessment

At the outset it is helpful to review the data available, which identify a shop or workplace as a potential ergonomics problem area. It is also useful to become familiar with the processes and job activities that are performed in each work area.

Step 2: Conduct a workplace/ work area visit

The evaluation needs to be arranged with relevant personnel working in that specific workplace. Various checklists may be used to evaluate the current work demands but should be used cautiously when making generalisations about the working environment.

Step 3: Complete an ergonomics assessment checklist

In conducting an assessment of a workplace it is important to ensure that task or job requirements are clearly detailed. The information needed to complete most work-related checklists can usually be collected by observation and by talking to the workers or their supervisor.

Worker involvement is critical in problem identification and problem-solving processes. Most checklists enable the recording of any comments or suggestions that a worker may have on how to improve the jobs/ processes. Worker suggestions can be helpful later when controls for identified hazards are being evaluated and selected.

Step 4: Assess hazards

Potential workplace hazards will become apparent during the completion of a risk assessment. There are very few workplaces where there are no hazards, so quantification of exposure is important unless the situation is so blatantly hazardous as to warrant immediate cessation of activities.

A useful guideline is to assess the frequency of exposure and to make general notes relating to the type of work done for the majority of the working shift.

Step 5: Hazard control selection (corrective actions)

Once workplace hazards are identified and evaluated using a checklist, the next logical step is to identify appropriate corrective actions (controls) for the hazards that pose the greatest risk of work-related musculo-skeletal disorders (WMSDs). Generally, corrective actions should be identified for any task hazard that receives a task rating of "medium" or "high."

The goal is to eliminate or reduce the magnitude of the risk to the point where the task in question would be rated as "low" risk on follow-up evaluation.

Step 6: Summarise recommendations

Once a list of potential corrective actions has been developed, a final report that summarises the recommendations (with justifications) is mandatory. The intent of this recommendation report is for management to use it for planning and implementing “Corrective Actions”.

Since this report is a summary, only the most critical information from the Checklist Scoring Summary and the Corrective Actions List should be provided.

Evaluation and Interpretation of Results

A key purpose of ergonomics is to enable a work system to function better by improving the interactions between workers and machines [3]. Following a basic ergonomics survey it is essential to evaluate the results collected in a workplace.

The risk assessment should have assisted in the identification of any current or potential hazards to the workers. In evaluating the results it is important to consider the following aspects of any manual task

- Force
- Posture
- Repetition
- Duration

As mentioned previously, certain jobs may require a high level of specialist input by an occupational hygienist, occupational medical practitioner or ergonomist, especially where the work-related problems are not simple to interpret or where corrective steps may require significant workplace changes.

Summary of Procedures

Ideally, actions to prevent ergonomics-related hazards should proceed before injuries and/ or symptoms develop. Sound ergonomics principles should be applied proactively rather than reactively in a workplace.

The first step in a hazard survey is to establish whether functional job descriptions are available. A functional job description typically identifies essential functions, or fundamental job duties, and the physical and mental abilities needed to perform these functions.

If functional job descriptions are available, they may provide useful information for identifying potentially stressful jobs or jobs requiring unique skills or special endurance.

The next step in the identification of ergonomic risk factors in a workplace is a walk-through survey. Investigators observe job activities to detect obvious risk factors, interview workers and supervisors to obtain job information not apparent from observation, and use checklists to score job features against a listing of risk factors.

Hazard surveys should be conducted whenever a job, task or process is changed substantially, when new jobs are introduced, and periodically (especially after new cases of musculo-skeletal disorders are reported) to detect whether trends exist across jobs that use similar equipment, tools or processes.

Checklists

Examples of checklists that may be used for ergonomic hazard identification are provided in the Appendix. These include:

- a general ergonomics checklist (for use in cases when there are instances of heavy manual materials handling, high physical job demands, poor environmental conditions and lack of general workplace organisation);
- a checklist for evaluating vehicle cab design;
- a computer/ office ergonomics checklist and
- a manual tasks risk assessment tool using codes 1 to 5 to score the risk factors.

Reports

The ergonomics survey report must include relevant workplace information that identifies priority areas and practicable recommendations for improvement (see also Chapter 2 Report Writing).

Ergonomics Report Guidelines

The report should include, where relevant, a selection of the sub-sections listed below.

- Checklist findings and selection of priority/ action areas
- These findings should be based on the general ergonomics checklist in the following format:
  - Manual materials handling: list of the major risks associated with manual work
  - Physical energy demands: list of the major risks associated with energy outputs required from workers
  - Other musculo-skeletal demands: list of the major risks associated with working procedures (e.g., repetitive motions or poor working posture)
  - Environmental conditions: list of the major risks associated with environmental conditions (e.g., heat, cold, lighting or noise)
  - General workplace: list of major risks associated with the workplace including obstructions and working heights
- Short description of the current "worst case" or priority sites
- Practical recommendations for improvement

Guidelines for an Ergonomics Action Plan

An ergonomics report should also include an "action plan" that will allow progress to be monitored in priority areas. The plan provides a simple summary of the control options to ensure that progress is monitored.

