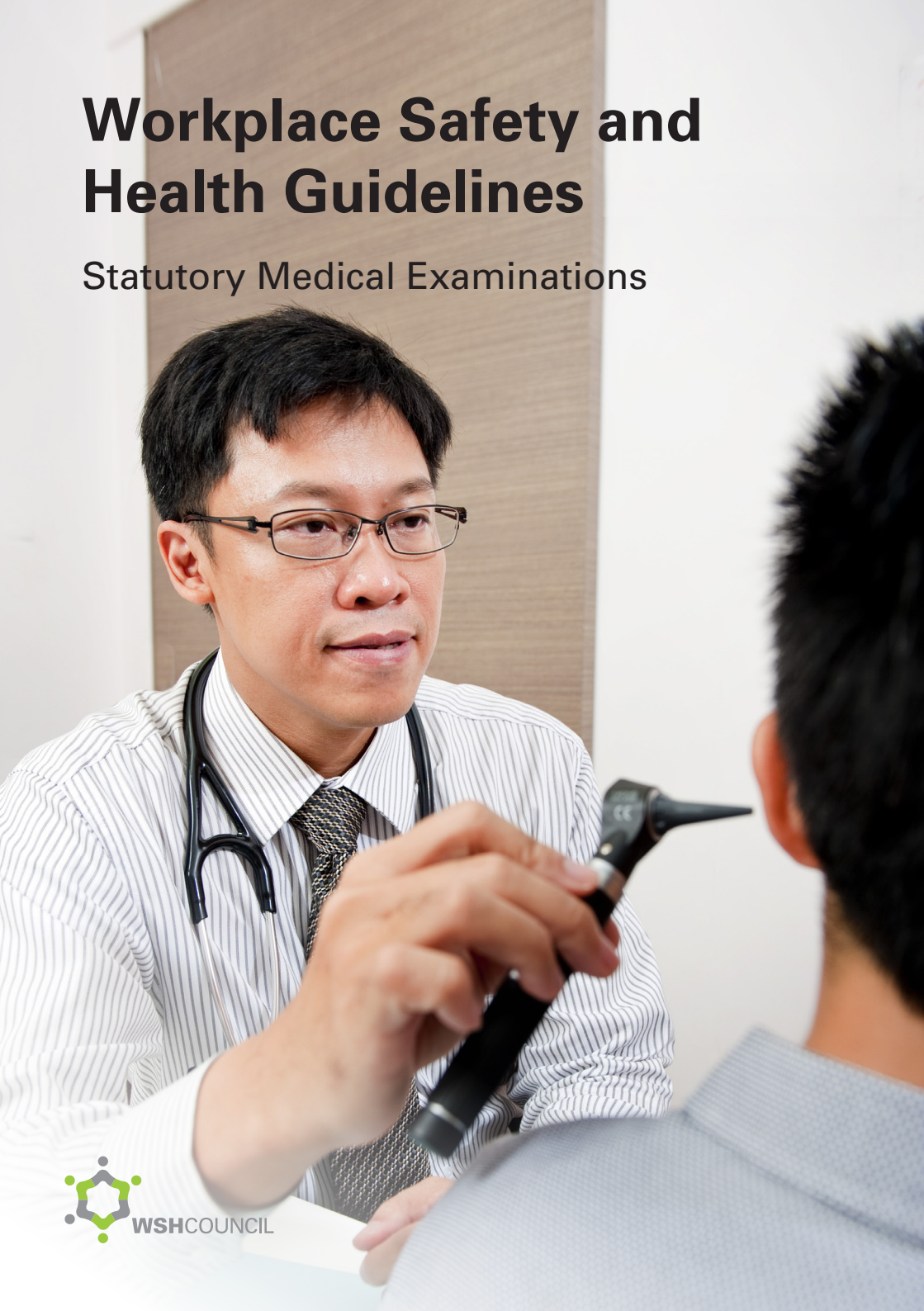
Workplace Safety and Health Guidelines

Statutory Medical Examinations



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1. Preface

Doctors have an important role to ensure that workers are medically fit to work with specific health hazards and to detect overexposure so as to prevent the development of overt occupational diseases. This can be done through specific pre-placement and periodic medical examinations which also enable the doctor to detect occupational diseases in their early stages. Early detection and intervention can prevent or minimise morbidity and disabilities from these diseases. It can also prevent further deterioration or recurrence and result in the protection of other employees who may be exposed to similar risks through the early implementation of preventive measures.

Statutory medical examinations for workers exposed to specific health hazards in factories were first introduced under the Factories (Medical Examinations) Regulations in 1985. These examinations must be conducted by Designated Factory Doctors (DFDs) registered with the Ministry of Manpower (MOM). Doctors who have successfully passed the Graduate Diploma of Occupational Medicine or the Masters in Public Health (relevant modules) can apply for registration as DFDs with MOM. The introduction of the Workplace Safety and Health (Medical Examinations) Regulations extends this requirement to all workplaces in Singapore and DFDs were renamed Designated Workplace Doctors (DWDs).

These guidelines on the statutory medical examinations were first issued in 1985 to provide guidance for DFDs on the conduct of such examinations and the follow up actions required. The guidelines were revised in 1995 and 1997. This fourth edition (2012) recognises the important role of DWDs in providing a more holistic management of workers' health and includes new chapters on work and health, statutory responsibilities, ethical issues, occupational safety and health management system, risk management, and workplace inspection. It also updates the chapters on the specific health hazards and provides useful reference information in the appendices. One significant update in this edition is the incorporation of the new tests required for benzene (2004) and the Biological Threshold Limit Values (BTLV) revision for cadmium (2004). You will be informed of further updates in the required tests or BTLVs from time to time in keeping with the raising of occupational health standards. It is therefore important for you to update your personal particulars and contact information with the Singapore Medical Council. In these guidelines we are introducing the concept of "Action levels" which has been set at 80% of the BTLV. The purpose of the action levels is to alert the DWD to take early preventive action even before the BTLV is reached. The DWD should work together with the employers and workers to reduce workers' risk of over-exposure and adverse effects.

MOM and the Workplace Safety and Health (WSH) Council would like to thank all the experts who contributed to the development of the guide, practitioners who have given us their valuable feedback and all who have made this guide possible. We hope that you would find this guide a convenient and practical resource in your practice of managing workers' health.

2. Scope

This set of guidelines would assist Designated Workplace Doctors (DWDs) in the conduct of the medical examinations for workers who are exposed to the following 19 hazards under the Workplace Safety and Health (Medical Examinations) Regulations:

- Arsenic and its compounds
- Asbestos
- Benzene
- Cadmium and its compounds
- Work in a compressed air environment
- Raw Cotton
- Lead and its compounds
- Manganese and its compounds
- Mercury and its compounds
- Noise
- Organophosphates
- Perchloroethylene
- Free Silica
- Tar, Pitch, Bitumen and Creosote
- Trichloroethylene
- Vinyl chloride monomer

Other WSH professionals and management of companies may also find these guidelines useful to understand the rationale for the recommendations made by the DWD.

3. Work and Health

Occupational health is concerned with preventing and treating diseases as well as promoting health among all people who work. The International Labour Organization (ILO) and World Health Organization (WHO) define occupational health as the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations. Thus, occupational health is the TOTAL HEALTH OF ALL AT WORK. Occupational health practice is a multidisciplinary responsibility and a mechanism for the provision of health services for the working population.

The two-way relationship between work and health can be depicted as:

WORK ↔ HEALTH

Work may not only have an adverse impact on health, but it can also be beneficial to health and well-being. The positive effects of work could include the improvement of physical capacity through physical work, and enhanced self-esteem and satisfaction through achievement of goals. The health status of the worker will have an impact on work. The worker who is healthy is more likely to be productive than an unhealthy worker. Workers with impaired health are not only less productive but could also be a danger to themselves as well as other workers and the community.

3.1 Occupational and Environmental Medicine (OEM)

OEM is the medical specialty devoted to prevention and management of occupational and environmental injury, illness and disability, and promotion of health and productivity of workers, their families and communities[1]. OEM is a specialty area within **Preventive Medicine**.

Its scope includes the identification, assessment and control of workplace hazards, the identification and control of occupational and work-related diseases, assessment of fitness to work and return to work, medical surveillance and health promotion of the working population.

3.2 Spectrum of Diseases in the Workplace

A worker may suffer the full spectrum of diseases. These are:

- diseases that are prevalent in the community;
- work-related diseases; and
- occupational diseases.

This means that an occupational health practitioner must recognise the relationship between work and disease, whichever the category of disease.

1 Definition by American College of Occupational and Environmental Medicine

3.3 Diseases Prevalent in the Community

Many chronic diseases are prevalent in the community. For instance, many people who have Diabetes Mellitus are employed in the workforce. Their health condition would have an impact on work performance (e.g., an insulin dependent diabetic who has to do shift work or who has to undertake frequent international travel). Work may also adversely affect their health condition (for example exposure to nephrotoxic agents may compound diabetic nephropathy).

3.4 Occupational Diseases

Occupational diseases occur as a direct result of exposure to physical, chemical, biological, ergonomic or psychosocial factors in the workplace (Table 1). These may occur as individual or combined exposures.

Hazardous Factor	Adverse Health Effect or Other Outcome
• Mechanical risk factors	Occupational accidents and injuries
• Physiological strain and heavy physical work	Musculoskeletal disorders Strain injuries, low back pain
• Ergonomic factors	Strain injuries, mental stress, lowered productivity and quality of work
• Physical factors e.g., noise, vibration	Noise-induced hearing loss, traumatic vasospastic disease
• Chemical factors	Poisoning, cancers, allergies Health effects to various organ systems
• Biological factors	Infections, allergies
• Psychological factors	Psychic stress, work dissatisfaction, burnout, depression
• Psychosocial aspects of work	Conflicts, lowered productivity, lowered quality of work, mental stress

Table 1: Occupational Health Hazards and its Adverse Health Effects

These factors in the work environment are predominant and essential in the causation of occupational diseases. For example, exposure to lead in the workplace is essential for lead poisoning, and exposure to silica in the workplace is essential for silicosis.

However, other factors such as individual susceptibility may play a varying role in the development of disease among exposed workers. Occupational diseases occur exclusively among workers exposed to specific hazards and are cause-specific. For example, asbestos causes asbestosis and excessive solvent exposure causes solvent dermatitis, encephalopathy and hepatitis.

3.5 Work-related Diseases

The World Health Organization categorises work-related diseases as "multifactorial" in origin. These are diseases in which workplace factors may be associated in their causation or may aggravate a pre-existing condition but need not be a risk factor in every case. These diseases are frequently seen in the general community.

Such work-related diseases include:

- musculoskeletal disorders; and
- chronic non-specific respiratory disease, chronic bronchitis, etc.

3.6 Occupational History Taking

Most occupational and work-related diseases do not have pathognomonic clinical features. Taking an occupational history is thus essential to diagnose occupational and work-related diseases. Even in non-work-related diseases, it is important to understand the nature of the work because the patient may not be fit to continue in his work, or pose a danger to his colleagues and public because of ill health.

An occupational history would allow the doctor to assess:

- The extent to which the illness was caused or related to the patient's job.
  For example, the patient's anaemia may be a result of lead exposure; and the "malingering" patient may be having difficulty coping with a highly stressful or hostile work environment.
- Fitness to return to work.
  Several factors need to be considered:
  - What are the long term effects of the disease?
  - What is the nature of the job the patient is returning to?
  - Is the return to work likely to cause a recurrence of disease or is it likely to aggravate the disease?
  - Is returning to work likely to cause damage or ill-health to other work colleagues or the general community?

  For instance, if the patient was seen for a condition which was clearly the result of occupational exposure, for e.g., occupational asthma, occupational dermatitis, musculo-skeletal disorders due to poor ergonomic factors; then obviously the worker returning to the same work situation will only result in a recurrence of the same condition. Corrective measures need to be taken at the workplace to prevent such recurrences and to protect the other workers.

Job titles described by the patient may not always be meaningful. It is better to ask the worker to describe his work. In general, the components of an occupational history include:

- full chronological listing of previous and current occupations (the patient may be holding more than one job) ; and
- enquiry into possible hazards in the workplace such as physical, chemical, biological, and psychosocial hazards, as well as possible ergonomic and safety issues.

Additional information to be asked for in the occupational history could be to ask if there are similar complaints among other workers, the time relationship between work and symptoms, and the relationship of illness to periods away from work. An estimate of the degree of exposure, and questions on the use of personal protective devices and methods of materials handling might also be helpful.

Relevant lifestyle factors, e.g., smoking, alcohol intake, drugs, and other non-occupational exposures, e.g., hobbies, should also be considered.

3.7 Management of Diseases in Working Populations

Once an occupational or work-related disease is diagnosed, management goes beyond prescribing medication. The following measures may be needed–suspension from further exposure, notification to relevant authorities, educating the patient and employer, identifying other cases, assessment of permanent disability and compensation. The approach should be with a view towards PREVENTION of diseases.

A conceptual framework for prevention includes controlling the source of exposure, decreasing the absorption of toxic substances, and monitoring the effects of absorption. In practical terms, this could take the form of:

- Removing or replacing the hazard if possible;
- Engineering measures to control hazard at its source, e.g., exhaust ventilation;
- Administrative measures, e.g., job rotation, temporary or permanent job re-assignment; and
- Environmental and biological monitoring.
  - Environmental monitoring
    Environmental or ambient monitoring measures external exposure to harmful agents so as to ensure that exposure is kept within permissible levels to prevent occurrence of disease. For each substance there is a level of exposure at or below which the exposed worker does not suffer any health impairment–these are the Permissible Exposure Levels (PELs). PELs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.
  - Biological monitoring
    Biological monitoring is the examination of a worker's biological fluids, e.g., (blood, urine, etc) or physiological parameters (e.g., FEV1, etc) for the presence of the toxicant, its metabolite or its effect. By undertaking biological monitoring on a regular basis it is possible to ensure that the levels of the toxicant absorbed by the worker is maintained at levels that do not cause adverse health effects.

In Singapore, statutory medical examinations are required for persons working with prescribed hazards. These examinations are performed by Designated Workplace Doctors (DWDs), who have postgraduate training in occupational medicine.

- Health education
- Proper use of appropriate personal protective devices
- Notification of occupational diseases to the Ministry of Manpower through iReport (www.mom.gov.sg/iReport).

Further Reading

1. D Koh, K Takahashi. Textbook of Occupational Medicine Practice, 3rd edition. World Scientific, 2011.
2. Centers for Disease Control and Prevention. National Institute of for Occupational Safety and Health Homepage. Retrieved from http://www.cdc.gov/niosh/
3. Occupational Health. World Health Organization. Retrieved from http://www.who.int/occupational_health/en/
4. Ministry of Manpower, Singapore. Workplace Safety and Health. Retrieved from http://www.mom.gov.sg/workplace-safety-health/Pages/default.aspx

4. Statutory Duties and Responsibilities

The overarching legislation which protects the safety and health of workers in all workplaces in Singapore is the Workplace Safety and Health (WSH) Act. The WSH (Medical Examinations) Regulations requires workers who are exposed to specific hazards to undergo prescribed pre-placement and periodic medical examinations. These examinations are to be conducted by Designated Workplace Doctors (DWDs) registered with the Ministry of Manpower.

The main features of the relevant legislation are detailed here to assist you in the management of your workers.

4.1 The Workplace Safety and Health Act

The Workplace Safety and Health Act (WSH Act) is targeted at cultivating good safety and health habits and practices in all individuals at the workplace–from top management to the last worker. It requires every person at the workplace to take reasonably practicable steps to ensure the safety, health and welfare of every worker at the workplace.

A workplace includes any premises where people carry out work. Persons who have duties and responsibilities under the WSH Act are listed below:

4.1.1 Duties of Employers or Principals

- To ensure, so far as is reasonably practicable, the safety and health of his employees or workers working under his direct control and all who may be affected by their work. This includes:
  - Conducting risk assessments to remove or control risks to workers at the workplace;
  - Maintaining safe work facilities and arrangements for the workers at work;
  - Ensuring safety in machinery, equipment, plant, articles, substances and work processes at the workplace;
  - Developing and putting into practice control measures for dealing with emergencies;
  - Providing workers with adequate instruction, information, training and supervision.

4.1.2 Duties of the Occupier

- To ensure, so far as is reasonably practicable, the following are safe and without risks to the health of every person within those premises, whether or not the person is at work or is an employee of the occupier:
  - The workplace;
  - All entrances to or exits from the workplace; and
  - Any machinery, equipment, plant, article or substance kept in the workplace.

- The occupier is responsible for the common areas used by employees and contractors. In particular, the following items:
  - Hoists and lifts, lifting gear, lifting appliances and lifting machines located in the common area;
  - Means of entry to or exit from the common area; and
  - Any machinery or plant located in the common area.

4.1.3 Duties of the Manufacturer or Supplier

- Where any hazardous substance is sold to any person for use in a workplace, the seller shall provide the buyer with a safety data sheet for the substance that:
  - gives accurate and adequate information on the substance; and
  - conforms with any Singapore Standard relating to safety data sheets or such other standards, codes of practice or guidance as is issued or approved by the Workplace Safety and Health Council.
- To ensure, so far as is reasonably practicable, that any machinery, equipment or substances provided are safe for use:
  - Provide proper information on the safe use of the machinery, equipment or hazardous substances;
  - Ensure that the machinery, equipment or hazardous substance has been tested and examined so that it is safe for use.

4.1.4 Duties of an Installer or Erector of Machinery

- To ensure, so far as is reasonably practicable, the machinery or equipment erected, installed or modified is safe and without health risks when properly used.

4.1.5 Duties of an Employee

- To adhere to safe working procedures and principles introduced at the workplace.
- To cooperate with the employer or principal to comply with the WSH Act and not endanger himself or others through unsafe behaviour such as tampering with safety devices or undertake any wilful or reckless acts and non-usage of required personal protective equipments.

4.1.6 Duties of the Self-employed Person

- To take measures, so far as is reasonably practicable, to ensure the safety and health of others such as members of the public or his own employees.

4.1.7 Penalties

The WSH Act states a general maximum penalty for offences. An individual first-time offender can face a maximum fine of up to $200,000 or a jail term of two years or both. A corporate body that is a first-time offender can face a maximum fine of up to $500,000. For a repeat offence, the maximum fine is doubled.

4.2 Workplace Safety and Health (Medical Examinations) Regulations 2011

The Workplace Safety and Health (Medical Examinations) Regulations applies to all workplaces where workers are employed in any occupation (referred to as hazardous occupation) involving:

- the use or handling of or exposure to the fumes, dust, mist, gas or vapour of arsenic, cadmium, lead, manganese or mercury or any of their compounds;
- the use or handling of or exposure to the liquid, fumes or vapour of benzene, perchloroethylene, trichloroethylene, organophosphates or vinyl chloride monomer;
- the use or handling of or exposure to tar, pitch, bitumen or creosote;
- the use or handling of or exposure to the dust of asbestos, raw cotton or silica;
- exposure to excessive noise; and
- any work in a compressed air environment.

All persons employed in any occupation involving the hazards specified above are required to undergo medical examinations conducted by a DWD registered with the Ministry of Manpower (MOM).

Pre-placement examinations must be conducted before or within 3 months of starting exposure to the hazard, except, for work in compressed air, where the examinations must be done within 30 days before starting employment. The types of medical examinations are specified in the **Schedule** of the WSH (Medical Examinations) Regulations and in Chapter 9 of this set of guidelines.

The frequency and types of periodic examinations required for workers employed in the specified occupations are also found in the **Schedule** of these regulations and Chapter 11 of this set of guidelines.

The Commissioner for Workplace Safety and Health (Commissioner) may exempt any workplaces or persons from any provisions of the Regulations subject to such conditions that he may specify in the Certificate of Exemption.

4.2.1 Duties of Responsible Person (Employer or Principal)

- To ensure that workers are medically examined by a DWD and certified fit to work in these hazardous occupations by arranging, granting paid leave and paying for the prescribed pre-placement and periodic medical examinations conducted by DWD registered with the MOM. To ensure workers suspended by the DWD do not work in the hazardous occupation.
- Where workers are required to undergo audiometric examinations, to ensure that the examinations are conducted by persons who have undergone a course of training acceptable to the Commissioner (as specified in MOM website). Failure to do so is an offence, liable on conviction to a fine not exceeding $1,000 and in the case of a second or subsequent conviction, to a fine not exceeding $2,000.