When completing an action plan after an ergonomics survey the following is a useful framework based on HSE (UK) guidelines [7].

- Summarise and prioritise the control options
  - Examine the completed general ergonomics checklist and the comments to prioritise action. Identify the categories with the highest number of 'Yes' ticks and then set up a priority listing. For example, manual materials handling may have 5 out of 5 'Yes' ticks and therefore requires immediate action in that area.
  - In areas where injury reporting is high or recent cases of injury have been recorded as well as risk factors established in the survey, view this combination as a HIGH PRIORITY for implementing control measures.
- Develop a short-, medium- and long-term strategy to implement controls with proposed completion dates.
- Propose a date for re-evaluation in the action plan table to ensure that implementation dates are monitored in a particular work area.

Practical Example of an Action Plan Summary of

Findings

A worker is required to lift heavy objects from floor level and place them overhead for the entire working shift. The load exceeds 25 kg and the task is repetitive in nature. During the task the worker bends to lift the load and there is also excessive twisting of the spine. The working environment is hot and noisy with only basic PPE provided. Housekeeping is acceptable and the floor is even and clear.

To address the above findings an action plan summary is provided in Table 23.1.

Table 23.1 Action Plan Summary: Workstation 1, Area X (Date of survey: 31March)

Controls to be Implemented	Responsible Person to Implement	Target Implementation Date	Date of Reevaluation
1. Manual Materials Handling. Priority: High			
• Minimise repetitive manual handling • Investigate a hoist	Person A	31 May	31 July
2. Physical Energy Demands. Priority High (load exceeds 25 kg)			
• Investigate reduced load • Job rotation to reduce operator	Person A	31 May	31 July
3. Other Musculo-skeletal Demands. Priority High (posture is poor)			
• Minimise repetitive motions	Person B	31 May	31 July
4. Environment. Priority: Moderate			
• Evaluate noise PPE • Ensure that fresh water is available	Person B	30 June	31 July
5. General Workplace. Priority: No			
• Housekeeping and work area	N/A	N/A	31 July

Checklists

General

When completing any checklist the procedures outlined below should be observed:

- Place a tick in the 'Yes' box where you observe examples of risk factors and a tick in the 'No' box when you do not. A 'Yes' answer may require further investigation.
- Write down a short note (in the comments column) of what the worker is doing in relation to that risk factor, including:
  - Body part(s) affected
  - How long the task is being done (times per minute, hour or day)
  - What aspects of the task are presenting the risk
  - Type of work equipment being used
- Write down any possible control measures that can be taken to minimise the risk of injury.

GENERAL ERGONOMICS CHECKLIST

AREA:	
Number of Workers:	

1. Manual Material Handling	Yes	No	Comments
• Is there lifting of loads, tools or equipment?			
• Is there lowering of loads, tools or equipment?			
• Is there overhead reaching for loads, tools or			
• Is there bending at the waist to handle loads, tools or equipment?			
• Is there twisting at the waist to handle loads, tools or equipment?			

2. Physical Energy Demands	Yes	No	Comments
• Do tools and equipment used weigh more than 25 kg?			
• Is reaching more than 55 cm?			
• Is bending, stooping, or squatting a primary task			
• Is lifting or lowering loads a primary task activity?			
• Is walking or carrying loads a primary task activity?			
• Is stair or ladder climbing with loads a primary task			
• Is pushing or pulling of loads a primary task activity?			
• Is reaching overhead a primary task activity?			
• Is operating equipment or tools above shoulder height a primary task activity?			

GENERAL ERGONOMICS CHECKLIST

(Continued)

3. Other Musculo-skeletal Demands	Yes	No	Comments
• Do manual tasks require frequent, repetitive motions?			
• Does work posture require frequent bending of neck, shoulder, elbow, wrist or finger joints?			
• Does the worker kneel (on one or both knees)?			
• Is the worker unable to change body position often?			
• Does the work involve forceful, quick, or sudden			
• Does the work involve whole-hand grasping with straight elbows?			
• Does job posture involve sustained muscle contraction of any limb for periods of more than 30 minutes?			
• Does the worker stand continuously for periods of more than 30 minutes?			

4. Environment	Yes	No	Comments
• Is the temperature too hot or too cold?			
• Is there dust?			
• Is the workplace poorly lit?			
• Is it a noisy environment?			
• Is the worker working with vibrating hand tools or equipment?			
• Is the worker working with hazardous chemicals?			
• Is the worker subjected to whole body vibration?			