- To maintain registers of persons who are employed in hazardous occupations, to keep it for not less than 5 years from the date it was made and to produce for inspection upon request by the Commissioner. Failure to do so is an offence, liable on conviction to a fine not exceeding $5,000 and in the case of a second or subsequent conviction, to a fine not exceeding $10,000.
- To maintain records of reports and summary of those reports for up to 5 years from the date of any medical examination. Failure to do so is an offence, liable on conviction to a fine not exceeding $5,000 and, in the case of a second or subsequent conviction, to a fine not exceeding $10,000.
- The responsible person can appeal within 14 days to the Commissioner against the DWD's decision for suspension from exposure.
- To provide the DWD with all relevant information to enable the DWD to carry out a proper medical examination on the workers.

4.2.2 Duties of Person in Hazardous Occupations

- To submit himself for such prescribed medical examinations and investigations. Failure to do so renders him liable on conviction to a fine not exceeding $1,000 and, in the case of a second or subsequent conviction, to a fine not exceeding $2,000.

4.2.3 Duties of Designated Workplace Doctor (DWD)

- To conduct and report the results of the prescribed pre-placement and periodic medical examinations to the responsible person in a form(s) determined by the Commissioner. These are the Report of Examinations and Summary Report of Examinations (see Appendices B and C) forms. Failure to do so is an offence, liable on conviction to a fine not exceeding $5,000 and, in the case of a second or subsequent conviction, to a fine not exceeding $10,000. The types of prescribed pre-placement and periodic medical examinations to be conducted by DWDs are given in the Schedule of the Regulations.
- To advise suspension for person(s) in hazardous occupation where person's health is likely to be or has been injuriously affected by his employment in the hazardous occupation. Upon advising suspension of any worker, the DWD is to complete a Certificate of Suspension and give a copy each to the affected person, the responsible person and the Commissioner.
- DWD may inspect any process or place of work where the person being examined by him is or is to be employed; and the occupier of the workplace and the responsible person shall provide all relevant information needed to enable the DWD to carry out the medical examination.

4.3 Other Relevant Subsidiary Regulations

4.3.1 Workplace Safety & Health (Risk Management) Regulations

Under these regulations it is the duty of the employer of every workplace to conduct a risk assessment in relation to the safety and health risks posed to any person who may be affected by his undertaking in the workplace. Environmental and biological monitoring would be part of the quantitative risk assessment for chemical and noise exposure.

4.3.2 Workplace Safety and Health (Incident Reporting) Regulations

These regulations are applicable for all workplaces. It places responsibilities on relevant parties to report occupational diseases, accidents and dangerous occurrences.

Failure to notify renders the individual to a fine not exceeding $5,000 for the first offence; and $10,000 or imprisonment for a term not exceeding 6 months, or to both, for second and subsequent offences.

What to report	Who should report	What you need to do
A workplace accident which resulted in the death of an **employee**	• the employer of the deceased worker	• notify immediately; and • submit the report within 10 days of the accident
An occupational disease	• the employer of the person with the disease and • the doctor who diagnosed the disease	• submit the report within 10 days of receipt of the written diagnosis (employer) • submit the report within 10 days of the diagnosis (doctor)
A workplace accident which resulted in the injury of an **employee** and who is given more than 3 consecutive days of medical leave or hospitalized for at least 24 hours	• the employer of the injured person	• submit the report within 10 days of the accident
A workplace accident which involved a **self-employed person** or **member of public** and resulted in his or her death for being taken to hospital for treatment of injury	• the occupier of the workplace	• notify immediately; and • submit the report within 10 days of the accident
A dangerous occurrence	• the occupier of the workplace	• notify immediately; and • submit the report within 10 days of the accident

4.3.3 Workplace Safety and Health (Noise) Regulations 2011

These Regulations cover all workplaces. The occupier and responsible person (employer or principal) has the duty to take reasonably practicable measures to reduce or control noise so that workers are not exposed to excessive noise, i.e., noise levels above the Permissible Exposure Limits (PELs) as specified in the Regulations (see Appendix G).

Where there are more than 50 persons exposed to excessive noise in the workplace, a competent person is to be appointed to advise the occupier on noise control measures. It is the duty of the occupier to implement the noise control measures recommended.

Where there are 10 or more persons exposed to excessive noise in the workplace, noise monitoring is to be conducted at least once every three years. Results are to be submitted by the occupier to the Commissioner within 30 days. Results are to be kept for at least 10 years.

The responsible person has the duty to provide hearing protectors to persons exposed to excessive noise and to institute a training programme within 3 months for new workers, and subsequently, once every 12 months.

4.3.4 Workplace Safety and Health (General Provisions) Regulations

These Regulations cover all workplaces. The atmosphere of any place of work in which toxic substances are manufactured, handled, used or given off must be tested by a competent person at sufficient intervals to ensure that toxic dust, fumes, gases, fibres, mists or vapours are not present in quantities liable to injure the health of persons employed. A record of the result of every test carried out must be kept available for at least 5 years from the date of the test.

Under these Regulations, occupiers and employers must ensure that persons employed are not exposed to toxic substances above the Permissible Exposure Levels (PELs) specified in the Regulations.

4.3.5 Workplace Safety and Health (First-aid) Regulations

The Regulations specify the duties of occupiers of factories and workplaces (except hospitals and medical clinics) to be responsible for the following:

- Provision and maintenance of first-aid boxes in every workplace;
- Appointment and training of first-aiders where there are more than 25 employees, of one first aider for every 100 persons employed or part thereof;
- Provision of suitable facility for quick drenching of body or flushing of eyes where toxic or corrosive substances are used.

For more information on the Workplace Safety and Health Act and its subsidiary regulations, please refer to the Ministry of Manpower website at www.mom.gov.sg and the Workplace Safety and Health Council website at www.wshc.sg

5. Ethical Issues

Doctors who look after the health of workers have ethical responsibilities, just like their medical colleagues in the traditional therapeutic relationship. The principles of this ethical relationship– autonomy, non maleficence (do no harm), beneficence (do good) and justice, first championed by Childress and Beauchamp in 1965, are just as relevant in the doctor-worker relationship in occupational health. Maintaining confidentiality of the doctor-worker relationship is also an important ethical duty. Its breach, without justification, will invite sanctions and censure.

Work, like all other activities of daily life, can pose inherent hazards and risks. It is inevitable and rightly so, that regulatory bodies and employers take an interest when these hazards contribute to actual injury and sickness, or to the risk of injury and sickness. This interest is legitimate. Health can also affect the ability of the worker to do the job safely, with unacceptable risk both to the worker and his or her colleagues. To some extent, our sense of ethics is also defined by the boundary of public interest which we are ready to manage and accept.

Thus there are features special to this ethical relationship because of collateral obligations that the doctor may have to these other parties. Often, DWDs may also be paid by the employers and may therefore be perceived as acting on their behalf. Ethical issues therefore can arise. Clear contractual terms and conditions must be spelt out early in the beginning of the relationship to avoid misunderstanding. Furthermore, it has to be realised that the ethical duties of the doctor and the ethical rights of the worker-patient cannot be contracted away resulting in harm to the worker-patients.

In Singapore, it is also recognised that DWDs, appointed by employers, often also provide curative and general medical care for the employees.

5.1 Autonomy/ Maintaining Confidentiality

Doctors who take care of workers have to respect their rights in making decisions for themselves. However, this right can be truly exercised only if they have information on which they can base their decisions. While fairly straightforward in the therapeutic sense, when the workers are also patients seeking clinical care, it may not be so with respect to medical decisions affecting employment and work, and which furthermore, may not have anything to do with treatment.

Doctors will have the duty in all circumstances to provide information as accurately as they can relating to risks about the hazards workers face at work that can affect their health. Doctors should seek information about exposure routes and the nature of work to enable them to make an accurate risk appraisal.

Doctors who obtain personal information from workers who are also patients have a duty to maintain the confidentiality of such information. Consent from the worker-patients must be obtained for disclosure of this information to third parties.

However, where it is mandated by law, such as in statutory medical examinations or notification of specified occupational diseases, it is no longer a matter to be decided on the basis of autonomy or consent.

Outside the statutory sphere, problems however, may also arise if the worker-patients are unwilling to give consent for disclosure in the face of a compelling need. Examples include investigation of a suspected work related illness, or when a job transfer is deemed necessary for health protection.

Case Study 1

A candidate at a pre-placement examination was noted to be colour blind. He has difficulty recognising green and red colours. The job as a technician requires him to be able to recognise colours on a computer screen in the control room. He has already completed his technician certificate qualification and strongly feels that working at this job should not be a problem. You are however unsure and would like to consult the employer about this. The candidate refuses permission for disclosure as he feels that this would jeopardise unfairly his chances of employment as has happened previously.

Commentary

This is a fitness to work examination. If colour perception is deemed or contemplated to have an impact on work, this information should be subject to disclosure to the employer if no strict rules about fitness on this have been laid down in the contract between the doctor and the employer. The doctor does not owe an ethical or legal duty to the applicant to ensure he gets the job. The doctor however owes the applicant a duty not to cause harm to him during the medical examination, and that includes the duty of disclosure of important health findings discovered during the medical examination. The doctor would also be required to give a competent assessment of fitness to work to the employer.

Case Study 2

A baker was found to have asthma. He works in a small bakery with limited resources. He is a foreign worker and has incurred great economic hardship to obtain a job overseas. He feels he has acquired some skill in his job and is understandably reluctant to leave his job. He also mentioned that he has had asthma on and off since his teens. He is willing to take the risk and continue with his job and you, as his DWD have documented this in the notes.

Over the next six months, his repeated asthma attacks are getting progressively worse, with increasing reliance on inhalers for control. Should workers be allowed to assume risks determined to be unacceptable to their health? Is this also an exercise of autonomy that has to be respected?

Commentary

Flour is an established cause of asthma in susceptible individuals. The physician taking care of patients who work in such environments must highlight this risk to the patients. If this is strongly suspected to be the cause, notification of occupational disease to the Ministry of Manpower can proceed, after the patient has been told. If an occupational disease is to be notified, the employer should also be informed of the diagnosis.

However, very often, further investigations must be conducted and this can be stalemated if the patient does not give consent for his condition to be divulged, as indicated in the above example. The risk of the harm may not have been appreciated by the patient. Furthermore, the hazard at the workplace may not have been highlighted to the employer to the extent necessary for him to implement preventive measures. If the patient's condition continues to deteriorate, there would be a strong justification to override the patient's objection and inform the employers.

While this may have economic consequences adverse to the worker, on the other hand, such actions may also lead to relocation of the worker to a different section with less exposure and better management of hazards at the workplace which will benefit all workers.

5.2 Non Maleficence and Beneficence

When can harm be considered done to workers from the point of view of a DWD? In this respect, harm can be in the form of actual injury and sickness, as well as the risk of injury and sickness. In the workplace, exposure resulting in sickness may take a long time. Indeed, many occupational diseases are characterised by periods of long latency, coupled with complex interactions with other non-occupational risks, such as smoking.

Advising about risks can be complex. Trading off possible harms against benefits is a decision that necessarily brings the expertise of the different areas to bear. A team consultation may involve hygienists, workplace safety and health officers (WSHOs), work supervisors and even experts in personal protective equipment. Concepts such as "ALARP"–as low as reasonably practicable–to be implemented requires the multiple inputs of such a team.

All doctors should always act in the health interest of the patients and workers under their care. This should be the case no matter who pays them. The containment of health care costs can be better achieved by administration policies and different payment scheme strategies, rather than attempts to limit the care of workers and patients. Employers have a legitimate economic interest to protect, but it is not up to doctors to perform this role at the expense of the health of the workers. On the other hand, acting in the best interests also, should not mean collusion with workers and patients to gain unfair advantages and benefits. Acting in the best interests should also mean being impartial and basing decisions on best available evidence.

Case Study 3

A screening test for risk exposure to a certain hazard has been mandated by legislation and was carried out for the workers. The results were normal and the management has used these results, properly anonymised, as sanctioned by the company doctor, to confirm that the workplace is safe, despite the repeated concerns of the workers and the union representatives.

Commentary

Screening tests making use of biomarkers of effects and exposure are commonly applied in occupational health. Screening tests results are also subject to limitations in its sensitivity and specificity of identifying the conditions for which it is screening. It can identify workers believed to be at risk thus permitting the appropriate action. However, they do not replace the need for primary prevention of harm at the workplace. On the part of the doctors, allowing and condoning the use of the screening tests results to justify this would be an ethical breach which could potentially harm the workers.

5.3 Justice

The principle of justice requires doctors to recognise the rights and dignity of workers and patients and to treat them fairly. For health protection at work, this would mean that how we treat and advise workers should be based on objective risk assessment.

Case Study 4

The protection of welders against the danger of welding fumes is well known. Are colleagues who are not involved directly in the welding process at risk?

Commentary

Welding is a hazardous work process. Welding fumes, depending on the materials used may give rise to health problems. Arc eye is another possible health concern. While the protection of welders is immediately obvious, that of colleagues in the vicinity may not be so, and they may be at equal risk if they have to work around the area. Justice would demand that equal attention be paid to the protection of their health.

Many areas of occupational health may have impact on the general community. Noise emission and inadequately treated trade effluent discharges are two examples. Justice demands that the impact on health of the communities also be addressed.

5.4 Protection of Information about Business Activities and Trade Secrets

Doctors with access to the workplace may come across information of their business activities. Many of these may relate to trade secrets which ought to be kept confidential, out of both an ethical and legal duty. However, where such information reveals dangers to health, which might have been intentionally suppressed, the argument of public interest may warrant disclosure. These occasions would be rare. Rarer would it be for such disclosures to be made without a discussion with the employers. In such cases, the proper legal advice and consultation with other medical colleagues should be sought.

5.5 Accountabilities and Responsibilities/ Relationship with other Doctors

The doctor is also accountable for the professional behaviour of the staff who reports to them. The composition of staff may vary according to the scale of work and resource. However, at a minimum, this may include nurses, health assistants and technicians. It is also possible for hygienists and other professionals to be part of the team.

The doctor has to ensure that they are properly trained and competent to perform their jobs. In addition, they should be held to the same ethical obligations as the doctor, specifically in areas of confidentiality. Besides being responsible for training, the doctor is also to ensure that a secure system of safekeeping of records and medical data is in place.

As with other fields of medicine, doctors responsible for workers' health should extend professional courtesy to their colleagues and refrain from denigrating the work of others. Where medical reports are required from other doctors, consent from the worker or patient should also be obtained.

Conclusion

Doctors with responsibilities for the health of workers may encounter ethical issues from time to time. The involvement of other parties and the nature of health issues at work, which may not be necessarily focused on a curative angle, are two of the reasons for this.

To some extent, ethical guidance worded into the contract for service by the doctors with the employers will go some way in reducing potential conflicts. If still not resolved, referrals and discussion with other colleagues in the same field should be sought.

Further Reading

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2. Guidance on Ethics for Occupational Physicians. Faculty of Occupational Medicine. Sixth Edition May 2006 .
3. Lee SM, Koh D. Fitness to Work: Legal Pitfalls. Annals of the Academy of Medicine, Singapore. 2008; 37:236-40.

6. Safety and Health Management System (SHMS)

The Safety and Health Management System (SHMS) is a systematic process for managing workplace safety and health, providing for goal setting, planning, performance measurements, and clear management commitments and direction. The establishment of an SHMS is the responsibility of the occupier and worker participation is an important element to ensure the effectiveness of the system.

Under the WSH (Safety and Health Management System & Auditing) Regulations, implementation of the SHMS is mandatory for the following workplaces:

- Construction worksites;
- Shipyards;
- Metalworking factories in which 100 or more persons are employed;
- Factories engaged in the processing or manufacturing of petroleum, petroleum products, petrochemicals or petrochemical products;
- Bulk storage terminals having a storage capacity of 5,000 or more cubic metres of toxic or flammable liquid;
- Factories engaged in the manufacturing of —
  - fluorine, chlorine, hydrogen fluoride or carbon monoxide; and
  - synthetic polymers.
- Factories engaged in the manufacturing of pharmaceutical products or their intermediates; and
- Factories engaged in the manufacturing of semiconductor wafers.

6.1 Shipyards

Workplace Safety and Health (WSH) is a key challenge for the marine sector. Although the sector has made progress in its WSH performance over the years, the potential risk of workplace fatality and injury is high. Hence, robust safety and health management systems are essential. The leading contributors of fatalities are falling from heights and being struck by falling objects. For occupational diseases, Noise-induced Deafness (NID) is most common, followed by occupational skin diseases.

Four strategies have been identified to improve and better manage WSH in the marine sector.

- **Strategy 1: Driving implementation of effective risk management**

  This would involve contractors, ship owners and crew. Programmes such as bizSAFE have been developed to guide companies in building their risk management capabilities. In addition, incident investigation should focus on both the direct cause and the broader systemic issues.

- **Strategy 2: Enhancing WSH capability building**

  To help stakeholders build capability, the training provided to marine workers will be contextualised, with focus placed on marine trade-specific competency courses, the marine industry training centre and raising the certification standards for supervisors and line managers.

- **Strategy 3: Developing and implementing intervention programmes**

  Industry-led taskforces would focus on the leading contributors of fatalities in the marine sector: confined spaces, working at heights and lifting operations.

- **Strategy 4: Strengthening stakeholders' involvement in WSH**

  The "Pledge for Zero" brings together the key players to achieve zero injury for the marine sector.

6.2 Construction

The characteristics of the construction sector present multi-fold and unique WSH challenges and require collective and focused efforts by the sector. It is one of the more hazardous and riskier workplaces and accounts for more than one third of all workplace fatalities. The number of injuries in the construction sector is the highest compared to other sectors and is above the national average.

Like the marine sector, four strategies have been identified to guide the industry's effort to achieve better WSH performance.

- **Strategy 1: Building strong capabilities to better manage WSH**

  This requires the concerted effort at the individual, corporate and industry levels. Also, an enhanced Construction Safety Orientation Course ensures that new workers are equipped with basic WSH knowledge before they enter the industry.

- **Strategy 2: Developing a performance-based regime**

  The move towards including designers and developers in the regulatory framework, improving management of workplace health, self regulation and setting of high industry WSH standards are all part of the performance-based regime to encourage strong ownership of WSH outcomes within the industry.

- **Strategy 3: Promoting the benefits of WSH and integrating WSH into business**

  Integrating WSH into business is an important thrust to engender a WSH culture where businesses are aware of the impact poor WSH performance has on bottom lines. The bizSAFE programme, "Pledge for Zero" (PfZ) initiative and the Construction Safety Audit Scoring System (ConSASS) are all part of the effort to promote and integrate WSH into business. However, this area can be further strengthened by encouraging developers and contractors to allocate adequate resources for WSH, putting in place a robust WSH management system, and strengthening the business case for integrating WSH into business.

- **Strategy 4: Creating and building partnerships**

  To further advance WSH standards in the construction sector, intra-industry and cross-industry taskforces, such as the National Work at Height and National Crane Safety

Taskforces, have been helpful in encouraging cross-fertilisation of ideas and coordination of efforts to improve WSH in specific areas of concerns.

6.3 Workplace Health Programmes

In Singapore, close to 95% of occupational diseases are attributed to Noise-induced Deafness and occupational skin diseases. At the global level, the International Labour Organization (ILO) has estimated that hazardous substances cause an estimated 651,000 deaths, mostly in the developing world. Asbestos alone claims about 100,000 deaths every year. These areas, hence, are areas of concern for us.

As articulated in the "Improving Workplace Health Management in Singapore" document, in the immediate term, we have put in place targeted intervention programmes to focus on capability building and enforcement efforts in these known problematic areas for workplace health. The four key areas are:

- Asbestos control programme;
- Confined space management programme;
- Hazardous chemical management programme; and
- Noise-induced deafness prevention programme.

6.4 Asbestos Control Programme

This programme aims to eliminate asbestos-related diseases over the long term through progressive elimination of asbestos use, and the minimisation of exposure during the use and removal, and management of asbestos in buildings. Target processes include work involving removal and abatement of asbestos in buildings, vessels and other premises.

The programme involves:

- strengthening the legislative requirements for asbestos removal work;
- introducing a licensing scheme for asbestos removal contractors; and
- raising awareness and capability building; engagement and enforcement.

6.5 Confined Space Management Programme

This programme aims to enhance confined space hazard management and prevent deaths from chemical poisoning and asphyxiation during confined space work and rescue operations. Shipbuilding and ship-repairing industries, manhole works, ISO-tank operations in logistics and other workplaces with confined space hazards are required to implement a confined space management programme. The programme consists of the following elements: hazard identification, evaluation and control, entry-permit system, atmospheric testing and monitoring, ventilation and emergency response.

The confined space management initiatives include:

- identification of workplaces with confined space hazards;
- raising awareness and capability building for confined space management; and
- implementing effective in-plant confined space programmes.

6.6 Management of Hazardous Chemicals Programme (MHCP)

The programme covers chemical manufacturers and workplaces using hazardous chemicals. The objectives of the programme are to prevent and control chemical hazards and protect persons at work against such hazards.

Companies under the programme are required to implement an in-plant chemical management programme consisting of the following key elements: hazard communication (labelling and safety data sheets), training and education, hazard assessment and control (with respect to storage, handling and disposal of chemicals), personal protective equipment, workplace monitoring, medical surveillance, and emergency response.

Results of regular exposure and biological monitoring are submitted to MOM. Where exposure levels are excessive, intervention actions should be initiated by the company. As DWDs involved in biological monitoring of chemical hazards, the toxicological test results you submit to the company and to MOM enables the identification of high risk activities, persons and workplaces for intervention.

6.7 Noise-induced Deafness Prevention Programme (NIDPP)

NIDPP aims to reduce the incidence of NID. Noisy workplaces include the metalworking, transport, manufacturing and shipbuilding/ship-repairing industries. Key elements of the in-plant Hearing Conservation Programme (HCP) include noise monitoring, noise control, hearing protection, audiometric examinations and health education.

Initiatives under this programme include:

- strengthening legislative requirements;
- identifying noisy workplaces for surveillance and control;
- managing noise hazards at workplaces through the implementation of in-plant HCP; and
- raising awareness and building capability in noise hazard management.

Further Reading

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7. Risk Management

Under the WSH framework, risk management has been mandated to foster a proactive accident prevention culture and to be used as a tool for prioritising implementation of preventive measures. Risk Management entails:

- Risk assessment of any work activity;
- Control and monitoring of such risks; and
- Communicating these risks and the control measures to all persons involved.

7.1 Risk Assessment

Every workplace should conduct risk assessments for all routine and non-routine operations undertaken.

The process involves:

- Hazard identification
  - identify hazards; and
  - identify potential accidents or incidents.
- Risk evaluation
  - conduct environmental and medical tests to determine the exposure level for noise and chemicals, where suitable tests are available;
  - estimate the risk level of hazards identified based on severity of harm and likelihood of accidents/incidents/diseases occurring; and
  - prioritize the hazards to be controlled.
- Risk control
  - formulate the control measures according to the Hierarchy of Controls; and
  - analyse and evaluate residual risks.

Biological monitoring, where appropriate, assists in risk evaluation and risk control by quantifying worker's exposure.

Hazard Identification

Hazard identification identifies the hazards associated with an activity and the type of potential accidents or incidents that could occur. During this phase, the aim is to spot hazards, brainstorm on all the possible types of accidents and ill health that can happen due to the hazard, and identify the persons that can be victims of the accident or ill health. Examples include excessive noise, chemicals, e.g., solvents, alcohols, metals; biological, e.g., viruses, etc. and these hazards can affect workers directly or indirectly.

Risk Evaluation

Risk evaluation is the process of estimating the risk levels for the hazards and their acceptability. This is used as a basis for prioritising actions to control these hazards and to minimise safety and health risks.

Risk is determined based on:

- Predicted **severity** of the hazard; and
- **Likelihood** of occurrence of the accident, incident or ill health taking into account the existing risk controls.

A simple 5 x 5 risk evaluation matrix can be used to assess the risk level of an activity.

Likelihood / Severity	Rare Not expected to occur but still possible	Remote Not likely to occur under normal circumstances	Occasional Possible or known to occur	Frequent Common occurrence	Almost certain Continual or repeating experience
Catastrophic Fatality, fatal diseases or multiple major injuries	Medium	Medium	High	High	High
Major Serious injuries or life-threatening occupational diseases	Medium	Medium	Medium	High	High
Moderate Injuries requiring medical treatment or ill-health leading to disabilities	Low	Medium	Medium	Medium	High
Minor Injuries or ill-health requiring first aid treatment only	Low	Medium	Medium	Medium	Medium
Negligible Not likely to cause injuries or ill health	Low	Low	Low	Medium	Medium

Figure 1: Risk evaluation matrix

The acceptability of the different risk levels could be as follows:

- low risk: acceptable;
- medium risk: moderately acceptable; and
- high risk: not acceptable.

Based on the risk level, risk control measures are to be put in place so as to reduce the risk to an acceptable level.

7.2 Risk Control and Monitoring

7.2.1 Hierarchy of Controls

The controls implemented are not mutually exclusive (Fig. 2). More than one control measure may be required to successfully reduce the risk.

- Elimination
  - most preferred; and
  - is a permanent solution that involves the total removal of hazard.
- Substitution
  - replacing with a lower risk hazard.
- Engineering controls
  - physical means that limit the hazard.
- Administrative controls
  - reduce or eliminate exposure to a hazard by adherence to procedures or instructions.
- Personal protective equipment
  - to be used only as a last resort, or as a short term contingency measure during emergency/ maintenance / repair or as an additional protective measure

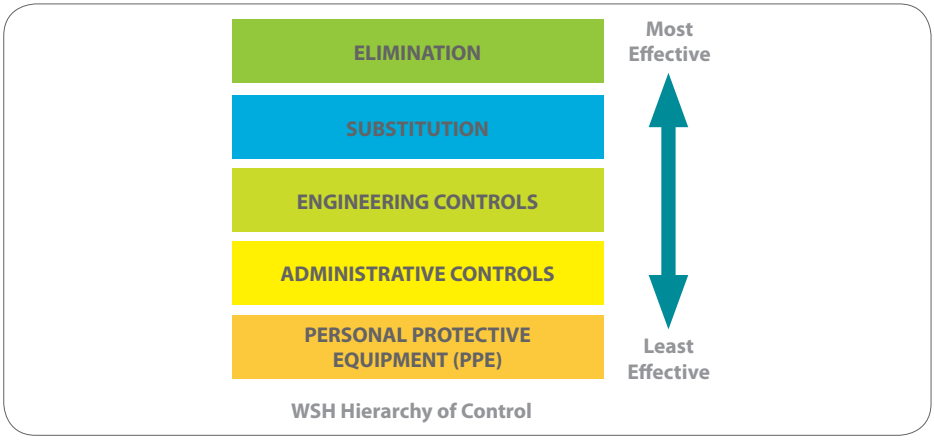

Figure 2: Hierarchy of controls

7.2.2 Record Keeping

A written description of the risk assessment must be kept for reference for 3 years. The Risk Assessment Form can be used for record keeping, training and reviewing. All risk assessment records should be concise and kept in a register.

7.2.3 Monitoring

Regular review of the risk assessment plan is critical. While employers are required to review their plans every 3 years, a review should take place whenever:

- New information on safety and health risks surfaces;
- There are changes to the area of work and /or process; and
- After any accident / incident.

Regular auditing is required to ensure that risk control measures have been implemented and are functioning effectively. For a list of workplaces that must be audited by approved workplace and health safety auditors, please refer to: http://www.mom.gov.sg/workplace-safety-health/safety-health-management-systems/Pages/default.aspx

7.3 Communication

Throughout the risk management process, communication amongst stakeholders at every step is essential (see Fig. 3).

Communication

- engages and involves people to contribute to the risk management process;
- provides clarity on the risks, processes, control measures, perceptions, etc.;
- helps stakeholders make informed decisions; and
- enables stakeholders to know the risks they face and the appropriate control measures to implement to reduce risks.

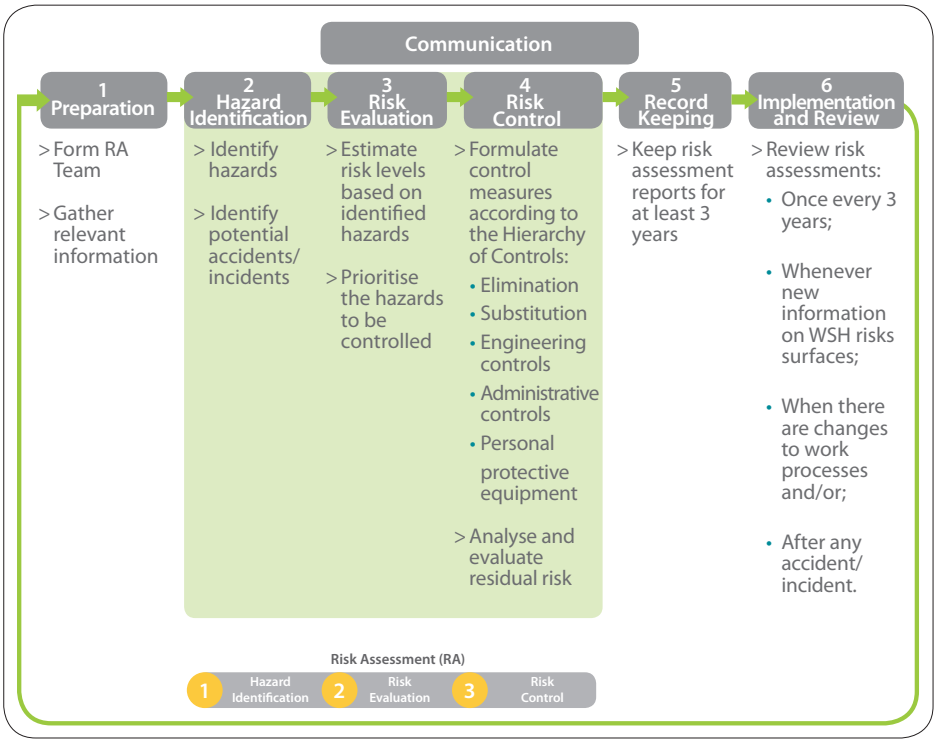

Figure 3: A schematic diagram of the risk management process and the importance of communication.

Further Reading

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   Retrieved from http://www.mom.gov.sg
2. Code of Practice on Workplace Safety and Health (WSH) Risk Management
   Retrieved from http://www.wshc.sg

8. Workplace Monitoring

8.1 Airborne Chemical Substances

Workplace monitoring is an integral part of evaluation of exposure to toxic or harmful substances present in the work environment. These substances may be in the form of gases, vapours or aerosols (solid or liquid particles suspended in air, e.g., dust, fumes, mists and fibres), that may affect the health of workers or employees. Prior to exposure measurements, the person who carries out the measurement must identify the airborne contaminants to be monitored. He must therefore assess the existing processes, operations or work, which may give rise to the contaminants. Appropriate sampling equipment and instruments can then be selected to measure or monitor the exposure of workers or employees who are exposed or liable to be exposed to the contaminants. The results of measurement or monitoring are compared with applicable occupational exposure standards so that judgment can be exercised to manage the exposure risks.

8.1.1 Objectives

Workplace monitoring helps to assess possible health risks resulting from exposure to toxic or harmful substances at work via inhalation. It determines the exposure levels of persons to airborne substances, i.e., whether they are in compliance with the exposure standards and whether additional control measures, e.g., local exhaust ventilation, respiratory protection is required. Workplace monitoring also provides a basis for correlating health effects with exposure to specific substances.

8.1.2 Exposure Standards

The exposure standards or permissible exposure levels of some 700 toxic substances are specified in the Workplace Safety and Health (General Provisions) Regulations (see Appendix G). The Permissible Exposure Level (PEL) is the maximum time weighted average (TWA) concentration of a toxic substance to which persons may be exposed. Two types of PEL are stipulated in the Regulations:

- PEL (Long Term) means the permissible exposure level over an 8-hour working day and a 40-hour working week.
- PEL (Short Term) means the permissible exposure level over a 15-minute period during any working day.

Where PEL (Short Term) of a toxic substance is not specified in the Regulations, PEL (Short Term) of the substance shall be deemed to be exceeded if the TWA concentration of the substance measured over a 15-minute period during any working day exceeds five times PEL (Long Term) of that substance as specified in the Regulations.

8.1.3 Concentration Units

There are basically two types of airborne substances: gases or vapours and aerosols. The PEL for gases and vapours are expressed in terms of volume concentration in parts per million (ppm) of substances in air, or mass concentration in milligram of substances per metre cube of air (mg/m^3) whereas the PEL for aerosols can only be expressed in mg/m^3.

Direct reading gas monitoring devices always give ppm of the gas concentration in air. However, if air samples are collected and analysed for airborne substances, the concentrations are often reported as mg/m^3 (which is equal to the mass analysed divided by the volume of air sampled).

Under normal temperature and pressure (NTP, 25°C, 760 mm Hg) at which exposure standards PEL are established, mass concentration in mg/m^3 can be converted to volume concentration in ppm by the following equation.

$$\text{ppm} = \frac{\text{mg/m}^3 \times 24.45}{\text{MW}}$$

where MW is the molecular weight of the substance.

Example

The PEL (Long Term) for ammonia (NH3, MW = 17) is 25 ppm. In terms of mass concentration, it is 25 x 17 / 24.45 = 17 mg/m^3 at NTP.

8.1.4 Time Weighted Average Concentration

In industrial work environment, the concentration of airborne substances often fluctuates over a wide range. An employee may have an elevated exposure during one time interval and a lower exposure in the next time interval. Excursions above the PEL (Long Term) are allowed provided that they are compensated by equivalent excursions below the limit during the workday and that the time weighted average concentration over the 8-hour work shift is within the PEL (Long Term).

Time weighted average (TWA) concentration takes into consideration both exposure concentration and exposure time. The purpose of time weighting the average is to give a more representative measure of exposure than just a simple mathematical average. TWA values thus provide the most practical and satisfactory way of monitoring airborne substances for compliance with the PEL.

TWA concentration is the concentration determined by adding together the products of each concentration (C_i) and the corresponding time (T_i) over which that concentration was measured, and dividing the sum by the total time over which the measurements were taken.

$$\text{TWA Concentration} = \frac{C_1 \times T_1 + C_2 \times T_2 + \text{------} + C_n \times T_n}{T_1 + T_2 + \text{.....} + T_n} = \Sigma \frac{C_i \times T_i}{T_i}$$

A duration of 8 hours or 480 minutes is used as the denominator for comparison with PEL (Long Term) and 15 minutes for comparison with PEL (Short Term).

For airborne contaminants having both PEL (Long Term) and PEL (Short Term), the long-term full-shift sample(s) should be supplemented by short-term grab samples to determine the peaks if there are wide fluctuations in concentration.

See Appendix L on methodology for carrying out the workplace monitoring and interpretation of results.

8.2 Noise

Noise measurements are essential for quantifying hazards to hearing and evaluating noise sources for noise control purposes. As sound is a form of energy, the hearing damage potential of a given sound environment depends not only on its level, but also its duration. Therefore, to assess the hearing damage potential of a sound environment, both the sound level and the duration of exposure must be measured and combined to determine the energy received. For constant sound levels, this is easy, but if the sound level varies, the level must be measured over a well-defined period. Based on these levels, it is then possible to calculate a single value known as the equivalent sound pressure level, which has the same energy as the varying sound level over the stated time period. In practice, an integrating sound level meter will measure the instantaneous sound pressure levels, and compute the equivalent sound pressure level over the period of measurement. Alternatively, noise exposure can be expressed as a percentage of noise dose which can be measured directly with a noise dosimeter.

8.2.1 Occupational Exposure Standards

The Workplace Safety and Health (Noise) Regulations stipulate that a person is deemed to be exposed to excessive noise, if the noise that he would be exposed to, when not wearing any hearing protector, exceeds:

- the permissible exposure limit for noise specified in the Schedule of the Regulations;
- an equivalent sound pressure level of 85 dB(A) over an 8-hour work day, in any case where the noise is at a fluctuating sound pressure level; or
- a peak sound pressure level exceeding 140 dB(C).

Higher noise levels are allowed but for shorter exposure periods. For every 3 dBA increase in noise level, the exposure time should be reduced by half. The permissible exposure levels are given in Appendix G.

The permissible exposure levels are based on the equal-energy principle, i.e., doubling the acoustic energy or placing two identical acoustic sources together, the combined sound pressure is increased by 3 dBA, and the permissible exposure period should be halved. Thus, at 88 dBA, the permissible exposure time would be 4 hours per day; and this would carry the same acoustic energy as that of 85 dBA for 8 hours of exposure.

The permissible exposure time (T) in hours is related to the exposure sound pressure level (SPL) by the following formula.

$$T = \frac{8}{2^{(SPL - 85)/3}}$$

Example
The permissible exposure time at 91 dBA is $8 / 2^{(91-85)/3} = 2$ hr, and the permissible exposure time at 100 dBA is $8 / 2^{(100-85)/3} = 8/32$ hr or 15 min.

Exposure to 140 dB(C) is the maximum allowed under the Regulations.

8.2.2 Noise Measurements

Nearly all instruments used for noise measurements or analysis have evolved from basic sound level meter, which senses sound pressure and indicates sound pressure levels. Most sound measuring instruments have data logging features for measuring equivalent sound level, noise dose and other parameters.

See Appendix L on methodology for carrying out noise monitoring and interpretation of results.

9. Biological Monitoring

Biological Monitoring refers not just to the measurement of exposure but also includes the detection of early and possibly reversible changes of biological effects. Therefore, biological monitoring of occupational exposure to chemicals refers to the assessment of the "internal dose" of the worker by determining:

- The concentrations of the chemicals or their metabolites in biological samples (measuring the exposure or body burden); and /or
- The indicators of biological effect related to the internal dose so as to identify early and reversible changes.

9.1 Objective

The primary objective of biological monitoring is to ensure that the current or past exposure of the individual is not harmful to the worker's health by detecting potential excessive exposure before overt adverse health effects occur.

9.2 Value and Limitations

In the workplace, chemicals are usually absorbed through inhalation, skin absorption and ingestion. Biological monitoring can provide a more accurate picture of the body burden of exposure and the effects of exposure; which in some situations could be contributed by non-occupational exposure. It could also test the effectiveness of engineering control measures and the efficacy of personal protective equipment.

On an individual basis, the results of biological monitoring may be used to estimate the amount of absorption of the chemical during a specific time interval. Most of the time, a single reading would not be as useful as serial results, as the latter provides additional information on the trend. On a group basis, the results provide an indication on whether the existing control measures at the workplace are adequate or not. The group result could be further analysed by categorising them by section, department, and type of job or duration of exposure at the workplace. This regrouping would enable one to identify the higher risk group for the focusing of more concentrated effort so as to prevent development of occupational disease.

Biological monitoring is complementary to environmental monitoring. It may, in fact, give a better indication of the health risk because it reflects the overall uptake (by all routes of entry) and takes into account other factors (e.g., individual variation in respiratory uptake, work habits, personal hygiene, physical exertion and pre-exposure burden). It is also useful in evaluating the effectiveness of certain engineering measures and or efficacy of personal protective equipment used.

Unfortunately, biological monitoring is not possible for all chemical exposures. The toxicokinetics differ from chemical to chemical. Acute-acting substances (such as irritants) are

not suitable for biological monitoring. Some chemicals or its metabolites may not be detected in the blood or urine or other biological material. Hence, for the majority of chemicals, we continue to depend on environmental monitoring data to provide us information on the workers' exposure.

9.3 Practical Considerations

Indicators of biological effects such as effects on liver functions, are determined on the basis of biochemical tests, the technique and interpretation of which are relatively straightforward. In contrast, the determination of concentrations of chemicals and metabolites in biological samples requires meticulous attention to detail both in sampling and analytical techniques because accuracy is crucial when trace levels are involved. Therefore specific instructions should be given to the company and workers to ensure that the time and method of sampling is as recommended in these guidelines.

Time of Sampling

For certain chemicals, the substance itself and/or its metabolite(s) may be rapidly eliminated from the body following exposure. In such cases, the time of sampling is critical. Depending on the rate of elimination, the biological sample may be collected during exposure, at the end of the work shift, just before the next work shift (i.e., 16 hours after the end of exposure) or before resuming work after the weekend (i.e., 60 to 64 hours after the last exposure). Timing is especially critical when measuring exposure to solvents which generally have a short half-life. As such, always confirm with the worker or company representative on the worker's work exposure before arranging for the collection and analysis of the biological sample.