5. General Workplace	Yes	No	Comments
• Are the walkways uneven?			
• Is the floor surface free of obstacles and flat?			
• Is the workplace at a gradient?			
• Is the ceiling height less than 2.5 m?			
• Is there inadequate clearance to or accessibility for performing the task?			
• Is housekeeping poor?			

CHECKLIST FOR EVALUATING THE CAB DESIGN OF A CONSTRUCTION OR MINING VEHICLE

	Area for Consideration	Yes	No	N/A
1	Is the seat height adjustable?			
2	Can the seat be adjusted horizontally?			
3	Is the seat set at the proper height?			
4	Does the seat have a back support?			
5	Does the seat have a lumbar support?			
6	Are there armrests available?			
7	Are the armrests adjustable?			
8	Are the armrests set at the proper height?			
9	Do you feel any vibration from the equipment through the seat?			
10	Do you feel any vibration from the equipment through the floor?			
11	Do you feel any vibration from the equipment through the controls?			
12	Is the seat firmly mounted to the floor of the cab?			
13	Can the seat be tilted backward?			
14	Can the seat swivel?			

15	Is the location of the controls or levers adjustable?			
16	Can you easily reach the levers or controls?			
17	Can you easily operate the levers or controls?			
18	Can you easily reach the pedals?			
19	Can you easily operate the pedals?			
20	Is the cab area large enough (e.g., uncramped area) for you?			
21	Do you have sufficient upward visibility?			
22	Is your view of the operation obstructed (e.g., by cab guards, pipes/hoses, etc.)?			
23	Do you feel the cab is noisy?			
24	Can you control the temperature of the cab?			
25	Does the equipment have steps?			
26	Does the equipment have handrails?			
27	Can you easily open/ close the cab doors?			
28	Does the equipment have proper means for entering the cab?			
29	Does the equipment have proper means for exiting the cab?			
30	Do you have a good general view of the ground?			
31	Are the cab windows free from distracting reflections?			

NIOSH COMPUTER AND OFFICE EVALUATION CHECKLIST

Desk/ Workstation		Yes	No
1	Do you have enough room on your work surface for all your computer		
2	Is your desk surface deep enough to provide at least 45 cm between your eyes and the computer screen?		
3	Are your most frequently accessed items (e.g., phone, manuals) easy to		
4	If your desk has a fixed height, is the keyboard tray adjustable?		
5	Have you removed all under-desk obstructions?		
6	Do you have a document holder to hold paper for prolonged computer		
7	Do your arms rest on, or contact any sharp or square edges on your work		
8	If a large percentage of your time involves using a phone do you use a		
9	Is your source light out of your line of sight?		

Chair		Yes	No
1	Is your chair height adjustable?		
2	Is your chair back adjustable up and down?		
3	Is your chair back contoured to support the lower back?		

4	Is your backrest large enough to support your entire back, but not interfere with the use of your arms?		
5	Is your lumbar support a minimum of 30 cm wide?		
6	Is there room (5 - 10 cm) between the front edge of the seat pan and the back of your knees?		
7	If your feet do not rest flat on the floor when your chair is properly adjusted, do you use a footrest?		
8	Is the top of your footrest covered with a non-skid material to reduce		
9	Do your chair arms interfere with you getting close to your work?		
10	Do your chair arms allow you to sit with your shoulders relaxed and not		
11	Does your chair have removable armrests?		
12	Is the distance between your armrests adjustable?		
13	Are your knees bent forming approximately a 90 degree or greater angle?		
14	Does the chair have a stable base supported by five legs with castors?		

Monitor		**Yes**	**No**
1	Is the viewing distance to your computer monitor somewhere between		
2	Is the top of your computer screen at or just below eye level?		
3	If you wear bifocals or trifocals, can you see the computer monitor without having to tilt your head back to read the screen or other items		
4	Is your computer monitor free of glare or reflections?		
5	Is the monitor screen clean?		
6	Is the character size easy to read?		
7	Do you have blinds on the windows near your computer?		
8	Do you use a glare screen to reduce glare on your monitor?		

Keyboard		**Yes**	**No**
1	With your chair adjusted properly is your work surface at approximately		
2	Are your shoulders relaxed and not elevated when you work at your work		
3	Is the height of your keyboard low enough so your arms are relaxed at		
4	When you address your work surface to type or write is there approximately a 90 degree angle between your forearms and upper arms and are your elbows close to your body?		
5	When you address your work surface to type are your wrists in line with your forearms and not bent upwards, downwards, or side-to-side?		
6	Do you have a wrist rest to support your wrists in a straight and neutral		

Work Habits		Yes	No
1	Do you take short and frequent breaks every 20 - 30 minutes?		
2	Do you frequently change body positions while working?		
3	Do you provide your eyes with vision breaks every half hour?		
4	Are you free from experiencing any pain or discomfort while working?		

Mouse, Trackball, or Other Input Device		Yes	No
1	Is your mouse, trackball, or other input device (i.e., touch-pad, etc.) located directly in your immediate reach zone?		
2	Is your mouse or trackball positioned next to your keyboard?		
3	Is your mouse or trackball placed together with your keyboard on an adjustable work surface or tray?		
4	Is your mouse work surface stable?		
5	Is the mouse or trackball at the same level as your keyboard?		

Manual Tasks Risk Assessment Tool (ManTRA) V 2.0 Scoring Matrix

Body Region	Task Codes									Cumulativ
	To	Duration	Cycle Time	Repetition Risk	Force	Speed	Exertion Risk	Awkwardness	Vibration	
Lower Limbs										
Back										
Neck/ Shoulder										
Arm/ Wrist / Hand										

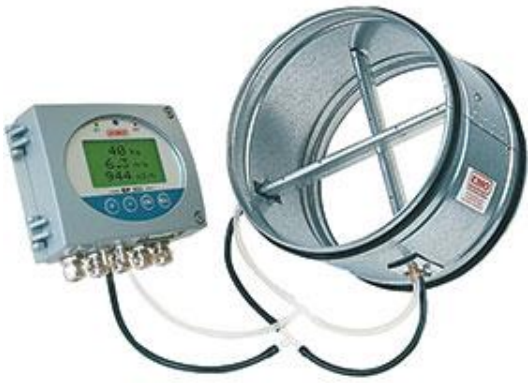
Codes				
1	**2**	**3**	**4**	**5**
Total Time (Total time which would be spent performing the task on a typical day)				
0 - 2 h/day	2 - 4 h/day	4 - 6 h/day	6 - 8 h/day	> 8 h/day
Duration of Continuous Performance (Time for which repetitions of the task are performed				
< 10 min	10 - 30 min	30 - 60 min	1 - 2 h	> 2 h
Cycle Time (Duration of task which is performed more than once without interruption)				
> 5 min	1 - 5 min	30 s - 1 min	10 - 30 s	< 10 s
Force (A maximum force score corresponds to the maximum force possible)				
Minimal force		Moderate force		Maximum force
Speed (The least risk arises when a task involves slow to moderately paced movement**s)**				
Slow movements	Moderately paced	Little or no movement - static posture	Fast and smooth movements	Fast, jerky movements
Awkwardness (Typically postures which involve significant deviations from the mid range of				
All postures close to neutral	Moderate deviations from neutral in one direction only	Moderate deviations in more than one direction	Near end range of motion posture in one direction	Near end range of motion in more than one direction
Vibration (**Whole body:** lower limbs, back, and neck regions. **Peripheral:** shoulder/ arm and wrist/				
None	Minimal	Moderate	Large amplitude	Severe Amplitude

Codes:	**1**	**2**	**3**	**4**	**5**
Scoring key for Repetition					
Cycle Time	**Duration**				
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	4	4	5
4	2	3	4	5	5
5	3	4	5	5	5
Scoring key for Exertion					
Speed	**Force**				
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	4	4	5
4	2	3	4	5	5
5	3	4	5	5	5

Action may be indicated if, for any region, the Exertion risk factor is 5, the sum of exertion and awkwardness is 8 or greater, or the cumulative risk is 15 or greater.

Instruments used for hygiene measurements to Air velocity and pressure

Air velocity and flow measurement in system ducts Pressure Measurement & Control



Kimo manufactures a new system to measure air velocity and airflow in ducts.

The Debimo measuring blades can easily be installed inside any circular or rectangular duct and the streamlined design avoids any air loss and turbulence inside the duct. This system is based on a differential probe – also called an averaging Pitot tube – and can measure dynamic pressure at different locations.

This pressure is measured with the new generation of Kimo CP300 transmitters. These models have the accuracy required to measure differential pressure, to calculate air velocity from 2 to 100 m/s and to control airflow in ducts.