Collection of Specimen

- Container:
  - For urine samples, disposable wide-mouthed plastic bottles (with screwed caps) should be used.
  - For whole blood samples, metal-free disposable syringes and plastic tubes (with screwed caps) should be used. Lithium heparin is the usual anti-coagulant. The tube should be shaken well. For blood samples where solvents e.g. toluene is to be measured, glass tubes with Teflon caps are preferred. It is best not to use rubber stoppers (most vacuum tubes have rubber stoppers) as the solvent in the blood may react with the rubber.
  - See Appendix H for information on the type of containers to use.
- Cleanliness:
  - Blood or urine specimens should be collected in a clean environment after the individual has washed his hands and preferably changed into clean clothing. This is to prevent any undesirable external contamination of the biological samples.

- Amount of specimen to be collected:
  - For whole blood analysis the exact amount will be dependent on the type of analysis. It is always important to check with the laboratory which is doing the analysis to ensure that a sufficient amount is taken.
- Storage:
  - Urine should generally be stored refrigerated or frozen until the analysis is carried out, rather than with added chemical preservatives.
  - Whole blood is collected as an unclotted sample and should be refrigerated until analysis.
  - During transportation, blood samples should, as far as possible, be kept in a suitable insulated container with ice packs. The actual transportation time should preferably not exceed 2 hours. All biological fluids should be analysed as soon as possible to avoid any loss due to prolonged storage.
- Labelling:
  - All specimen containers should be properly labelled. This should include the worker's name, Foreign Identification Number (FIN) or NRIC No. and the date and time of specimen collection.

Repeat Tests

If the result exceeds the BTLV, a repeat test may be necessary if one suspects that there could be possible contamination of the sample during the collection, errors arising from the analytical procedures and/or causes unrelated to job exposure. It should be evaluated together with the environmental monitoring results, if this is available.

Correction for Variation in Urinary Dilution

Urine samples that are too concentrated or dilute are generally not suitable for analysis. Wherever possible, urine creatinine concentration should be measured to correct for the urinary dilution factor.

As routine collection of 24-hour urine samples from workers is not practical, early morning specimens are generally preferred unless otherwise indicated (see Time of Sampling). When the sample is not a 24-hour urine specimen, the results should be corrected for variations in urinary dilution. This can be done either by using the specific gravity (SG) (see formula below) or creatinine concentration of the same sample.

There is no significant superiority of creatinine adjustment over specific gravity correction, although creatinine correction may be better for very concentrated and very dilute samples.

Formula for SG Correction:

$$\text{Corrected Value (to SG of 1.016)} = \text{Uncorrected Value} \times \frac{16}{\text{Last 2 digits of observed SG}}$$

Example:
If observed SG = 1.023
Corrected Value = Uncorrected Value x $\frac{16}{23}$

Note: In Singapore, correction is made to an SG of 1.016. This is close to the mean SG of urine in the Singapore population based on a sample finding.

9.4 Interpretation of Result

Action Level
Action Level represents the level when action is to be initiated by the DWD to assess and reduce workers' risk, working closely with the employer and the worker. Actions taken are documented in the *Report of Examinations*. MOM is to be updated on the actions taken through submission of the *Report of Examinations*.

For all chemical hazards except *organophosphates*, the Action Level is 80% of the Biological Threshold Limit Value (BTLV). For organophosphates, the Action Level is 70% of the worker's individual baseline level or lower limit of laboratory's normal range.

Biological Threshold Limit Value (BTLV)
BTLVs represent the maximum concentrations of toxic substances or metabolites in the biological media which would not be associated with significant risk to the worker's health. These limits generally represent the approximate biological equivalent of the established PELs for air contaminants.

For organophosphates, the BTLV will also be 70% of the worker's individual baseline level or lower limit of laboratory's normal range.

There are very few BTLVs available which are widely accepted. The reasons for this are the difficulty in establishing norms even among non-exposed populations and significant individual differences among workers.

Detection Limit
For biological monitoring, the selected analytical method should have a detection limit lower than the level for normal non-exposed subjects (see Appendix J). The detection limit is the minimum concentration of an element or compound which can be detected with 95% certainty,

i.e., the quantity which gives a significant reading equal to twice the standard deviation of the blank level. The method would then give reliable results for elevated concentrations expected in specimens from occupationally exposed workers.

9.5 Follow Up Action

When any worker's test results exceed the Action Level:

- repeat the test (usually not necessary unless you suspect sample contamination)
- if previous results are available, always compare with the worker's past biological results and the results of other workers in the same section;
- examine the worker for signs and symptoms of poisoning;
- evaluate adequacy of worker's personal protection and counsel worker on preventive measures;
- inform the company of the test results and advise the company to review their risk assessment with the view to implement additional control measures;
- visit workplace if necessary; and finally;
- update MOM of the repeat test results and findings of your investigation using the *Report of Examinations* form.

When the result of a biological sample exceeds the BTLV for that particular chemical (after excluding collection and laboratory errors and non-occupational causes), in addition to actions above, do the following:

- diagnose and notify as a case of occupational disease to the MOM through iReport (http://www.mom.gov.sg/iReport):
  - **Excessive absorption** (if asymptomatic) **or**
  - **Poisoning** (if the individual has signs and symptoms related to that particular chemical exposure);
- Inform the employer to similarly notify MOM through iReport;
- suspend the worker from further exposure to the hazard until subsequent follow up results fall below the Action level and there are no other abnormalities. A *Certificate of Suspension* should be completed and a copy given to MOM, employer and worker;
- visit the workplace if necessary; and finally
- update MOM of the repeat test results and findings of your investigation by submitting the *Report of Examinations* form.

9.6 Exemption from Biological Monitoring

Where workers' exposure to chemical hazards poses a low risk of poisoning or excessive absorption, they can be exempted from medical surveillance under Section 62(3) of the Workplace Safety and Health Act.

To evaluate the level of risk of poisoning or excessive absorption, use the following assessment criteria:

Type of Risk	Low Risk
Potential for skin contact	No risk of skin contact
Toxicological and clinical test results	Within normal range for normal unexposed population (refer to Appendix J)
Environmental monitoring results	Undetectable air levels or if <10% PEL, exposed for < 30 days / year
Duration and frequency of exposure	Infrequent short exposure
Type of preventive measure	Effective engineering controls, supplemented by personal protective equipment and administrative controls

You may assist companies in the application for exemption by submitting Appendix F to MOM. Depending on the level of potential risk, MOM may reject or approve the exemption, or alternatively, recommend a reduction in frequency for the medical surveillance.

Further Reading

1. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values and Biological Exposure Indices.
2. Biological Monitoring of Chemical Exposure in the Workplace. Vol 1. Geneva: World Health Organization, WHO, 1996.
3. Aitio A, Bernard A, Fowler BA, Nordberg G. Biological monitoring and biomarkers. In: Nordberg GF, Fowler BA, Nordberg M, Friberg LT, eds. Handbook of the Toxicology of Metals. Third Edition. San Diego: Elsevier; 2007. p. 65-78.
4. List of laboratories conducting biological toxicological analysis in Singapore. Retrieved from http://www.oehs.org.sg/links.aspx

10. Workplace Inspection

10.1 Precautions During Workplace Visit

Do remember that you are a guest and therefore act like one. Workplaces can be hazardous and precautions should be taken to safeguard your own safety.

- do not impose your rights or insist on getting answers they cannot give;
- be polite;
- be punctual;
- look where you are going and always be alert;
- dress appropriately and wear PPE where required, e.g., safety shoes, safety goggles, hearing protectors, respirators, etc.;
- ensure that you are always accompanied by a company personnel;
- do not touch anything unless told to as very hot surfaces may appear cold and articles which are touched could become defective;
- do not attempt to "smell" chemicals; and
- do not collect "souvenirs" unless permission is given.

There are several objectives when conducting a workplace visit:

- To understand the workplace processes, if unfamiliar;
- To identify sources of exposure to the hazard in question, and to recommend appropriate evaluation and control measures to protect workers' health;
- When investigating a case of suspected occupational disease, e.g., excessive absorption or poisoning, to establish if there is exposure to the hazard, to determine potential routes of absorption and adequacy and compliance to control measures;
- To conduct active case finding, i.e., whether other workers are similarly affected and might have been missed in the medical monitoring; and
- To assess the suitability of other work areas where a suspended worker can work in during his period of suspension.

A workplace inspection can be divided into three phases: pre-inspection, inspection and post-inspection.

10.2 Pre-inspection

Before going for a workplace visit, it is essential to determine the purpose of the visit. Review all available records, conduct a literature search on the company, the industry, the process, the hazards and any other relevant information so as to enable you to conduct an effective inspection. Pre-reading about the processes being carried out in the workplace – what it does, the raw materials used, the by-products, waste products and the final product produced would enable you to pre-empt potential hazards. Lists can be drawn up, for example for materials/chemicals, products (intermediate/final), work processes, machines and maintenance operations. A flow chart may also be useful to illustrate the work process and its hazards (Fig. 4).

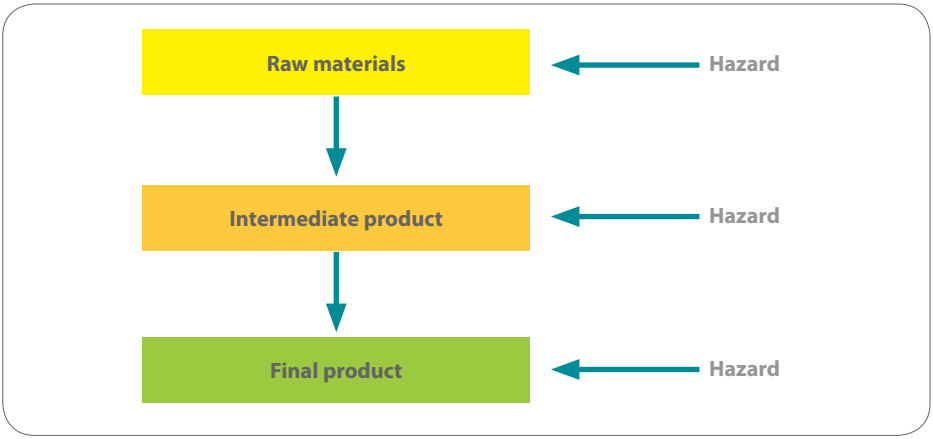

Figure 4: Work process flow chart

10.3 Inspection

During an inspection, use the "who, what, where, when and how" approach. A checklist will ensure that all bases are covered. Aside from looking for deviations from accepted work practices and hazards, take the opportunity to talk to workers to find out whether they have any health complaints and whether they have undergone safety and health training. Taking relevant photographs might also help for subsequent reference and writing up of the inspection report. You may also want to ask the company to show you relevant documents and records to assist you in your investigation. All workplace elements should be assessed–the environment, the equipment and the process, especially when investigating if a link between a hazard exposure and a disease/complaint is present.

10.4 Basic information

This includes:

- name and designation of person who accompanied you during the inspection;
- name of section where workers are exposed to the hazard in question;
- total number of workers exposed to the hazard; and
- entire life-cycle of the hazard in question, from entry to removal from the company to determine whether all who are potentially exposed are under medical surveillance.

Hazards

During the inspection, particular attention should be paid to:

- Health hazards
  - physical (e.g., noise, vibration, heat/cold and radiation);
  - chemical (e.g., dust, mist, fume, gas and vapour);
  - ergonomic (e.g., lifting, awkward postures and repetitive motion);
  - biological (e.g., soil, animals and infectious agents); and
  - psychological (e.g., work organisation, workload and morale).
- Safety hazards (e.g., fire, explosion, falling, electrocution and confined spaces)

Control Measures

Having identified the different hazards present, it is important to note the type and effectiveness of the control measures the company has put in place. Use the Hierarchy of Controls when exploring possible control measures. Start by discussing the feasibility of reducing risk at source, e.g., through elimination and substitution. If a risk cannot be controlled completely by engineering measures, it is necessary to supplement by protecting the employees through administrative control or personal protection. These control measures are not mutually exclusive. More than one measure is usually necessary.

- Elimination (e.g., eliminate sharp protrusions in work areas);
- Substitution (e.g., substitute solvent-based paint with water-based paint);
- Engineering controls (e.g., local exhaust ventilation, enclosures and barriers);
- Administrative controls (e.g., warning labels and signs and good work practices); and
- Personal protective equipment (e.g., safety boots, helmets and protective glasses).

Maintenance Programme

Enquire about maintenance of the equipment, how it is done, safe work procedures, maintenance frequency, worker training, and whether risk assessment has been conducted for it.

Safety Systems and Facilities

Bigger companies would have Workplace Safety and Health (WSH) management systems and structures in place to manage the workplace hazards. These are:

- WSH policies;
- WSH Officer (WSHO) (mandatory for shipyards, workplaces processing petroleum or petroleum products, building operations or works of engineering construction of a contract sum > $10 million, and any work place with >100 persons except workplaces manufacturing garments);
- WSH committee (any workplace with > 50 workers);
- Emergency plans and procedures;
- Signages;
- Fire extinguishers (note the different types of fire extinguishers suited for the different classes (A-D) of fires); and/or
- Emergency showers and eye washes.

Welfare Facilities and General Working Environments

It is also important to consider the general working environments and welfare facilities provided for workers. Issues such as poor ventilation, inadequate lighting, overcrowding and poor housekeeping, etc., should be observed. Workers should also have access to basic welfare provisions like clean drinking water, toilet and shower facilities.

Detailed Assessments

To assist in your investigation, you may need to advise the company to send samples of material for analysis or advise on environmental assessments for specific occupations or specific work areas. Therefore, familiarity with the Permissible Exposure Levels (PELs) stipulated in the Workplace Safety and Health (General Provisions) Regulations would be useful.

Additional tests which may be required to further assess workers' exposure to the hazard include:

- collecting bulk samples for analysis;
- conducting environmental monitoring to assess noise or chemical exposure; and
- measuring effectiveness of local exhaust systems.

Interview with Occupiers or Employees

The interview is an important component of a workplace visit to gain a better understanding of the safety and health measures put in place and/ or situation leading up to an incident. If you are interviewing the employee with high biological test results as part of your inspection, you may want to observe him at work and ask questions to determine:

- symptoms of over-exposure;
- problems with usage of PPE; and
- awareness on types of hazards he is exposed to and awareness of safe work procedures.

Post- Inspection

Have a post-inspection discussion with management on immediate actions that can be taken to alleviate any WSH issues. Write up a detailed report on the workplace visit and communicate with the company management on the recommendations and actions to be taken. Subsequently, follow-up with the company to ensure that all issues raised are resolved.

Further Reading

1. Health and Safety Inspections, a TUC Guide. Trades Union Congress, United Kingdom. Retrieved from http://www.tuc.org.uk/extras/insbooklet30auglowres.pdf on 11 Oct 2010
2. Inspection of the Workplace. Health and Safety Executive, United Kingdom Retrieved from http://www.hse.gov.uk/involvement/inspections.htm on 11 Oct 2010
3. Effective Workplace Inspection. Canadian Centre for Occupational Health and Safety. Retrieved from http://www.ccohs.ca/oshanswers/prevention/effectiv.html on 11 Oct 2010

Workplace Visit Findings Checklist

Date of visit:
Time of visit:

Name of workplace			
Address of workplace			
Contact no. of workplace			
Name(s) of workplace personnel			
Purpose of visit			
Product manufactured			
Type of workshift	8 / 12 hr shift	Rotating/ permanent	
Manufacturing process workflow and potential hazards	**Manufacturing process**	**Hazards (no. of exposed workers)**	**Preventive measures**
Manufacturing process: • Raw material by-products • Final products • Waste disposal **Risk Assessment** Hazards: • Chemical • Physical • Ergonomics • Biological • Psychological **Preventive measures:** • Local exhaust ventilation • Labelling of containers and areas			

Worker training • Medical and Hygiene surveillance • Work habits and housekeeping • Personal protective equipment • Amenities • First aid facilities **General environment** **No. of workers exposed to hazard**			
Maintenance process: • Frequency • By whom • Risk assessment • Safe Work Procedure for Shut down and maintenance			
Recommendations to company • Problems identified • Environmental assessment • Biological assessment • Medical surveillance • Control measures • Suspension of worker; appropriate area to transfer suspended worker to			
Recommendations to worker • if worker is to be suspended, inform on implications of suspension • compliance with safe work procedure, including usage of PPE			

11. Hazards Requiring Statutory Medical Examinations

11.1 Arsenic and its Compounds

11.1.1 Toxic Effects

Inorganic arsenicals are generally more toxic than organic arsenicals; trivalent arsenic being more toxic than pentavalent arsenic.
Effects of arsine gas exposure are mainly acute, causing massive intravascular hemolysis.

Inorganic Arsenic

- Acute poisoning
  - Rare; usually accidental.
  - If ingested, symptoms of throat constriction, dysphagia, epigastric pain, vomiting and watery diarrhoea develop within ½ to 4 hours. Fatal dose of ingested elemental arsenic is 70-180 mg. If not fatal, exfoliative dermatitis and peripheral neuritis may develop.
  - If inhaled, respiratory symptoms–rhinitis, cough, chest pain, dyspnoea, pharyngitis, laryngitis–may occur.
- Chronic poisoning
  - Skin: Increased pigmentation, desquamation, herpetic lesions about the mouth, hyperkeratoses (especially of palms and soles);
  - Respiratory tract: Perforation of nasal septum, chronic bronchitis, basilar fibrosis of lung;
  - Liver: Liver cirrhosis, chronic hepatitis;
  - Peripheral nervous system: Peripheral neuritis characterised by numbness of hands and feet, progressing to painful "pins and needles"; initially sensory, later motor;
  - Haematopoietic system: Normochromic anaemia, neutropenia, thrombocytopenia, aplastic anaemia; and
  - Vasospastic tendency: Raynaud's syndrome.
- Other conditions
  - IARC Group 1 carcinogen–Cancer of lung (no specific tumour type), urinary bladder and skin.
  - Genotoxic: chromosomal aberrations in human lymphocytes

Note: Some inorganic arsenic compounds (e.g., arsenic acid, arsenic trichloride) can be absorbed through intact skin.

11.1.2 Main Industries and Occupations at Risk

Inorganic Arsenic

- Manufacture and use of pesticides (wood preservatives):
  - tanning, wood preservation;
- Manufacture of semiconductors:
  - gallium arsenide substrate production and wafer processing; and
  - cleaning and maintenance of ion implant machines.
- Manufacture of alloy (with copper or lead);
- Smelting of arsenical (especially non-ferrous) ores:
  - dust generated during grinding, screening, transfer and maintenance work on furnaces, flues and filters.
- Pigment manufacture and use;
- Manufacture and use of anti-fouling paints;
- Sawing, sanding and burning wood treated with arsenical preservatives;
- Use as herbicide, pesticide and defoliant; and
- Additives for animal and poultry feed.

11.1.3 Medical Examinations

Indications

Any occupational exposure to **inorganic arsenic and its compounds**.
Not required for arsine gas exposure as effects are acute.

Types of Tests and Frequency of Examinations

- Pre-placement medical examinations: within three months of exposure
  - Clinical examination shall include detailed medical and work history with emphasis on:
    i. Past, present and anticipated future exposure to arsenic; and
    ii. nervous system, respiratory, liver, skin, nasal septum and lymph nodes.
  - Tests:
    i. Analysis of urinary total arsenic (U-As) content in an early morning urine specimen (corrected to SG of 1.016); ensure that worker avoids seafood and seaweed for three days prior to urine collection.
    ii. Liver function tests (serum bilirubin, alkaline phosphatase, gamma glutamyl transferase, alanine and aspartate aminotransferase estimations.)
    iii. Full-sized chest x-ray examination.
  - Unfit for exposure to arsenic:
    i. Persons with abnormal liver function test results; and
    ii. Pregnant women and nursing mothers.

- Periodic medical examinations: every 12 months
  - Clinical examination shall include detailed medical and work history with emphasis on nervous system, respiratory, liver, skin, nasal septum and lymph nodes.
  - Tests:
    i. Analysis of U-As content in an early morning urine specimen (corrected to SG of 1.016); ensure that worker avoids seafood and seaweed for three days prior to urine collection.