When the duct sizes have been configured the system enables the user to:

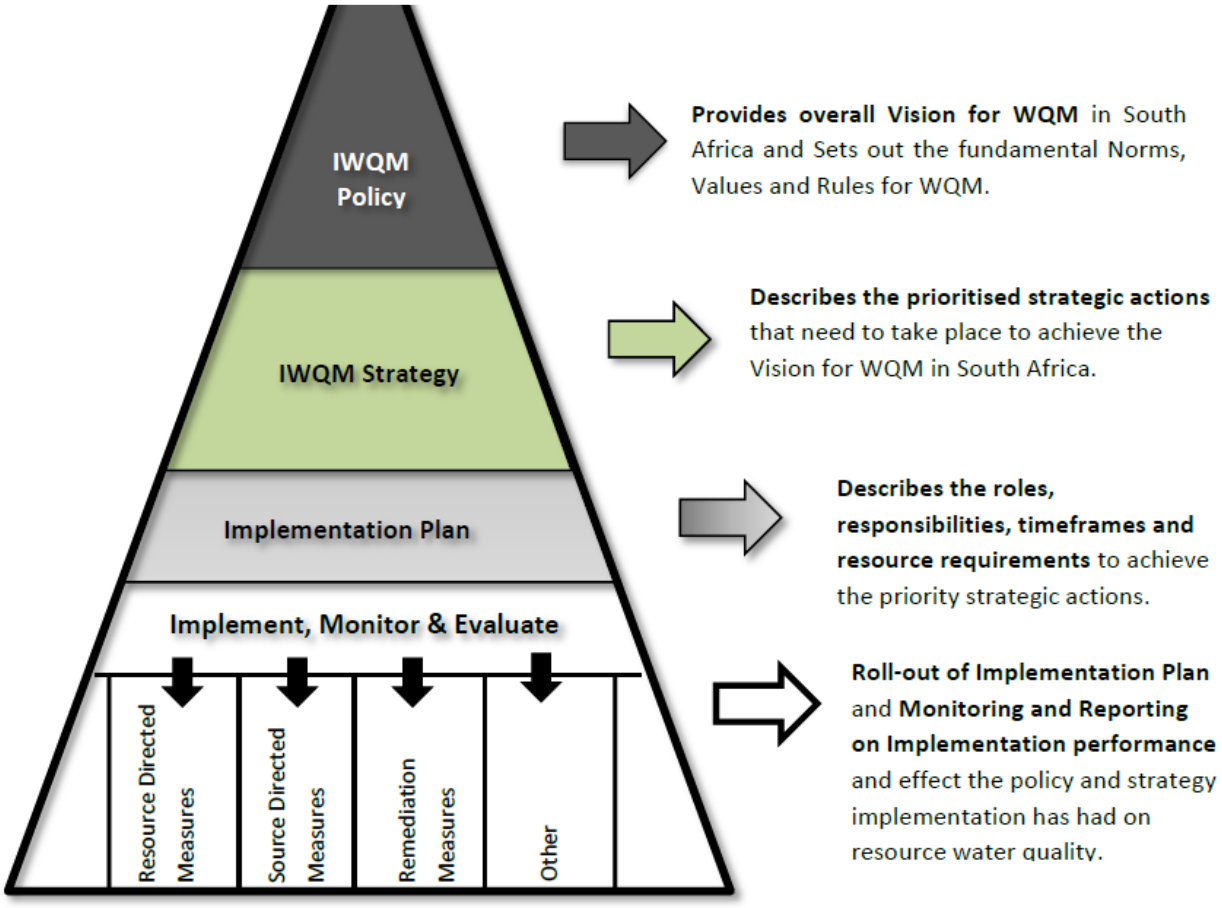
• *Compensate air velocity and airflow according to air temperature.*

• *Enable different setpoints on 2 relays.*

The data can be sent through two 4-20 mA or 0-10 V analog outputs, or through the RS-485 Modbus digital output.

Instruments used for hygiene measurements to Water quality

The Monitoring and Evaluation Framework articulates the indicators to be monitored to determine the progress of the actions to be implemented and provide the foundation required to manage water quality adaptively. It also outlines the reporting structures and processes to be followed.



Different Ways to Test Water Quality

What is the best way to test water quality for your purpose? This article discusses and compares commonly used scientific water quality testing kits that can be used to quantify the quality of various water parameters.

Biological Indicators

Biological monitoring metrics is the simplest and least expensive method. It involves monitoring the presence and abundance of members of bio-indicators common to the area, eg:

- ***Insects*** such as the mayfly, stone-fly and caddisfly. Generally, the greater the number found, the better the water quality. Organisations in the United States, such as EPA offer guidance on developing a monitoring program and identifying members of these and other aquatic insect orders.
- ***Bivalve molluscs*** are largely used as bio-indicators to monitor the health of aquatic environments in both fresh water and the marine environments. A typical project is the Mussel Watch Programme,[22] but today they are used worldwide.
- ***Benthic macro-invertebrates*** (such as the aquatic earthworm) is a bio-monitoring tool that is used by the Southern African Scoring System (SASS) system to measure river health. miniSASS is a simpler scoring system that can be used by anyone, even school children.

Test Strips

Test strips for various water quality parameters are available, such as pH, chlorine, etc. Here you dip a little paper strip with graduated colours into your water sample and match it with a colour on a printed list, to determine the level of the parameter.

Test strips are inexpensive, quick and easy to use, but offer the least accuracy and precision, due to printing variations, poor resolution and the variability of the human eye.

Titration / Drop Test Kits

This simple method uses visual titration. A chemical (reagent) is added to a water sample and the concentration is then determined by counting the number of reagent drops or tablets required to induce a colour change.

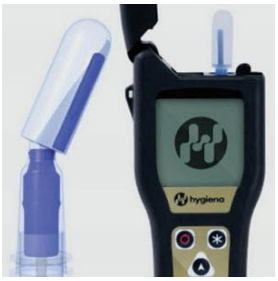
It offers higher accuracy than test strips, but involves some technical ability, because careful counting, basic calculations and and the ability of the human eye will be required. It is a rapid, economical test for all chemical parameters, such as pH.

The exception to the rapidity of the testing are microbiological tests, such as those for coliform / e.coli. These require incubation for 12 – 48 hours.

ATP / Luminescence Tests

A luminometer and a consumable testing device can be used to instantly measure the presence or absence of bacterial contamination in water. It is ideal for quick screening, but more in-depth and time consuming testing will need to be undertaken if more detail is required.

Here the initial cost of the luminometer instrument is costly, but replacement consumables less expensive.



Electro-Chemical Testers

These testers comprise of a pen-type, hand-held or bench-top meter and an electrode. They are very useful for in-the-field / in-situ testing and are usually rugged and waterproof.

However, the electrode needs to be carefully maintained and will need to be replaced every few months to few years, depending on circumstances.

Only a few key parameters can be measured in this way, such as pH, electrical conductivity, dissolved oxygen, total dissolved solids and salt. The many other water quality parameters will need to be measured using another method.

Colorimetric / Comparator Test Kits

Colorimeters or comparators have been widely used by companies for well over 100 years, to measure the quality of water. A reagent is added to a known sample of water. The intensity of colour is then compared with coloured plastic or glass filters, in order to see the concentration of chemical present in the water (eg. Chlorine).

These require some skill to use and are dependent on the variability of the human eye, which means that it is less accurate than a digital photometer.

Comparator discs are available in plastic and glass. There are hundreds of different discs available, to measure different parameters and different ranges. Plastic discs are less expensive than glass discs, but do not last as long. The glass discs are very stable, Selectech has customers who have used them for decades.

Photometric Test Kits

The most popular option today is the modern electronic photometer. This is the easiest and most accurate way to test water, if you are performing frequent water testing, or require precise results.

The micro-processor controlled digital systems have highly reproducible results as they are not dependent on the human eye. No special training is required to use a photometer that comes with step-by-step instructions.

After the initial outlay for the instrument, the cost per test for both the comparators and photometers is lower than many other products.

The cost per test for a glass comparator test kit vs a digital photometer is very similar.

Spectrophotometers

For specialised water testing that requires many parameters to be tested with the highest precision levels, a spectrophotometer is the ultimate instrument.

This instrument features a dual beam optical system, one of which is reference beam, for above average accuracy. UV light and / or visible light can be used. Further functions can include measurement of transmission and absorbance, scanning of spectra and kinetics analysis.

Newer photometers and spectrophotometers are equipped with the latest pre-programmed methods that can be updated via an internet connection.

Further technological features include interfaces to a PC, blue-tooth, USB and Ethernet.

Instruments used for hygiene measurements to Chemical agents

Aim:

- To control health hazards to workers arising from exposures to potentially hazardous chemical agents/substances;
- HCS definition: any toxic, harmful, corrosive, irritant or asphyxiant substance or a mixture of substances for which an occupational exposure limit is prescribed or a substance that can be shown to be harmful to health.

Scope:

- All employers, or self-employed person carrying out work at a workplace;
- Excludes: workers exposed to biological and radioactive agents, working on the mines;
- Superseded by Asbestos and Lead regulations.

INFORMATION AND TRAINING: Employer's duty to train and the worker's right to know:

Obligation on employer to provide training on:

- contents and scope of the regulations;
- possible sources of exposure;
- potential hazards to health and to reproductive capabilities (male and female);
- protective measures, including PPE, hygiene, engineering controls, work practices, etc.;
- necessity of environmental monitoring and medical surveillance;
- emergency procedures.

Includes those transporting HCSs (eg. drivers).

Responsibilities on both employer to provide, and worker to accept training.

Obligation on workers:

Places obligation on exposed worker to obey lawful instructions relating to:

- control of exposures;
- wearing PPE;
- medical surveillance and environmental monitoring
- hygiene measures;
- training and information.