BTLV for U-As = 300 mcg/L
Action Level for U-As = 240 mcg/L

ii. Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Differential Diagnosis	Actions to Take
If U-As >240 to 299 mcg/L:	• Inaccurate analysis • High risk exposure	Note: Not required if due to inaccurate analysis • Examine • Reduce risk • Update MOM
If U-As ≥ 300 mcg/L	• Inaccurate analysis • Excessive absorption (if asymptomatic) • Poisoning (if symptomatic)	Note: Not required if due to inaccurate analysis • Examine • Reduce risk • Notify • Suspend • Refer • Update MOM
If diagnosed with lung, urinary bladder or skin cancer	• Work-related cancer • Not work-related cancer	• Examine • Reduce risk • Notify (if suspect work-relatedness) • Suspend • Refer • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of poisoning, skin, urinary bladder and lung cancer. • To determine work-relatedness of condition, obtain detailed occupational history from worker to document arsenic exposure (past and present). • Ask worker whether he had complied with seafood abstinence prior to urine sampling. If not, to repeat urinary arsenic estimation with clear instructions on food abstinence and sampling methodology. • After excluding inaccurate analysis, if U-As ≥ BTLV, to conduct: liver function test (serum bilirubin, alkaline phosphatase, gamma glutamyl transferase, alanine and aspartate aminotransferase estimations) and compare with pre-placement test results.
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review risk assessment and adequacy of control measures in workplace. - Worker i. Evaluate adequacy of worker's personal protection; and ii. Counsel worker on preventive measures and suspension. • If U-As exceeds Action Level, monitor worker closely by repeating U-As 3-monthly or earlier till results are below the action level. • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry Of Manpower(MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM for basis for diagnosis • Inform employer of diagnosis in writing

Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension, period of suspension and date of review. • For cases suspended temporarily: - when U-As levels are below Action level and liver function test is normal, implying that worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker; and - after return to arsenic exposure, continue to monitor worker's abnormal test result (if any) every 3-monthly for the next 6 months. • For cases on permanent suspension: - monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the *Report of Examinations* form.
Refer	• Referral to toxicologist or other specialist for additional tests, where necessary: - Inorganic Arsenic and metabolites [monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA)]; - Arsenic concentration in hair to assess past exposures; - Liver function tests; - Full blood count including differential count; - Kidney function tests including albumin, retinol binding protein, urinary β2 microglobulin; - Electromyography, nerve conduction test; and - Chest X-ray.
Update MOM	• Inform MOM on all test results and actions taken by submitting *Report of Examinations* by e-mail or post.

11.1.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases of definite or suspected arsenic excessive absorption i.e. asymptomatic cases with levels of urine arsenic of 300 mcg/L or more;
- All pregnant and breastfeeding women; and
- Workers with persistent liver abnormalities (one or more abnormal liver function test result on at least 2 occasions, the tests being carried out preferably not more than one month apart).

Indications for Permanent Suspension

- All cases of definite arsenic poisoning; and
- All cases of lung, urinary bladder and skin cancer.

Indications for Return to Inorganic Arsenic Exposure

- Urinary As concentration < Action level i.e. 240 mcg/L; and
- Normal liver function test result.

11.1.5 Special Instructions

Inform all women that they are to inform supervisor as soon as they are found to be pregnant. All pregnant and breastfeeding women are to be temporarily suspended from exposure to arsenic.

11.1.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- Urinary arsenic test results within range for normal unexposed population (See Appendix J); and
- Arsenic-in-air levels are not detectable.

11.1.7 Treatment

Refer for hospital treatment. BAL is the antidote for inorganic arsenic poisoning.

Further Reading

1. American Conference of Governmental Industrial Hygienists (ACGIH). Threshold Limit Values and Biological Exposure Indices 2011.
2. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Values and Biological Exposure Indices., 7th edition, 2001: Arsenic and Soluble Inorganic compounds.
3. Occupational Safety and Health Administration. Occupational Safety and Health Guideline for Arsenic, Organic compounds (as As) accessed on 11 Nov 2009 http://www.osha.gov/SLTC/healthguidelines/arsenic/recognition.html
4. Occupational Safety and Health Administration (OSHA) Regulations (Standards - 29 CFR) Inorganic arsenic. - 1910.1018 http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10023
5. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for Arsenic: Chapter 3. Health effects http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=22&tid=3
6. Finnish Institute of Occupational Health: Biomonitoring of Exposure to Chemicals. Guideline for specimen collection 2009 - 2010 http://www.ttl.fi/en/work_environment/biomonitoring/Documents/guideline_for_specimen_collection.pdf
7. World Health Organization: Biological Monitoring of Chemical Exposure in the Workplace Guidelines 1996. Volume 2, Chapter 1. 1996. http://whqlibdoc.who.int/hq/1996/WHO_HPR_OCH_96.2.pdf

11.2 Asbestos

11.2.1 Health Effects

- Chronic Effects
  - Asbestosis (latency period: 15 or more years after initial exposure) usually related to high cumulative exposure;
  - Pleural plaques/calcification (latency period: 10 to 20 years after initial exposure which may be low or intermittent);
  - Pleural thickening and adhesions resulting in rounded atelectasis;
  - Benign pleural effusion; and
  - Aggravates chronic obstructive lung disease.
- Cancer
  - Lung Cancer (cigarette smoking is an important synergistic factor and the risk may be increased by more than 50 times when compared to an unexposed non-smoker);
  - Mesothelioma (mainly pleural and peritoneal; latency period: more than 30 years which may be low or intermittent); and
  - Gastro-intestinal cancers and laryngeal cancer (association evidence).

11.2.2 Main Industries and Occupation at Risk

- Renovation/ demolition work, e.g., old buildings and power stations where asbestos material may have been used as roof tiles, fire-proof doors/partitions, rubbish chutes in high rise buildings;
- Ship breaking and repairing of old ships where asbestos is used for insulation of boilers, pipes and for partitions;
- Insulation work, e.g., replacement and removal of asbestos insulation of pipes, furnaces, ovens, boilers;
- Handling of asbestos products, e.g., fireproof cloth and gaskets; and
- Repair and replacement of asbestos brake linings by car and bus mechanics.

There are manufactured products in current or past use which may contain asbestos, particularly in the construction and transport industries. Workers such as roofers, demolition workers, fitters, electricians, mechanics, welders and carpenters may potentially be exposed if they are working in areas with asbestos-containing materials.

11.2.3 Medical Examinations

Indications:

Any occupation where workers are liable to be exposed to airborne asbestos fibres

Types of Tests and Frequency of Examinations:

- Pre-placement medical examinations: within three months of exposure
  - Clinical examination with particular emphasis on the respiratory (basal crepitations), cardiovascular and gastrointestinal systems;
  - Full-size chest x-ray examination;

- Unfit for exposure to asbestos:
  Workers who are unable to wear respirators.

- Periodic medical examinations: every 36 months
  - Clinical examination with particular emphasis on the respiratory (basal crepitations), cardiovascular and gastrointestinal systems;
  - Full-size chest x-ray examination;
  - Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Actions	Suspension
Abnormal clinical findings of lungs and abdomen	• Examine • Reduce risk • Refer • Update MOM	Refer to section below on indications for suspension
Abnormal chest X-ray, suggestive of asbestosis	• Examine • Reduce risk • Refer • Notify • Update MOM	Permanent suspension if symptomatic
If previously diagnosed as asbestosis	• Examine • Reduce risk • Update MOM	Refer to section below on indications for suspension
Signs and symptoms suggestive of lung cancer or mesothelioma	• Examine • Reduce risk • Refer • Notify • Update MOM	Permanent suspension
Other clinical findings	• Refer • Update MOM	Refer to section below on indications for Suspension

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of chronic asbestos conditions. • Review previous and latest chest X-rays to look for changes. • To determine work-relatedness of condition, obtain detailed occupational history from worker to document asbestos exposure (past and present). • Conduct lung function test.
Reduce risk	• To do the following within 1 month: - Employer i. Inform employer to review risk assessment and adequacy of control measures in workplace. - Worker i. Evaluate adequacy of worker's personal protection. ii. Counsel worker on preventive measures and suspension (if indicated). • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport). • Provide MOM with basis for diagnosis. • Inform employer of diagnosis (in writing).
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension. • Monitor worker closely by examining worker and repeating abnormal chest X-ray (CXR) annually to observe for changes till advised otherwise by MOM; update MOM using the *Report of Examinations* form.
Refer	When diagnosis is unclear or worker requires further investigation or management : • Refer to relevant clinical specialist for additional tests, e.g., Lung function test, i.e., forced vital capacity (FVC), forced expiratory volume in one second (FEV_1); • Diffusing capacity of the lung for carbon monoxide (DLCO); • High resolution computerized tomography of the chest (HRCT); and • CT scan, etc.
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post.

11.2.4 Suspension from Exposure

Indications for Permanent Suspension

- All cases of definite or suspected asbestosis who are symptomatic;
- All cases with evidence of lung cancer and mesothelioma; and
- Workers with deteriorating lung function or deteriorating chest X-ray findings in a worker less than 35 years old.

11.2.5 Special Instructions

Radiologists interpreting the chest X-rays should compare them against the standard films–ILO 2000 on Classification of Radiographic Appearances of the Pneumoconioses.

Young persons under 18 years of age should not be exposed to asbestos.

Workers should be advised to stop smoking.

11.2.6 Criteria for Exemption

Employers may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential exposure;
- Asbestos-in-air levels are not detectable; and
- Workers have completed at least two rounds of examinations and the Chest X-rays of all workers are normal.

11.2.7 Treatment

There is no definitive treatment for asbestosis. All cases of suspected lung cancer or mesothelioma should be referred for further management by a respiratory physician or oncologist. Asbestosis cases may require symptomatic treatment as and when indicated.

Further Reading

1. Margaret R Becklake. Asbestos-related diseases: Encyclopaedia of Occupational Health and Safety, International Labour Office, Geneva, 4th edition; Volume 1; Volume 5, p1050-63, 1998.
2. International Classification of Radiographs of Pneumoconioses (revised 2000) Occupational Safety and Health series 22 (rev 80) (International Labour Office, Geneva), 2000.
3. American Thoracic Society. Diagnosis and initial management of non-malignant diseases related to asbestos. Am J Respir Crit Care Med 2004; 170:691–715.
4. Asbestos: Medical Guidance note. 4th Edition. Health and Safety Executive, 2005. http://www.hse.gov.uk/pubns/ms31.pdf
5. Fact sheet on Asbestos Exposure and Cancer Risk. National Cancer Institute of the National Institutes of Health. http://www.cancer.gov/cancertopics/factsheet/Risk/asbestos

11.3 Benzene

Benzene is an aromatic hydrocarbon (C_6H_6) and is a volatile, flammable, clear or colourless to light-yellow liquid with a sweet odour.

It is used primarily as a solvent in the chemical and pharmaceutical industries, as a starting material and intermediate in the synthesis of numerous chemicals, and in petrol. Benzene is used as an additive in petrol, but it also is present naturally in petrol, because it occurs naturally in crude oil and is a by-product of oil refining processes. The percentage of benzene in unleaded gasoline is approximately 1% to 2% by volume.

11.3.1 CAS Number: 71-43-2

Common Synonyms:

- Benzol;
- Phenyl hydride

11.3.2 Routes of Exposure

- Primarily by inhalation of vapours;
- Dermal from direct contact with liquid benzene; and
- Ingestion of liquid benzene (uncommon).

11.3.3 Toxic Effects

Acute Poisoning

- Narcosis , CNS depression and death (~20,000 ppm for 5-10 minutes)
- Dose dependent central nervous system toxicity (~300–3000 ppm)
  - drowsiness, dizziness, headache, vertigo, tremor, delirium, loss of consciousness.
- Skin and mucous membrane irritation (>33 ppm)

Chronic Poisoning

- Non-specific manifestations, e.g., anorexia, headache, dizziness
- Bone marrow depression
  - leucopenia, thrombocytopenia, anaemia, pancytopaenia; and
  - aplastic anaemia.
- Skin irritation (repeated skin contact)
  - dry, scaly dermatitis; and
  - erythema and/ or blistering.
- Immunological effects
  - decrease in humoral and cellular immunity.

Others

- Leukaemia (most common being acute myeloid leukaemia); and
- Non-Hodgkin's lymphoma.

11.3.4 Main Industries and Occupations at Risk

- Petrochemical industries, e.g., manufacture of benzene, production of carbon black;
- Petroleum refineries;
- Petrol retailers, e.g., oil terminals (loading and unloading), service stations, airport terminal workers (aviation gasoline);
- Manufacture of some types of plastics, synthetic fibres and nylon (cyclohexane), detergents, synthetic resins, butadiene rubber, styrene, phenol, lubricants, dyes and pesticide;
- Laboratories, e.g., use of benzene in analytical techniques;
- Work involving use of commercial solvents such as toluene and xylene (benzene may be present as a contaminant);
- Work involving handling of fuels containing benzene, e.g., vehicle workshops;
- Bulk storage terminals loading, unloading, storage of petrol and related products, benzene etc;
- Waste treatment plants handling benzene-containing waste material; and
- Sampling of waste water from plants handling benzene.

11.3.5 Medical Examinations

Indications

Any occupational exposure to benzene

Types of Tests and Frequency of Examinations

- Pre-placement medical examination: within three months of employment
  - Clinical examination with particular emphasis on:
    i. past, present, and anticipated future exposure to benzene;
    ii. haematological and central nervous system disorder; and
    iii. current usage of medication with potential hematotoxic side-effects
  - Tests:
    i. Haemoglobin (Hb);
    ii. Full blood count–total white blood cells, red blood cells and platelets (FBC);
    iii. Peripheral blood film (PBF) to look for blast cells; and
    iv. Urinary tt-muconic acid (ttma) or s-phenylmercapturic acid (spma) estimation in an end-of-the-shift urine sample taken mid-week (creatinine-corrected; inhalation of tobacco smoke and use of sorbitol increases background levels and this should be considered in the interpretation of the results).
  - Unfit for exposure to benzene:
    i. History of myelodysplastic syndrome;
    ii. Young persons under 18 years of age;
    iii. Pregnant / nursing mothers; and
    iv. Persons diagnosed with liver disease.

Note: Persons with thalassaemia minor may work with benzene.

- Periodic medical examination: every 12 months
  - Clinical examination with particular emphasis on haematological and central nervous systems.
  - Estimation of Urinary tt-muconic acid (ttma) or s-phenylmercapturic acid (spma) estimation in an end-of-the-shift urine sample taken mid-week (creatinine-corrected).
    i. Inhalation of tobacco smoke and use of sorbic acid increases background levels and this should be considered in the interpretation of results:

    Urinary ttma: BTLV = 1.6 mg/g Cr; Action level = 1.3 mg/g Cr
    Urinary spma: BTLV = 45 mcg/g Cr; Action level = 36 mcg/g Cr

  - Hemoglobin (Hb) and FBC
    Normal = 95% or more of laboratory minimum with no declining trend
  - Peripheral Blood Film (PBF)
  - Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	U-ttma or U-spma levels		
	Below Action levels	**Between Action and BTLV levels**	**Exceed BTLV levels**
If Hb or FBC is <95% of laboratory minimum or abnormal PBF	• Examine • Suspend • Refer • Update MOM	• Examine • Reduce risk • Suspend • Refer • Update MOM	• Examine • Reduce risk • Suspend • Refer • Notify • Update MOM
If Hb, FBC and PBF are normal	No action	• Examine • Reduce risk • Update MOM	• Examine • Reduce risk • Suspend • Notify • Update MOM
If evidence of cancer	• Examine • Suspend • Refer • Notify (if work-related) • Update MOM	• Examine • Reduce risk • Suspend • Refer • Notify (if work related) • Update MOM	• Examine • Reduce risk • Suspend • Refer • Notify • Update MOM

Description of Actions to Take

Actions to Take	Description
Examine	• Examine for signs and symptoms of poisoning / cancer • To determine work-relatedness of condition, obtain detailed occupational history from worker to document benzene exposure (past and present) • Check serial Hb, FBC results for declining trend
Reduce risk	• To do following within 1 month: - Employer: i. Inform employer to evaluate adequacy of control measures in workplace - Worker: i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Monitor abnormal test result(s) monthly till results are normal • Visit workplace if necessary
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • For cases suspended temporarily: - when U-spma or U-ttma levels are below Action level and Hb, FBC and PBF are normal, implying that worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker - after return to benzene exposure, continue to monitor worker's abnormal test result (if any) every 3-monthly for the next 6 months • For cases on permanent suspension: - monitor worker at least 6-monthly untill advised otherwise by MOM; update MOM using the *Report of Examinations* form
Refer	• Referral to toxicologist or haematologist for additional tests e.g., - Bone marrow biopsy - Liver function test
Update MOM	• Inform MOM of all test results and all actions taken by submitting *Report of Examinations* form by e-mail or post

11.3.6 Indications for Suspension from Exposure

Temporary Suspension

- Pregnant/nursing mothers;
- All cases of excessive absorption, i.e., cases with U-ttma levels of 1.6 mg/g Cr and more or U-spma levels of 45 mcg/g Cr and more, in the absence of symptoms; and
- Cases with abnormal Hb or FBC.

Permanent Suspension

- All cases of poisoning;
- All cases of pre-leukaemia, leukaemia, lymphoma; and
- Persons with diagnosed liver disease.

Indications for Return to Benzene Exposure

- U-spma or U-ttma level < Action level; and
- Normal FBC results; and
- No symptoms of benzene poisoning.

11.3.7 Criteria for Exemption from Medical Surveillance

Employers may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- U-ttma or U-spma test results within range for normal unexposed population (See Appendix J); and
- Benzene-in-air levels are not detectable.

11.3.8 Treatment

All cases of benzene poisoning must be immediately removed from exposure. Acute poisoning cases must be referred for hospital treatment.

Further Reading

1. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values and Biological Exposure Indices.
2. Toxicological profile for Benzene. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. 2007. Sections 3.8.1 and 3.8.2. http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=40&tid=14
3. NIOSH Pocket Guide to Chemical Hazards, Benzene http://www.cdc.gov/niosh/npg/npgd0049.html. Accessed 24 June 2011
4. Martyn T. Smith, Rachael M. Jones, and Allan H. Smith. Benzene Exposure and Risk of Non-Hodgkin Lymphoma. Cancer Epidemiol Biomarkers Prev 2007;16:385-391.
5. Steinmaus C, Smith AH, Jones RM, Smith MT. Meta-analysis of benzene exposure and non-Hodgkin lymphoma: biases could mask an important association. Occup Environ Med. 2008 Jun;65(6):371-8.
6. International Agency for Research on Cancer, Monographs on Benzene, Volumes 29, Supplement 7, 99, 100F.

11.4 Cadmium and its Compounds

Cadmium is a soft bluish-white metal with a melting point of 321 ^{0}C and boiling point of 767 ^{0}C. It is a by-product of zinc production.

11.4.1 Toxic Effects

- Acute Poisoning
  - Metal fume fever with flu-like symptoms of weakness, fever, headache, chills, sweating and muscular pain.
  - Delayed pulmonary oedema following fume inhalation; onset within 8 to 24 hours and peaking by 3 days; mortality 15%. If death does not occur, symptoms may resolve within a week.
  - Acute renal failure after inhalation of high concentration of fumes.
  - Gastrointestinal tract irritation following accidental ingestion.
- Chronic Poisoning
  - Renal dysfunction (tubular and/or glomerular damage with low molecular weight proteinuria, e.g., beta2 microglobulinuria, glucosuria, amino aciduria, albuminuria and reduced creatinine clearance) with latency of about 10 years.
  - Emphysema.
  - Bone pain; osteomalacia, osteoporosis and fractures.
  - Anaemia, teeth discoloration and anosmia.
- Others
  - IARC Group 1 carcinogen–Cancer of lung.
  - Elevated risk of prostate, kidney and bladder cancers.

Note: Cigarette smoking adds to cadmium burden. Each cigarette contains about 1 - 2 mcg cadmium (Cd) of which approximately 25 -50% is retained in the lungs.

The average normal gastrointestinal absorption in man ranges from 3 - 7% of ingested cadmium. This increases to as high as 20% with nutritional deficiencies of calcium, iron or protein.