EXPOSURE ASSESSMENT:

Introduces mandatory Risk Assessment process for Employers. Have to identify:

- the HCS to which employees potentially exposed;
- possible health hazards associated with the process;
- in what physical form and where HCS likely to be present;
- routes of exposure;
- nature of the work process and the controls present.

Risk Assessment must be done in consultation with health and safety reps or committee.

Repeat at least ***every 2 years***, or more frequently if change in process or inputs.

Triggers both environmental monitoring and medical surveillance.

AIR MONITORING:

- Follows from Risk Assessment;
- Must be done by ***"Approved Inspection Authority"*** or equivalent;
- Must follow NIOSH sampling method (OESSM): personal sampling;
- In consultation with the safety reps or committee;

- ***Frequency:***
  12 months for HCS with ***control-OEL*** (Table 1 of HCS Regulations. - Open "Book" Regulations, "Book" Hazardous Chemical Substances Regulations, then "Book" Annexure 1 and see "Occupational Exposure Limits - Control Limits" page)
  25 months for HCS with ***recommended-OEL*** (Table 2 of HCS Regulations. - Open "Book" Regulations, "Book" Hazardous Chemical Substances Regulations, then "Book" Annexure 1 and see "Occupational Exposure Limits - Recommended Limits" page);
- If OELs exceeded, prompts remedial action: control measures, PPE, respirator zone.

RESPIRATOR ZONE:

- Where not possible to reduce environmental exposure below recommended OEL, can reduce personal exposures by using respiratory PPE. Leads to establishing a Respirator Zone.
- Demarcated as such, strict controls: PPE, no food, smoking etc.

MEDICAL SURVEILLANCE:

Follows from Risk Assessment.

Prompted if:

- Exposure to substances with known biological exposure indices (Table 3 of HCS Regulations. - open "Book" Regulations, "Book" Hazardous Chemical Substances Regulations, then "Book" Annexure 1 and see "Biological Exposure Indices" page);
- Substance not listed but known to be a health hazard and can be monitored.
- Recommendation of occupational health practitioner.

Includes:

- initial examination and history (within 15 days of employment);
- appropriate clinical assessment including special tests;
- follow up at set intervals (at least ***2 yearly***).

Practitioner can remove worker from exposure based on medical monitoring results (declare worker unfit to work).

Forms of medical surveillance:

- ***Biological monitoring***: measures the extent of absorption of HCS into the body eg. Blood lead, urinary arsenic;
- ***Biological effect monitoring***: measures the intensity of biochemical or physical damage due to exposure eg. Red cell cholinesterase;
- ***Medical screening***: detects any adverse health effects of HCS on the worker eg. Lung function test for asthma.

Biological Exposure Indices (Table 3 of HCS Regulations):

- ***Reference values*** for guidance in the evaluation of potential health hazards;
- Indicates level of HCS (or metabolite) detectable from a specimen of a healthy worker exposed to a HCS to the same extent as a worker with inhalation exposure to an OEL-TWA;
- Apply to 8-hr exposure 5 days a week;

- If measurements persistently exceed the BEI, the cause must be investigated and proper action taken;
- Are ***NOT*** intended for use as a measure of adverse effects or for diagnosis of an occupational illness;
- See Table 3 of HCS Regulations: Meaning of Notations:
  A : identifiable population may have increased susceptibility to HCS
  B : background (non-occupational sources) levels are included in the BEI
  C : non-specific (but better correlate to exposure than specific tests)
  D : quantitative interpretation of measured value is ambiguous.

RECORDS AND CONFIDENTIALITY:

- all records of medical, environmental monitoring and risk assessments kept;
- records kept for at least ***30 years***;
- transfer of records to regional DOL when workplace closes down;
- confidentiality maintained.

CONTROL OF HCSS:

Establishes ***hierarchy of control*** measures - PPE is a last resort:

HIERARCHY OF CONTROLS SPECIFIED IN HAZARDOUS CHEMICAL SUBSTANCES REGULATIONS:

ADMINISTRATIVE CONTROLS:

1. Substitute.
2. Limit amount used.
3. Limit number of employees exposed.
4. Limit period of exposure.

ENGINEERING CONTROLS:

1. Enclose, automate or separate process.
2. Install local extraction ventilation.
3. Use wet methods.

WORK PROCEDURES:

1. Safe handling and disposal.
2. Maintain equipment.
3. Clean working areas.
4. Take early corrective action.

IF CONTROL IS NOT REASONABLY PRACTICABLE BY THE ABOVE METHODS:

PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING:

1. Appropriate to hazard.
2. Employees trained and supervised in use.
3. Careful maintenance, storage, cleaning and disposal.
4. Washing facilities, dual lockers and change rooms.

(Section 12 deals with adequacy of control equipment and need for audit of control measures every 25 months by an approved inspection authority).

Two types of HCSs:

- Those for which level is a health-based limit = ***Recommended OEL (R-OEL)***: Table 2 of HCS Regulations;
- Those for which health-based limits moderated by considerations of practicability = ***Control OEL (C-OEL)***: Table 1 of HCS Regulations.

For substances with ***Recommended OELs (R-OELs)***, employer must aim to achieve levels below OEL as far as possible. Temporary excursions can be tolerated if without significant risk of exposure and does not signify failure of control mechanisms.

For substances with ***Control OELs (C-OELs)***, employer ***HAS*** to keep levels below OEL. If cannot do so by engineering controls, etc, can declare a Respirator Zone and use respiratory PPE to protect workers (last resort). No excursions tolerated due to presence of residual risk. Usually for known carcinogens and where no threshold of effect identified.

STEL (Short-term exposure limit) vs TWA (time-weighted average):

To differentiate between acute and chronic effects of HCSs:

- ***TWA***: The long-term (8-hour) time weighted average exposure limit is intended to control effects by restricting the total intake by inhalation over one or more workshifts.
- ***STEL***: Short-term exposure limits (usually 15 minute) apply to HCS, which produce effects with brief single or repeated exposures. If not STEL is specified, rule of thumb is three times the long-term limit.

Dusts:

Not all dusts have been assigned an exposure limit. In such cases personal exposure limits assigned for:

- inhalable dusts: 10 mg/m^3
- respirable dusts: 5 mg/m^3

Skin:

- For certain substances (lipid soluble), dermal route is a more significant route of absorption eg. phenol, aniline, certain pesticides;
- Denoted as ***Sk*** in Table 1 and Table 2 of HCS Regulations;
- Biological monitoring may be more useful in such cases.

Sensitizers:

- Certain HCS may cause sensitization in susceptible individuals and cause health effects after very minute concentrations of the HCS eg. isocyanates;
- May be through respiratory or dermal route;
- Result typically in asthma, rhinitis, extrinsic allergic alveolitis, allergic contact dermatitis;
- Denoted as ***Sen*** in Table 1 and Table 2 of HCS Regulations;
- Activities associated with short-term peak concentrations may be more important.

Mixed exposures:

- Majority of exposure limits relate to single compounds;
- Effects may be independent, additive or synergistic
- For additive effects exposure limit defined as: $C_1/L_1 + C_2/L_2 + C_3/L_3 + ... < 1$
  (C: TWA concentration for a specific HCS, L: exposure limit for that substance).

SUMMARY OF THE ASSESSMENT CYCLE:

Timetable of Actions Required by Hazardous Chemical Substances Regulations:

BASELINE		THEREAFTER
1. Exposure risk assessment	Immediate [1]	2-yearly
2. Air monitoring [2, 3] Control limit substances Recommended limit substances	 Immediate Immediate	 Annual 2-yearly
3. Review of control measures by approved inspection authority	Immediate	2-yearly
5. Medical surveillance [2]	Immediate	2-yearly [5]
Notes: 1. And at change in use or breakdown of controls. 2. Contingent on findings of exposure assessment. 3. Carried out or verified by an Approved Inspection Authority. 5. Or otherwise at the discretion of the occupational medicine practitioner.		

PERSONAL PROTECTIVE EQUIPMENT (PPE):

PPE is clearly last resort after engineering, administrative and other controls. Obligation placed on employers to:

- provide respiratory and skin PPE as required;
- ensure PPE in good working order and well maintained;
- accompanied by training of workers;
- supported by adequate storage, cleaning and changing facilities.

(Section 5 places obligation on worker to use the PPE).

OTHER: PROHIBITIONS, LABELLING OF HCSs:

Smaller section of the Regulations deal with specific prohibitions (ban use of compress air, control of smoking and eating by workers, etc.). Labeling, packaging and transport of HCS dealt with by referring to SABS codes. Environmental emissions and disposal of HCSs in terms of environmental legislation.

ISSUES AND PROBLEMS:

1. No statutory protection against job loss on medical grounds - left to general labour legislation and section 26(2) of OHSA, which prevents victimisation.
2. Does not address mixtures of HCSs well. Assumes either additive or no interaction. Schedules do not list whole formulation.
3. Not well suited to HCS whose main route of absorption is dermal. Relies on air levels. Not suited for working in an open environment.
4. Not explicit on Risk Assessment process.
5. Confusion around definition of occupational health practitioner.
6. Shortage of skills to provide sufficient "approved inspection authorities".
7. Shortage of enforcement personnel.

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