11.4.2 Main Industries and Occupations At Risk

- Waste treatment plants handling cadmium-containing waste;
- Sampling of waste water from plants handling cadmium;
- Cadmium electroplating;
- Plastics industry, especially compounding of polyvinyl chloride (PVC); used as thermal stabiliser;
- Nickel-cadmium battery manufacturing (tableting and assembly of Cd electrodes);
- Pigment manufacture and use e.g., for plastics, textile, paper, rubber industries; in inks, enamels and glazes;
- Alloy manufacture, e.g., low melting-point brazing alloys, Ag-Cd & Cu-Cd;
- Fungicides manufacture and use;
- Silver brazing using cadmium-containing fillers, welding on cadmium-containing alloys;

- Manufacture of refrigerators, air-conditioners, television picture tubes, semiconductors, photo-cells & fluorescent lamps, and as neutron absorber in nuclear reactors;
- Jewellery manufacture;
- Automobile and aircraft industries;
- Smelting and refining of Zn, Pb or Cu ores and scrap processing;
- Spray painting using cadmium-containing paints, removal of cadmium paints by blasting or scraping; and
- Manufacture of cadmium telluride solar panels.

Footnote: Locally, high exposures are sometimes seen in the Waste treatment industry.

11.4.3 Medical Examinations

Indications:
Any work where workers are exposed to cadmium.

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on:
    i. past, present, and anticipated future exposure to cadmium;
    ii. renal, olfactory, cardiovascular, respiratory, haematopoietic, reproductive, and/or musculo-skeletal system dysfunction;
    iii. current usage of medication with potential nephrotoxic side-effects; and
    iv. a history of smoking.
  - Tests:
    i. Blood cadmium (B-Cd) estimation (venous blood in heparinised container); and
    ii. Urine Beta$_2$ – microglobulin (U-β_2m) estimation.

Note: Special instruction for collection of specimen for U-β_2m estimation:
DO NOT USE EARLY MORNING URINE SPECIMEN. Collect morning urine specimen 2 hours after drinking 15 ml. Mist Potassium Citrate. Discard specimen if urine pH lower than 5.6. Keep specimen refrigerated after collection and in ice during transportation. Specimens should reach the laboratory within 2 hours after collection.

  - Unfit for exposure to cadmium:
    i. History of renal dysfunction or persons with raised U-β_2m test results; and
    ii. Pregnant women.
- Periodic medical examinations: every 12 months
  - Clinical examination shall include a detailed medical and work history with emphasis on:
    i. renal, olfactory, cardiovascular, respiratory, haematopoietic, reproductive, and/or musculo-skeletal system dysfunction;
    ii. current usage of medication with potential nephrotoxic side-effects; and
    iii. a history of smoking.

- Tests:
  i. B-Cd estimation (venous blood in heparinised container)

  BTLV for B-Cd = 5 mcg/L
  Action Level for B-Cd = 4 mcg/L

- U-β_2m estimation
  Normal level ≤290 mcg/L Creatinine
- Actions to take when there are abnormal clinical findings:

	B-Cd Levels		
	B-Cd < 4 mcg/L	**B-Cd 4 to < 5 mcg/L**	**B-Cd ≥ 5 mcg/L**
U-β_2m < 290 mcg/g creatinine	• No action	• Examine • Reduce risk • Update MOM	• Examine • Reduce risk • Suspend • Notify • Update MOM
U-β2m ≥290 mcg/g creatinine	• Examine • Suspend • Refer • Update MOM	• Examine • Reduce risk • Suspend • Refer • Update MOM	• Examine • Reduce risk • Suspend • Refer • Notify • Update MOM
If evidence of cancer	• Examine • Suspend • Refer • Notify (if work-related) • Update MOM	• Examine • Reduce risk • Suspend • Refer • Notify (if work-related) • Update MOM	• Examine • Reduce risk • Suspend • Refer • Notify • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of poisoning and lung cancer. • To determine work-relatedness of condition, obtain detailed occupational history from worker to document cadmium exposure (past and present). • Check serial B-Cd and U-β_2m levels for increasing trends. • If B-Cd > BTLV, to analyse U-Cd levels. BTLV for U-Cd = 5 mcg/g Creatinine Action level for U-Cd = 4 mcg/g Creatinine
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review Risk Assessment and adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Monitor worker closely by repeating B-Cd / U-Cd 3-monthly untill results are below the action level. • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport). • Provide MOM with basis for diagnosis. • Inform employer of diagnosis (in writing).
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension. • For cases suspended temporarily: - when B-Cd / U-Cd levels are below action level and U-β_2m level is normal, implying that worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker; and - after return to cadmium exposure, continue to monitor worker's abnormal test result (if any) every 3-months for the next 6 months. • For cases on permanent suspension: - monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the *Report of Examinations* form.

Refer	• Referral to toxicologist or other specialist for additional tests, e.g., : - 24-hour Urine total protein; - Urine albumin and transferrin, glucose, calcium, phosphates and amino acids and microscopic examination; urine protein electrophoresis; - Full-size chest x-ray and lung function tests (FEV_1 and FVC); - Abdominal X-ray (for renal stones) and X-rays of long bones, scapula and pelvis (for osteomalacia, osteoporosis and fractures); - Haemoglobin estimation; - Blood pressure measurement; - Serum creatinine and urea estimation; and - Creatinine clearance test (CCT).
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post.

11.4.4 Indications for Suspension from Exposure

Temporary Suspension

- All cases of excessive absorption, i.e., asymptomatic cases with B-Cd concentration of 5 mcg/L or more;
- All cases of raised U-β_2m levels (> 290 mcg/g Creatinine); and
- All pregnant women.

Permanent Suspension

- All cases of cadmium poisoning;
- All cases with evidence of lung cancer; and
- Workers with persistent renal and lung abnormalities (one or more abnormal result on at least 2 occasions, the tests being carried out preferably not more than one month apart).

Indications for Return to Cadmium Exposure

- B-Cd / U-Cd levels < Action level; and
- U-β_2m levels < 290 mcg/g Creatinine.

11.4.5 Special Instructions

Inform all women that they are to inform their supervisors as soon as they are found to be pregnant. All pregnant women are to be suspended from exposure to cadmium.

11.4.6 Treatment

All employees found to have been poisoned by cadmium must be immediately removed from further exposure. Acute poisoning cases must be referred for hospital treatment.

11.4.7 Criteria for Exemption from Medical Surveillance

Employers may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- Blood cadmium test results within range for normal unexposed population (See Appendix J); and
- Cadmium-in-air levels are not detectable.

Further Reading

1. Agency for Toxic Substances & Disease Registry – Toxicological Profile for Cadmium, September 2008.
   http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=48&tid=15
2. Occupational Safety and Health Administration, US Department of Labor – Regulations (Standards – 29 CFR) Cadmium – 1910.1027
   http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10035
3. Finnish Institute of Occupational Health. Biomonitoring of exposure to chemicals – Guideline for specimen collection 2009 – 2010
4. IPCS INCHEM. Cadmium (PIM 089)
   Accessed on 21 Oct 2009: http://www.inchem.org/documents/pims/chemical/cadmium.htm

11.5 Work In Compressed Air Environments

11.5.1 Health Effects

- Compressed Air Illness (CAI) otherwise called Decompression Sickness:
  - Acute:

    Type I: mild form, onset at any time from final stages of decompression to 12 or even 36 hours after decompression; "bends" (limb pains), skin mottling.

    Type II: more severe form; onset usually early (within 45 minutes of decompression) neurological, respiratory, cardiac or gastrointestinal involvement
  - Chronic dysbaric osteonecrosis; usually involving shoulder, hip or knee; may be asymptomatic. Lesions may be in the head, neck or shaft or femur. Disability with persistent joint pain and stiffness is likely only if the articular surfaces are affected. Condition may develop months or even years later.
- Barotrauma:
  - Pulmonary (may be complicated by pneumothorax, cerebral air-gas embolism, surgical emphysema)
  - Sinus;
  - Aural (sensorineural hearing loss in inner ear barotrauma, conductive loss in perforated/damaged tympani); and
  - Others such as dental, face mask and suit barotraumas.
- Toxicity from toxic environments or contaminated breathing gases such as carbon monoxide, resulting in acute or chronic health effects.
- Hypoxia from lack of oxygen in breathing gas or work environment.

11.5.2 Main Industries and Occupations at Risk

- Tunnelling or shaft sinking operations in water bearing strata;
- Caisson work on river beds;
- Medical lock attendants;
- Healthcare staff who oversee medical treatments conducted in hyperbaric chambers; and
- Checking for leaks within pressurised compartments.

11.5.3 Medical Examinations

The medical examination should preferably be conducted by a DWD who has undergone further training and is familiar with Hyperbaric/Diving Medicine. These doctors would be registered with MOM under the DWD (CAW) Register.

Minimum age for a compressed air worker is 18 years. There is no upper age limit provided the worker is able to satisfy the medical standards.

Indications

Any work environment in which workers are exposed to pressure greater than normal atmospheric pressure.

Types of Tests and Frequency of Examinations

Pre-placement medical examinations are to be conducted within 30 days **before** employment.

Medical Examination	Frequency of Examination
• A clinical examination for compressed air illness & fitness for compressed air work (with particular emphasis on the ENT, respiratory, cardiovascular, neurological and gastrointestinal systems)	• Pre-placement • Thereafter: - Not less than once in every 3 months for working pressures not exceeding 1 bar; - Not less than once in every 4 weeks for working; pressures at or exceeding 1 bar - Not more than 3 days prior to reemployment in compressed air environment: i after a worker has not been employed for > 14 consecutive days; ii after a worker has suffered from a cold, chest infection, sore throat or earache; and iii after a worker has suffered from any illness or injury necessitating absence from work for more than 3 consecutive days.
• Height, weight and body fat estimation*	Pre-placement and 12 monthly
• Dipstick urinalysis (glucose, protein and blood)	Pre-placement and 12 monthly
• Lung Function tests (FEV1, FVC and FEV1/FVC ratio)	Pre-placement and 12 monthly
• Resting electrocardiography (for workers aged 35 yrs and above), treadmill exercise tests when indicated	Pre-placement and 12 monthly
• Audiometric testing where the air conduction is abnormal, to include bone conduction testing and auroscopic examination	Pre-placement and 12 monthly

• Full blood count and peripheral blood film	Pre-placement
• Test in lock (to 10 metres)**	Pre-placement
• Full size chest X-ray (PA–full inspiration and expiration)	Pre-placement
• Radiographic examination of shoulder (AP), hip (AP) and knee joints (AP and lateral)	• Pre-placement (for all working pressures) • 12 monthly or just before stopping work, whichever is earlier (for working pressures at or exceeding 1 bar)

* Body fat can be estimated via the skin fold measurements or bioelectrical impedance analysis.
** Done in a hyperbaric centre equipped with a medical lock or hyperbaric chamber, operated by a qualified chamber or lock attendant.

11.5.4 Absolute Contradictions for Compressed Air Work

Persons with the following conditions should be certified to be unfit for compressed air work.

- chronic upper respiratory tract infection, particularly recurrent sinus infection;
- chronic suppurative otitis media;
- chronic lung disease (past or present), bronchial asthma, bronchiectasis, history of pneumothorax;
- peptic ulcer;
- hernia;
- heart disease, e.g., right-to-left cardiac shunts, heart failure;
- hypertension (uncontrolled);
- Diabetes Mellitus (uncontrolled);
- epilepsy or other disease of the central nervous system;
- gross obesity;
- bone disease;
- pregnancy; and
- patent ductus arteriosus.

11.5.5 Indications for Suspension from Exposure

Temporary Suspension

- Persons suffering from a cold, chest infection, sore throat or ear infection; and
- Cases of CAI.

Permanent Suspension

- Cases with evidence of conditions for which compressed air work is contraindicated; and
- Cases with juxta-articular lesions of the bone .

11.5.6 Notification to Ministry of Manpower

Submit a *Certificate of Suspension* to Minnistry of Manpower (MOM) for all cases recommended for suspension.

Notify the Commissioner for Workplace Safety and Health, MOM through iReport for all suspected cases of CAI, barotrauma and ill-health related to environmental and breathing gases, providing basis for the diagnosis and test results. Update MOM on actions taken in the *Report of Examinations* form.

11.5.7 Treatment and Follow-up

- Immediate Medical Treatment
  CAI and cerebral air-gas embolism should undergo therapeutic recompression. This can be initiated at the Medical Lock on-site with minimal delay, supported by additional resuscitation means such as intravenous hydration.

  The casualty is to be evacuated in a supine position and given surface oxygen during the transfer to the Medical Lock and to the hospital. At the earliest possible time, the physician should also go to the site to evaluate the worker.

  Medical advice should be sought from a Hyperbaric/ Diving Medicine Physician for all cases of CAI and cerebral air-gas embolism. The 24-hour hotline (Tel 63332233) is for contacting both Singapore General Hospital and Singapore Navy.

  Treatment is available at:
  - During office hours: Hyperbaric and Diving Medicine Centre, Singapore General Hospital (Tel: 63213427)
  - After office hours: Accident and Emergency Department, Singapore General Hospital

- Subsequent follow-up
  CAI cases will require a medical evaluation to determine fitness to return to work.

  CAI cases should be followed up with skeletal x-rays (shoulders, hips and knees) 1 year later. They may also require an echocardiogram of the heart to exclude right-to-left shunts upon recommendation by the Hyperbaric/ Diving Medicine Physician.

  For workers with "undeserved bends"*, to investigate further for predisposing factors, e.g., patent foramen ovale.

  *Refers to cases of bends occurring despite following proper procedures and tables.

Further Reading

1. Health and Safety Executive. A Guide to the Work in Compressed Air Regulations 1996.
2. Hong Kong Factories and Industrial Undertakings (Work in Compressed Air) Regulations 1998.
3. International Labour Organization: Encyclopaedia of Occupational Health and Safety, 4th edition, 1998.
4. Singapore Standard SS 511:2010: Code of Practice for Diving at Work. SPRING Singapore.

11.6 Cotton Dust

11.6.1 Health Effects

- Mill fever
  - Upper respiratory irritation, cough, chills, fever, occasional nausea and vomiting;
  - Occurs with first contact with mill or upon return after prolonged absence; and
  - Symptoms disappear after a few days as tolerance develops.
- Chronic Bronchitis
- Byssinosis
  - Occurs after years of exposure/mill fever;
  - Chest tightness, breathlessness, coughing and/ or wheezing;
  - Symptoms begin at the start of the work week and subside later on or when worker is away from the workplace; and
  - Ultimately, leads to chronic bronchitis, emphysema and respiratory failure.

11.6.2 Main Industries and Occupations at Risk

- Raw cotton processing in textile industry;
  - Carding (separating fibres and forming them into bundles of roughly parallel fibres); most dusty operation;
  - Opening, cleaning and picking of bale cotton using beaters and/or saw cleaners (fibre preparation);
  - Spinning (reducing size of roving and imparting twist);
  - Winding (winding yarn into cones or tubes);
  - Drawing and roving (straightening fibres, reducing strand or sliver size and imparting a slight twist);
  - Twisting (twisting strands of yarn together to form ply yarns);
  - Weaving; and
  - Ginning (removing fibre from seed).
- Cotton harvesting by hand or machine (spindle picker or stripper); and
- Raw cotton processing in other industries, e.g., preparation of substrate for growing of mushrooms.

11.6.3 Medical Examinations

Indications:

Any occupational exposure to raw cotton dust–defined as dust generated from the processing of cotton fibres, cotton or cotton fibre by-products (excluding dust from handling or processing of woven materials).

Types of Tests and Frequency of Examinations:

- Pre-placement medical examinations: within three months of exposure
  - Clinical history and examination with emphasis on:
    i. past, present, and anticipated future exposure to cotton dust; and
    ii. respiratory system dysfunction.

- Lung function tests: Forced expiratory volume in one second (FEV1) and Forced vital capacity (FVC);
  i. Pre- shift test on the first day of the working week; and
  ii. Post-shift test to be done after at least 6 hours of exposure on the same day.
- Unfit for exposure to cotton:
  i. history of asthma and other symptomatic respiratory diseases.

- Periodic medical examinations: every 12 months
  - Clinical history and examination with emphasis on respiratory system;
  - Lung function tests: Forced expiratory volume in one second (FEV1) and Forced vital capacity (FVC);
    i. Pre- shift test on the first day of the working week;
    ii. Post-shift test to be done after at least 6 hours of exposure on the same day
    iii. Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Actions	Suspension
If evidence of chronic bronchitis and/or emphysema	• Examine • Reduce risk • Refer • Update MOM	• Permanent suspension
If lung function test results show 10% or more drop in FEV_1 over the shift on the first day	• Examine • Reduce risk • Refer • Notify • Update MOM	• Permanent suspension
If FEV_1 of <80% predicted value and FEV1/FVC ratio of <75%, tested after at least 2 days off work	• Examine • Reduce risk • Refer • Notify • Update MOM	• Permanent suspension
If previously diagnosed as byssinosis	• Examine • Reduce risk • Update MOM	• Refer to section below on indications for suspension
Other clinical findings	• Refer • Update MOM	• Refer to section below on indications for Suspension

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of byssinosis. • Review previous and latest lung function test results to look for changes. • To determine work-relatedness of condition, obtain detailed occupational history from worker to document raw cotton exposure (past and present).
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review risk assessment and adequacy of control measures in workplace. - Worker i. Evaluate adequacy of worker's personal protection. ii. Counsel worker on preventive measures and suspension (if indicated) • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport). • Provide MOM with basis for diagnosis. • Inform employer of diagnosis (in writing).
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension. • Monitor worker closely by examining worker and repeating abnormal lung function test annually to observe for changes until advised otherwise by MOM; update MOM using the *Report of Examinations form*.
Refer	• When diagnosis is unclear or worker requires further investigation or management: Refer to relevant clinical specialist for additional tests, e.g., Chest X-ray, diffusing capacity of the lung for carbon monoxide (DLCO), High resolution computerized tomography (HRCT), etc.
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post.

11.6.4 Indications for Suspension from Exposure

Permanent Suspension

- Workers with Grade 2 symptoms, i.e., chest tightness and/ or breathlessness on the first day of the working week and other days;
- Cases of chronic bronchitis and emphysema; and
- Workers with abnormal lung function:
  - 10% or more drop in FEV_1 over the shift on the first day; or
  - FEV_1 of <80% predicted value and FEV1/FVC ratio of <75%, tested after at least 2 days off work.

11.6.5 Criteria for Exemption

Employers may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential exposure;
- Cotton-in-air levels are not detectable; and
- Workers have completed at least two rounds of examinations and the lung function test results of all workers are normal.

11.6.6 Treatment

All byssinosis cases and cases of bronchitis or emphysema should be referred for further investigations, including full lung function tests, preferably in a chest hospital/ clinic.

Further Reading

1. National Institute for Occupational Safety and Health: Criteria for a recommended standard: Occupational exposure to Cotton Dust. U.S. Department of Health, Education and Welfare, USA, 1974. (HEW Publication No (NIOSH) 75-118).
2. Occupational Safety and Health Administration, US Department of Labor – Regulations (Standards – 29 CFR) Cotton dust – 1910.1043 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10053) Accessed on 24 Sept 2010.
3. International Labor Organization. Chapter 89: Respiratory effects and other disease patterns in the textile industry by E. Neil Shachter. (http://www.ilo.org/safework_bookshelf/english?content&nd=857171066) Accessed on 24 Sept 2010.
4. Labour Department of Hong Kong, 1986 – Code of practice for protection of cotton spinning workers from byssinosis.
5. Schilling RSF: Byssinosis. In: Encyclopedia of Occupational Health and Safety, International Labour Organization, Geneva, 3rd edition, 1983: 350 -3.
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11.7 Lead And Its Compounds

Inorganic Lead Compounds

11.7.1 Toxic Effects

- Haemotological:
  - Anaemia, or a falling haemoglobin level; pallor and fatigue may be present.
- Gastrointestinal:
  - Mild: anorexia, epigastric discomfort, constipation or diarrhoea;
  - Severe: abdominal colic; and
  - Burton's line, a bluish-black pigmentation at margins of gums, is an indication of lead exposure, not of lead poisoning.
- Peripheral nervous system:
  - Paresis (rarely paralysis), often affecting extensors of the hand or foot, with no sensory changes.
- Central nervous system:
  - Encephalopathy may occur with severe poisoning (drowsiness, convulsions, coma); and
  - Slow mental changes may occur (learning difficulty, behavioural changes etc have been described in children with lead exposure).
- Renal:
  - Chronic nephritis and tubular degeneration.
- Reproductive:
  - Lead can cross the placenta and may cause neurological damage to the foetus.

Note: In our local experience we have not encountered cases of classical lead poisoning. Our cases usually present with mild anaemia or falling haemoglobin levels and a blood lead level of 70 - 80 mcg/100 ml, without any neurological signs. Generally they are asymptomatic as they are detected early.

11.7.2 Main Industries and Occupations at Risk

- Manufacture and use of lead stabilisers in PVC compounding;
- Manufacture of lead-acid storage batteries (accumulators);
- Burning, welding or cutting of lead-coated structures, e.g., shipbreakers and welders;
- Manufacture and use of ammunition, e.g., firing range instructors;
- Manufacture and use of lead-based paints;
- Manufacture of solder;
- Manufacture and use of glazes for porcelain, enamels, tiles; and
- Manufacture of alloys.

11.7.3 Medical Examinations

Indications:

Any exposure to inorganic lead or its compounds

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on:
    i. past, present and anticipated future exposure to lead;
    ii. renal, haematological, gastrointestinal and nervous system dysfunction;
    iii. current usage of medication with potential nephrotoxic side-effects; and
    iv. smoking history.
  - Estimation of:
    i. blood lead level (B-Pb)(venous blood in heparinised container); and
    ii. haemoglobin level (g/dL).
  - Unfit for exposure to inorganic lead:
    i. History of renal, haematological, gastrointestinal and nervous system dysfunction.

Note: Persons with thalassaemia minor may work with inorganic lead.

- Periodic medical examinations: every 6 months
  - Clinical examination shall include a detailed medical and work history with emphasis on the haematological and nervous systems.
  - Estimation of:
    i. blood lead level (venous blood in heparinised container)

For males of all ages and females ≥ 50 yrs:

BTLV for B-Pb : 50 mcg/100 ml
Action level for B-Pb : 40 mcg/100 ml

For females < 50 yrs:

BTLV for B-Pb : 30 mcg/100 ml
Action level for B-Pb : 24 mcg/100 ml

ii. haemoglobin level (g/dL)

Normal:95% or more of laboratory minimum with no declining trend

Actions to take when there are abnormal clinical findings:

Blood Lead (mcg/100 ml)	Haemoglobin (g/dl)		
	Normal ≥95% Laboratory Lower Limit	**Mild Anaemia**	**Significant Anaemia Hb≤11 (males) Hb≤10 (females)**
Males (all ages) and females ≥ 50 yrs < 40 mcg/100 ml	• No action	• Examine	• Examine • Suspend • Refer • Update MOM
40 – 49 mcg/100 ml	• Examine • Reduce risk • Update MOM	• Examine • Reduce risk • Update MOM	• Examine • Reduce risk • Suspend • Refer • Update MOM
≥ 50 mcg/100 ml (excessive absorption if asymptomatic; poisoning if symptomatic)	• Examine • Reduce risk • Suspend • Notify • Update MOM	• Examine • Reduce risk • Suspend • Notify • Refer • Update MOM	• Examine • Reduce risk • Suspend • Notify • Refer • Update MOM
Females < 50 yrs < 24 mcg/100 ml	• No action	• Examine	• Examine • Suspend • Refer • Update MOM
24 – 29 mcg/100 ml	• Reduce risk • Update MOM	• Examine • Reduce risk • Update MOM	• Examine • Suspend • Reduce risk • Refer • Update MOM
≥ 30 mcg/100 ml (excessive absorption if asymptomatic; poisoning if symptomatic)	• Examine • Reduce risk • Suspend • Notify • Update MOM	• Examine • Reduce risk • Suspend • Notify • Refer • Update MOM	• Examine • Reduce risk • Suspend • Notify • Refer • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of lead poisoning. • If anaemia is significant, repeat Hb immediately to determine whether suspension is indicated. • Investigate cause of anaemia. Treat anemia and repeat Hb 3-monthly until normal. • Check serial Hb and B-Pb results for declining and increasing trend respectively. • To determine work-relatedness of condition, obtain detailed occupational history from worker to document lead exposure (past and present).
Reduce risk	• To do following within 1 month: - Employer: i. Inform employer to evaluate risk assessment and adequacy of control measures in workplace. - Worker: i. Evaluate worker's personal protection and personal hygiene; and ii. Counsel worker on preventive measures and suspension. • Monitor worker closely by repeating B-Pb 3-monthly until results are below the action level. • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport). • Provide MOM with basis for diagnosis. • Inform employer of diagnosis (in writing).
Suspend	Note: Not required for thalassaemia minor • Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension. • For cases suspended temporarily: - when B-Pb level is below Action level and Hb is normal, implying that worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker; and - after return to lead exposure, continue to monitor worker's abnormal test result every 3-monthly for the next 6 months. • For cases on permanent suspension: - monitor worker at least 6-monthly until advised otherwise by MOM; update MOM using the *Report of Examinations* form.

Refer	• Referral to toxicologist or other specialist for additional tests, e.g., - urinary lead (pre-and-post chelation) - urinary coproporphyrin
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* form by e-mail or post.

11.7.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases with blood lead levels as follows:

Males of all ages and females ≥ 50 yrs : B-Pb ≥ 50 mcg/100 ml
Females < 50 yrs : B-Pb ≥ 30 mcg/100ml

- Cases of significant anaemia:
  Haemoglobin levels of 10 g/dL or less for females and 11 g/dL or less for males, based on at least two sets of results.
- All pregnant women and nursing mothers.

Indications for Permanent Suspension

- All cases of lead poisoning; and
- Persons with diagnosed renal disease.

Indications for Return to Inorganic Lead Exposure

- Blood lead level < Action level; and
- Hemoglobin level > 95% of laboratory minimum level

11.7.5 Treatment

All cases of lead poisoning must be immediately removed from exposure and referred for hospital treatment.

11.7.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- Toxicological test results within range for normal unexposed population (See Appendix J); and
- Lead-in-air levels are not detectable.

Further Reading

1. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values and Biological Exposure Indices.
2. Toxicological Profile for Lead U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry August 2007 http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf (last access 16 Oct. 09)

Organic Lead

(Tetraethyl lead - TEL, Tetramethyl lead - TML)

11.7.9 Toxic Effects

Mainly on the central nervous system (usually acute)

Mild : Headache, tremor, nervousness, agitation, insomnia, troubled dreams

Severe : Hallucinations, mental confusion, coma, death

(Note : In addition to the inhalation route, organic lead may be absorbed through the skin)

11.7.10 Main Industries and Occupations at Risk

- Cleaning of tanks containing leaded gasoline or aviation fuel
- Production and transportation of anti-knock agents (organic lead compounds)
- Blending anti-knock agents and raw gasoline at refineries

11.7.11 Medical Examinations

Indications

Any Exposure to Organic Lead Compounds

Types of Tests and Frequency of Examinations:

- Pre-placement medical examinations: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on:
    i. past, present and anticipated future exposure to organic lead; and
    ii. CNS dysfunction.
  - Estimation of urinary lead concentration (U-Pb) in an early morning urine specimen collected at the end of the work week.
- Periodic medical examinations: every 6 months
  - Clinical examination with particular emphasis on the CNS.
  - Estimation of urinary lead concentration (U-Pb) in an early morning urine specimen collected at the end of the work week.
    i. More frequent tests may be done depending on exposure.
    ii. In the case of intermittent exposures, e.g., tank cleaning, tests need only be done before and after the job.
    iii. BTLV for urinary lead = 110 mcg/L (for males); 25 mcg/L (for females).
    iv. Action level for urinary lead = 88 mcg/L (for males); 20 mcg/L (for females).
  - Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Differential Diagnosis	Actions to Take
For males: If U-Pb >88 to 109 mcg/L For females: If U-Pb >20 to 24mcg/L	• High risk exposure	• Examine • Reduce risk • Update MOM
For males: If U-Pb ≥ 110 mcg/L For females: If U-Pb ≥ 25 mcg/L	• Excessive absorption (if asymptomatic) • Poisoning (if symptomatic)	• Examine • Reduce risk • Suspend • Notify • Refer • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of poisoning • Check serial U-Pb results for increasing trend • If U-Pb exceeds BTLV, to conduct blood lead estimation BTLV = 50 mcg/100ml (males), 30 mcg/100ml (females) Action level = 40 mcg/100ml (males), 24 mcg/100ml (females)
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to evaluate risk assessment and adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Monitor worker closely by repeating U-Pb 3-monthly until results are below the action level. • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport). • Provide MOM with basis for diagnosis. • Inform employer of diagnosis (in writing).

Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension. • For cases suspended temporarily: - when U-Pb / B-Pb levels are below Action level, implying that worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker. - after return to lead exposure, continue to monitor worker's abnormal test result (if any) every 3-monthly for the next 6 months. • For cases on permanent suspension: - monitor worker at least 6-monthly and update MOM using the *Report of Examinations* form
Refer	• Referral to toxicologist or other specialist for additional tests, e.g., - Electroencephalography (EEG)
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post.

11.7.12 Suspension from Exposure

Indications for Temporary Suspension

- All cases of organic lead excessive absorption i.e. asymptomatic cases with U-Pb > BTLV in 2 successive examinations

Indications for Permanent Suspension

- All cases of organic lead poisoning
- All persons with diagnosed central nervous system disorders

Indications for Return to Organic Lead Exposure

- U-Pb and B-Pb levels < Action level; and
- No symptoms of organic lead poisoning

11.7.13 Treatment

All cases of organolead poisoning must be immediately removed from exposure. Acute poisoning cases must be referred for hospital treatment.

Treatment with chelating agents does not appear to be useful for organolead poisoning. Symptomatic and supportive treatment is indicated. Several weeks to years may be necessary for recovery, which may not be complete.

11.7.14 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- Urinary lead test results within range for normal unexposed population (See Appendix J); and
- Lead-in-air levels are not detectable.

Further Reading

1. Control of Lead at Work (3rd edition) – Control of Lead at Work Regulations 2002 Approved Code of Practice and guidance, Health and Safety Executive http://www.hse.gov.uk/pubns/priced/l132.pdf
2. Federal Register: Occupational exposure to lead - final standard: USA 1978.
3. World Health Organization: Recommended health-based limit in occupational exposure to heavy metals; Technical Report Series 647, 1980.
4. Philippe Grandjean: Biological effects of organolead compounds. CRC Press, 1984.
5. Alberto Furtado Rahde: Organic Lead. IPCS: May 1994. Accessed on 9 November 2009: http://www.inchem.org/documents/pims/chemical/organlea.htm

11.8 Manganese

11.8.1 Toxic Effects

- Acute Poisoning
  - Minor irritation to the eyes and mucous membranes of the respiratory tract;
  - Metal fume fever; and
  - Caustic effects (higher valency manganese salts).
- Chronic Poisoning
  - Damage to the central nervous system (manganism):
    Dose-response relationship, with 3 stages observed:
    i. Sub-clinical stage with vague symptoms forgetfulness, anxiety or insomnia;
    ii. Early clinical stage with acute psychomotor, e.g., speech and gait disturbances, tremors;
    iii. Fully developed stage with manic depressive psychosis and Parkinsonism-like symptoms
  - Damage to the lungs:
    i. Increased incidence of pneumonia, acute and chronic bronchitis
- Others
  - Fall in blood pressure;
  - Reduced urinary 17-ketosteroids;
  - Changes in haemoglobin level and blood counts; and
  - Increased serum calcium, enzymes (e.g., adenosine deaminase) and albumin/globulin ratio.

11.8.2 Main Industries and Occupations at Risk

- Milling of manganese ore;
- Manufacture of dry-cell batteries (manganese dioxide);
- Iron and steel industry as a reagent to reduce sulphur and oxygen;
- Manganese electroplating;
- Manufacture of paints, varnishes, inks and dyes, fertilisers, feed additives, disinfectants and bleaching agents, glass and ceramics (decolouriser and colouring agent);
- Manufacture of matches and fireworks;
- Manufacture of potassium permanganate;
- Welding operations with manganese-coated rods;
- Water treatment; and
- Exposure to fuel additive methylcyclopentadienyl manganese tricarbonyl (MMT) and mangafodipir to increase octane level of gasoline and improve anti-knock properties of fuel.

11.8.3 Medical Examinations

Indications:

Any exposure to manganese and its compounds

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on:
    i. past, present and anticipated future exposure to manganese; and
    ii. behavioural and neurological changes (speech and emotional disturbances, hypertonia, tremor, equilibrium, gait, handwriting and adiadochokinesis).
  - Test:
    i. Urine manganese (U-Mn) estimation on post-shift urine specimen collected at end of workweek, corrected to SG of 1.016.
  - Unfit for exposure to manganese:
    i. Persons diagnosed with Parkinsonism.
- Periodic medical examinations: every 12 months
  - Clinical examination with particular emphasis on the CNS;
  - Estimation of urinary manganese (U-Mn) estimation a post-shift urine specimen at collected end of workweek, corrected to SG of 1.016

BTLV for urinary manganese (U-Mn) = 50 mcg/L
Action level for U-Mn = 40 mcg/L

  - Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Differential Diagnosis	Actions to Take
If U-Mn >40 to 49 mcg/L:	• Inaccurate analysis • High risk exposure	Note: Not required if due to inaccurate analysis • Examine • Reduce risk • Update MOM
If U-Mn ≥ 50 mcg/L	• Inaccurate analysis Excessive absorption (if asymptomatic) • Poisoning (if symptomatic)	Note: Not required if due to inaccurate analysis • Examine • Reduce risk • Suspend • Notify • Refer • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of poisoning • Repeat U-Mn with strict instructions on urine collection technique • To determine work-relatedness of condition, obtain detailed occupational history from worker to document manganese exposure (past and present) • Check serial U-Mn results for increasing trend
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review Risk assessment and adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Monitor worker closely by repeating U-Mn 3-monthly till results are below the action level • Visit workplace if necessary
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • For cases suspended temporarily: - when U-Mn levels are below Action level, implying that worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker - after return to manganese exposure, continue to monitor worker's abnormal test result (if any) every 3-monthly for the next 6 months • For cases on permanent suspension: - monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the *Report of Examinations* form

Refer	• Refer to toxicologist or other specialist for additional tests e.g. - Blood manganese estimation (BTLV = 30 mcg/100 mL; Action level = 24 mcg/100mL) - Full blood count (including total white and differential count) - Serum calcium estimation - Urinary 17-ketosteroids estimation (24-hour urine specimen) - Basal metabolic rate
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

11.8.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases of manganese excessive absorption

Indications for Permanent Suspension

- All cases of manganese poisoning
- All cases diagnosed with behavioural and/or neurological disorders.

Indications for Return to Manganese Exposure

- U-Mn /B-Mn level < Action level; and
- No symptoms of manganese poisoning.

11.8.5 Treatment

All cases of manganese poisoning must be removed immediately from exposure and referred for hospital treatment. Calcium EDTA may be used for chelation in the early stages. Oral L-dopa reduces hypertonia, contractions and speech disturbances, etc.

11.8.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- Urinary manganese test results within range for normal unexposed population (See Appendix J); and
- Manganese-in-air levels are not detectable.

Further Reading

1. Employment Medical Advisory Service. Occasional Paper 1, Biochemical Criteria in certain biological media for selected toxic substances. Dept of Employment, UK, 1974.
2. National Institute for Occupational Safety and Health, Occupational Diseases - A Guide to their Recognition, Rev Ed, US Department of Health, Education and Welfare, USA, 1977. (DHEW Publication No (NIOSH) 77-181).
3. International Labour Organization: Encyclopaedia of Occupational Health and Safety, Geneva, 3rd edition, 1983.
4. World Health Organization. Recommended Health-based Limits in Occupational Exposure to Heavy Metals - Report of a WHO Study Group, Technical Report Series 647, 1980.
5. World Health Organization. Early detection of occupational diseases Chapter 11 Diseases caused by manganese & its toxic compounds, 1986.
6. World Health Organization, Geneva–Biological Monitoring of Metals, 1994 (IPCS)
7. Health & Safety Executive. Occupational Exposure Limits: Criteria Document Summaries–Manganese, 1993.
8. American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values and Biological Exposure Indices, 6th edition, 1991.
9. Roels HA, Ghyselan P, Buchet JP, Ceulemans E, Lauwerys RR. Assessment of the permissible exposure level to manganese in workers exposed to manganese dioxide dust. BJIM 1992; 49; 25-34.
10. Finnish Institute of Occupational Health. Biomonitoring of exposure to chemicals. Guideline for specimen collection, 2009-2010.
11. Agency for Toxic Substances and Disease Registry. Accessed on 15 Jun 2011: http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=102&tid=23

11.9 Mercury

Elemental Mercury volatises at room temperature. Mercury can be absorbed through intact skin and inhalation of vapours.

11.9.1 Toxic Effects

Inorganic and Elemental Mercury

- Acute Poisoning;
  - Chemical pneumonitis;
  - Gastrointestinal tract irritation;
  - Circulatory collapse; and
  - Acute renal failure.
- Chronic Poisoning
  - Weight loss;
  - Insomnia;
  - Erethism;
  - Tremor;
  - Dysarthria;
  - Mercurialentis;
  - Gingivitis;
  - Stomatitis;
  - Excessive salivation;
  - Metallic taste; and
  - Nephrotic syndrome.

Organic Mercury (alkyl compounds, e.g., methyl mercury and aryl compounds, e.g., phenylmercury acetate)

- Acute irritative effects:
  - Irritation of the mucous membranes
  - Chemical pneumonitis
- Poisoning (may be acute or chronic)
  - Neurological symptoms, e.g., paraesthaesia, concentric constrictions of the visual fields, impairment of hearing, rigidity, tremor, ataxia, chronic seizures;
  - Fatigue, dyspnoea, chest and abdominal pain, vomiting;
  - Symptoms of inorganic poisoning may be present including renal damage;
  - Dermatitis; and
  - Prenatal intoxication may occur resulting in foetal brain damage.

11.9.2 Main Industries and Occupations at Risk

Inorganic Mercury

- Electrolytic production of sodium hydroxide, chlorine and acetic acid (as a fluid cathode);
- Manufacture of artificial silk;
- Manufacture of scientific instruments (e.g., barometers, thermometers), electrical equipment (e.g. batteries, meters, switches, rectifiers), mercury vapour and incandescent lamps, X-ray tubes and radio valves;
- Dentistry (i.e., amalgams);
- Manufacture of amalgams (with copper tin, silver or gold) and solders (with lead and tin);
- Plating of gold, silver, bronze and tin (jewellers);
- Paint and pigment manufacture;
- Tanning and dyeing, felt making;
- Used as a catalyst in the chemical industry, e.g., production of acetic acid and acetaldehyde from acetylene;
- Taxidermy;
- Photography and photogravure;
- Mining and extraction; extracting gold and silver from ores; and
- Laboratories
  - soil testing (mercury used as a pressure medium);
  - brewery (analysis for protein content in malt); and
  - schools.

Organic Mercury

- Manufacture and use of certain pharmaceutical products (e.g., antiseptics, germicides, diuretics and contraceptives);
- Manufacture and use of pesticides (e.g., algicides, fungicides, herbicides);
- Manufacture and use of paints and waxes (e.g., antifouling paints, preservatives in paints, latex paints, fungus proofing of fabrics, paper, wood); and
- Used as catalysts and alkylating agents in the chemical industry.

11.9.3 Medical Examinations

Indications:

Any exposure to mercury or its compounds

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on:
    i. past, present and anticipated exposure to mercury; and
    ii. central nervous system disorders, including tremors.
  - For inorganic mercury exposure, estimation of urinary total mercury (U-Hg)

i. USE EARLY MORNING URINE SPECIMEN. Collect urine specimen directly into clean containers. Advise worker to avoid seafood for at least 3 days prior to collection.

ii. Results are corrected to SG of 1.016.

- For organic mercury exposure, estimation of blood mercury concentration, at end-of-shift end-of workweek
- Unfit for exposure to mercury:

i. Persons diagnosed with renal, behavioural or neurological disorders

- Periodic medical examinations: every 12 months
  - Clinical examination and history with particular emphasis on the central nervous system, symptoms of weight loss, insomnia and personality changes
  - In the case of organic mercury, examine the skin for dermatitis or burns
  - For inorganic mercury exposure, estimation of total urinary mercury (U-Hg) concentration in an early morning urine specimen

BTLV for urinary mercury (U-Hg) = 50 mcg/L
Action level for U-Hg = 40 mcg/L

  - For organic mercury exposure, estimation of blood mercury (B-Hg) concentration, at end-of-shift end-of workweek

BTLV for blood mercury (B-Hg) = 25 mcg/L
Action level for B-Hg = 20 mcg/L

  - Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Differential Diagnosis	Actions to Take
For inorganic Hg: If U-Hg >40 to 49 mcg/L For organic Hg: If B-Hg > 20 to 24.9 mcg/L creatinine	• Inaccurate analysis • High risk exposure	Note: Not required if due to inaccurate analysis • Examine • Reduce risk • Update MOM
For inorganic Hg: If U-Hg ≥ 50 mcg/L For organic Hg: If B-Hg ≥ 25 mcg/L	• Inaccurate analysis • Excessive absorption (if asymptomatic) • Poisoning (if symptomatic)	Note: Not required if due to inaccurate analysis • Examine • Reduce risk • Suspend • Refer • Notify • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of poisoning • For U-Hg test, if you suspect analytical error after checking with laboratory on their quality assurance scheme for analysis of U-Hg, repeat test • Check serial U-Hg/B-Hg results for increasing trend • To determine work-relatedness of condition, obtain detailed occupational history from worker to document mercury exposure (past and present)
Reduce risk	• To do following within 1 month: - Employer i . Inform employer to review risk assessment and evaluate adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Monitor worker closely by repeating U-Hg/B-Hg 3-monthly till results are below the Action Level • Visit workplace if necessary
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • For cases suspended temporarily: - when U-Hg/B-Hg levels are below Action level and worker is fit to return to exposure, submit *Certificate of Fitness* to employer, MOM and worker - after return to mercury exposure, continue to monitor worker's abnormal test result (if any) every 3-monthly for the next 6 months • For cases on permanent suspension: - monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the Report of *Examinations form*

Refer	• Referral to toxicologist or other specialist for additional tests e.g. - Urine for albumin and microscopic examination - Other renal function tests - Serum albumin/globulin - Mercury concentration in nails and hair
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post.

11.9.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases of mercury excessive absorption; and
- All pregnant women.

Indications for Permanent Suspension

- All cases of mercury poisoning; and
- All cases diagnosed with renal, behavioural and/or neurological disorders.

Indications for Return to Mercury Exposure

- U-Hg / B-Hg level < Action level; and
- No symptoms of mercury poisoning

11.9.5 Special Instructions

Females in the reproductive age should not work in areas where there is significant mercury exposure (particularly alkyl mercury compounds).

11.9.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact;
- No likelihood of oral ingestion;
- U-Hg / B-Hg test results within range for normal unexposed population (See Appendix J); and
- Mercury-in-air levels are not detectable.

11.9.7 Treatment

All cases of mercury poisoning must be immediately removed from exposure. Acute poisoning cases must be referred for hospital treatment. BAL is to be used only in severe poisoning cases. Treatment is otherwise symptomatic.

Further Reading

1. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Values and Biological Exposure Indices. 7th edition, 2001: Mercury, elemental and inorganic.
2. Australian NOHSC Guidelines for Health Surveillance http://safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Pages/GN1995HealthSurveillance.aspx
3. Occupational Safety and Health Authority Occupational Safety & Health Guidelines for Mercury Vapour http://www.osha.gov/SLTC/healthguidelines/mercuryvapor/recognition.html
4. World Health Organization Concise International Chemical Assessment Document 50 http://www.who.int/ipcs/publications/cicad/en/cicad50.pdf
5. Apostoli P, Mangili A, Alessio L. Significance of biological indicators of mercury exposure. Med. Lav. 2003; 94:231-244 http://www.ncbi.nlm.nih.gov/pubmed/12852206
6. Health and Safety Executive http://www.hsl.gov.uk/media/74591/bm%20leaflet_lo%20res.pdf
7. Finnish Institute of Occupational Health Biomonitoring of Exposure to Chemicals http://www.ttl.fi/en/work_environment/biomonitoring/Documents/guideline_for_specimen_collection.pdf
8. Japan Society for Occupational Health OEL based on Biological Monitoring http://joh.sanei.or.jp/oel/

11.10 Noise

11.10.1 Health Effects

- Acute effects
  - Acoustic trauma
    i. acute rupture of the tympanum with or without bleeding;
    ii. Subjective sensation of pain in both ears at the time of noise exposure ;
    iii. Usually caused by sudden explosive noise; and
    iv. Conductive hearing loss affecting all frequencies.

Note: There may also be evidence of sensorineural loss, depending on whether the cochlea is affected.

- Chronic effects
  - Noise-induced deafness (NID)
    i. Irreversible sensorineural hearing loss developing after prolonged exposure to excessive noise (≥ 85 dBA over an 8-hr period per day or its equivalent for more than 5 years);
    ii. Worker is initially unaware of his hearing defect;
    iii. May present with tinnitus;
    iv. Audiogram: Bilateral high frequency sensorineural loss with a V-shaped pattern, worst in the 4 and/or 6 KHz frequencies (with hearing loss of > 30 dBA at these frequencies); and
  - Depending on the severity of hearing loss, NID cases may be classified into 2 forms.
    NID (Early): mild to moderate hearing loss, (diagnosed by the audiogram picture of bilateral high frequency sensorineural loss where the average hearing threshold over 1, 2 & 3 KHz for air conduction in the better ear is < 50 dBA, with a noise exposure history of ≥ 5 years).
    NID (Advanced): severe and disabling hearing loss (diagnosed by the audiogram picture of bilateral sensorineural loss where the average hearing threshold over 1, 2 & 3 kHz for air conduction in the better ear is ≥ 50 dBA with an exposure history of ≥ 10 years).
- Other effects of noise exposure:
  - Some physiological responses have been reported, e.g., hypertension, variation in heart and respiration rate; and
  - Temporary threshold shift results following short exposures to excessive noise. This condition is reversible.

11.10.2 Main Industries and Occupations at Risk

- Shipbuilding & ship repairing–fitters, mechanics, etc;
- Granite quarries – crushers, drillers, etc;
- Engineering works–grinding, sawing involving high velocity equipment;
- Iron and steel mills, other heavy metal industries;
- Metal working industries, e.g., making of ball and roller bearings, nuts, bolts and screws, metal cans;
- Woodworking industry;
- Textile industry;
- Paper industry;
- Engine testing, e.g., jet engines;
- Industries with bottling processes and operations involving cans and metal boxes; and
- Landscaping – use of leaf blowers, lawnmowers and trimmers.

11.10.3 Medical Examinations

Indications:
Workers exposed to noise exceeding the permissible exposure limit and duration, as specified in the Workplace Safety and Health (Noise) Regulations 2011.

The total duration of excessive noise exposure shall be obtained by adding up all the excessive exposures within the work day, whether short or long exposures. When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered. Every continuous, impulsive or impact noise of sound pressure levels from 80 dB(A) to 140 dB(A) must be included in the computation of the noise exposure of the person.

Refer to Appendix L for calculation of the equivalent sound pressure level and calculation of noise dose for different noise exposures.

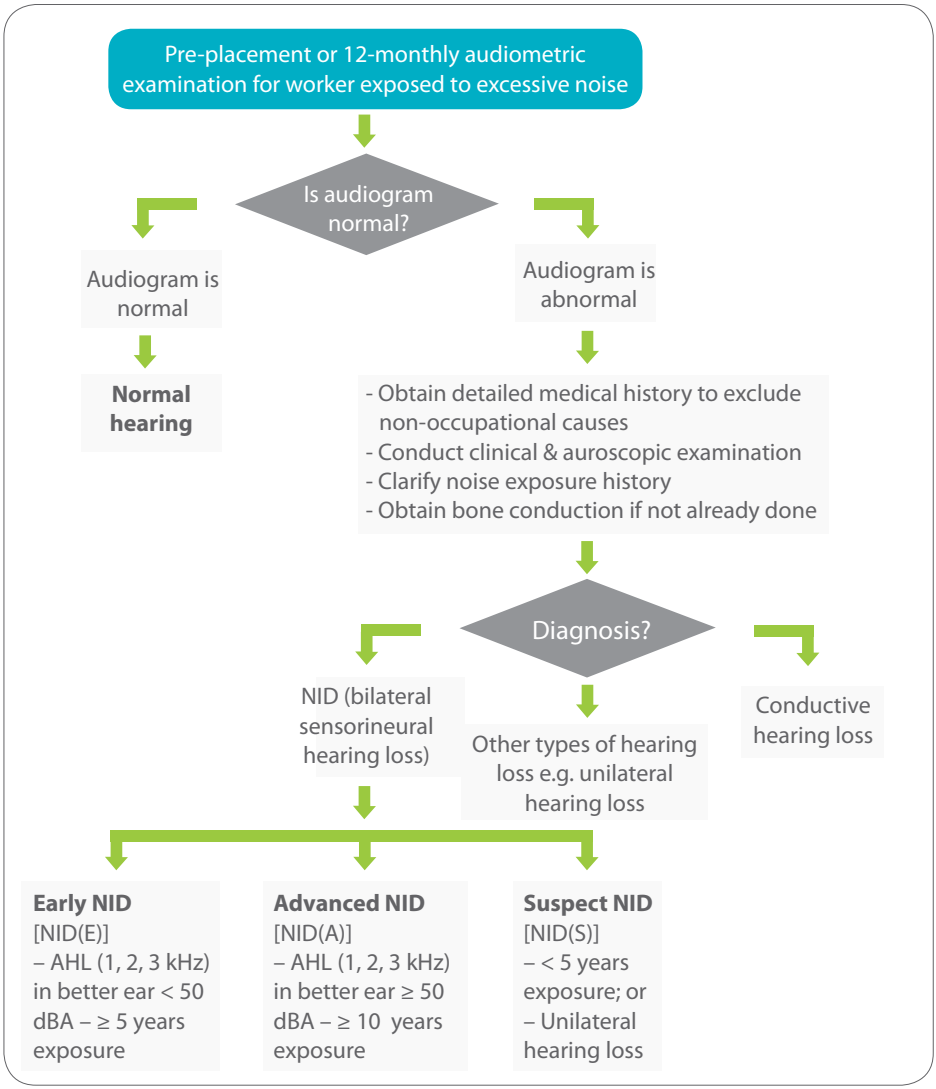
For any noise level, use table in Appendix G to determine whether the maximum duration for exposure has been exceeded.

The permissible exposure limit is exceeded if a person is exposed to noise at a sound pressure level in excess of the corresponding duration as listed in Appendix G.

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within three months of exposure
  - Audiometric examination
    Bone conduction and auroscopic examination should be done if any of the air conduction result is more than 30 dB(A).
- Periodic medical examinations: every 12 months
  - Audiometric examination
    Bone conduction and auroscopic examination should be done if any of the air conduction result is more than 30 dB(A).

Flowchart for Determining Diagnosis



Note: Guidance on diagnosing noise induced hearing loss and acoustic trauma can be found in the chapter on Occupational Hearing Loss published in "Workplace Safety and Health Guidelines–Diagnosis and Management of Occupational Diseases" by the Workplace Safety and Health Council in collaboration with MOM.

Actions to Take Upon Diagnosing Hearing Loss:

Diagnosis	Actions	Suspension
Newly diagnosed NID(Early) case	• Examine • Reduce risk • Notify	No
Previously confirmed NID(Early) case	If there is significant deterioration compared to pre-placement audiogram: • Examine • Reduce risk • Notify	No
Newly diagnosed NID(Advanced) case	• Examine • Reduce risk • Notify – provide all audiograms to MOM • Update MOM	No
If there is mild to moderate hearing loss in a worker age < 35 years old with noise exposure of < 5 years	• Examine • Refer • Update MOM	Suspend permanently if hearing deteriorating
Significant deterioration: deterioration of >20 dB(A) within 1 year	• Examine • Refer • Update MOM	Suspend permanently if hearing deteriorating
Other forms of hearing loss, e.g., Unilateral hearing loss, conductive hearing loss, sudden hearing loss (if not acoustic trauma) etc	• Examine • Refer (if unsure of diagnosis or for further management)	No

Definitions and Actions Required for the Following Terms:

Actions to Take	Description
Examine	• Occupational history and clinical examination to exclude other causes of hearing loss • Evaluate audiograms including tests such as Weber and Rinne test. • Auroscopy
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review Hearing Conservation Programme (HCP), evaluating adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	Note: Not required for NID(E) or NID(A) • Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • If indicated, usually permanent suspension
Refer	Note: When diagnosis is unclear or worker requires further investigation or management • Referral to ENT specialist for additional tests: e.g. tympanometry, BERA, Stenger's test, MRI, etc
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

Note:

- Ensure that all audiograms are done after the worker has been away from noise exposure for at least 16 hours.
- Ensure audiograms are done in a proper booth with background noise levels not exceeding the table below.

MAXIMUM ALLOWABLE OCTAVE-BAND SOUND PRESSURE LEVELS FOR AUDIOMETRIC TEST BOOTHS

The background noise levels in audiometric booths should comply with the following values:

Octave-Band Centre Frequency (Hz)	Sound Pressure Level (dB)
250	40
500	40
1000	40
2000	47
4000	57
6000	62
8000	67

11.10.4 Suspension from Exposure

Indications for Permanent Suspension

In general, it is not necessary to suspend suspected NID cases. If suspension is indicated it is usually on a permanent basis.

- Where there is rapid deterioration of hearing of 20 dB(A) or more over a 1 year period in at least 3 frequencies in the 1 – 6 kHz range in either one or both ears when compared to the previous audiogram; and
- Where there is severe hearing loss and good hearing is required for detection of auditory warning signals.

11.10.5 Special Instructions

The following types of cases need not be notified to MOM:

- Cases with unilateral hearing loss
- Cases with conductive hearing loss (air-bone gap of ≥ 20 dB)
- Cases with less than 5 years of noise exposure.

  All cases notified should be accompanied by their latest audiograms. The total noise exposure history, including previous noise exposure in other jobs should be provided, indicating the number of years of exposure from work overseas and from work locally.

11.10.6 Treatment

Workers with early NID should be counselled to wear appropriate PPE. Workers with rapid deterioration of hearing should be removed immediately from exposure.

11.10.7 Criteria for Exemption from Medical Surveillance

On a case by case basis, an employer may apply for a reduction in the frequency of examinations to once in 2 years if the following conditions are met:

- Noise exposure in the workplace is below 85 dB(A);
- A good hearing conservation programme is in place; and
- No significant deterioration in workers' audiogram results over the past 5 years.

Further Reading

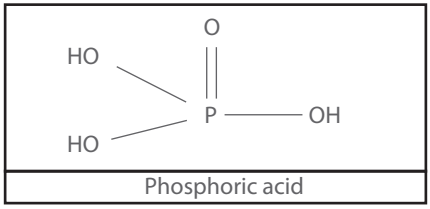
1. Criteria for a Recommended Standard: Occupational Noise Exposure – Revised. DHHS (NIOSH) Publication No. 98-126 (1998), National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Health and Human Services.
2. Prevention of Noise-Induced Hearing Loss, Report of a WHO-PDH Informal Consultation, Geneva, 28-30 October 1997.
3. The Workplace Safety and Health (Noise) Regulations, 2011.
4. Health and Safety Executive, Guidance on Control of Noise at Work Regulations 2005.
5. American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1971 (R1976) for Audiometric test room allowable background noise: Accessed on 23 June 2011:

   http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9739

11.11 Organophosphates

The organophosphates mentioned in The Workplace Safety and Health (Medical Examinations) Regulations, generally refer to cholinesterase inhibitors derived from the molecule H_3PO_4 by substitution of any of the hydrogen or oxygen atoms. They are usually used as pesticides (insecticide, acaricides, etc).

To determine whether any particular organophosphate compound requires workers to undergo medical examinations, you should try to obtain the structural formula and all other information related to the organic phosphate from the company. Compare this with the phosphoric acid molecule. As a guide, below are some of the common examples of organophosphates (OP).



Phosphoric acid

$(R\text{-}O)_2\text{-}P\text{-}O\text{-}X$

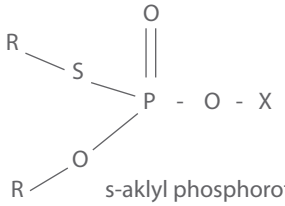
phosphate,e.g., dichlorvos (2,2-dichlorovinyl dimethyl phsophate)

(R-O)2-P-S-X

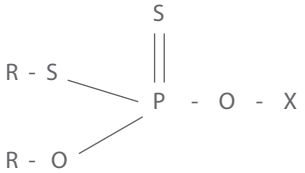
O-alkyl-phosphorothioate, e.g.,parathion

$(R\text{-}O)_2\text{-}P\text{-}S\text{-}X$

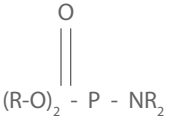
phosphorodithioate, e.g., dimethoate malathion



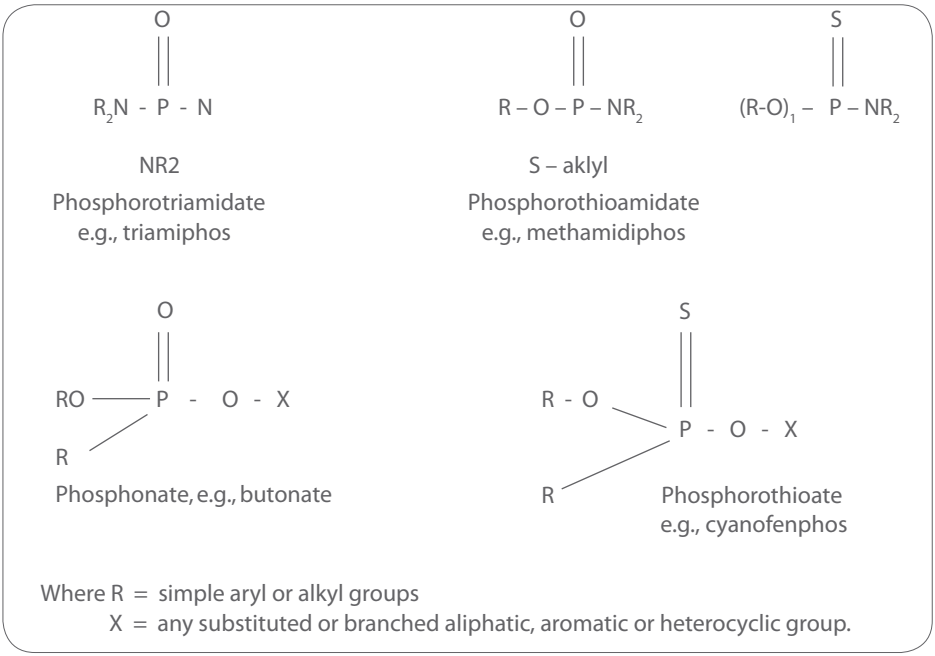
s-aklyl phosphorothioate, e.g., profenofos



s-alkyl phosphorodithioate e.g., prothiofos



phosphoromidate e.g., cruformate



Where R = simple aryl or alkyl groups
X = any substituted or branched aliphatic, aromatic or heterocyclic group.

11.11.1 Toxic Effects

- Acute Poisoning
  - Onset is prompt but may be delayed up to 12 hours;
  - Central Nervous System, e.g., anxiety, dizziness, headache, sleeplessness, confusion, coma, convulsions;
  - Respiratory, e.g., dyspnoea, chest tightness, bronchospasm, bronchial hypersecretion, pulmonary oedema;
  - Gastrointestinal, e.g., salivation, nausea, vomiting, abdominal colic, diarrhoea, pancreatitis;
  - Ocular, e.g., lacrimation, miosis, blurring of vision; and
  - Muscular, e.g., fasciculations, cramps.
- Chronic Poisoning
  - Non-specific, e.g., headache, quick onset of fatigue, disturbed sleep, anorexia;
  - Central and Autonomic Nervous System, e.g., nystagmus, tremors, failing memory, disorientation; and
  - Peripheral Nervous System e.g. paresis, neuritis, paralysis.

Note: Organophosphates (OP) are readily absorbed through the skin.

11.11.2 Main Industries and Occupations at Risk

- Horticulture–gardeners, greenhouse workers;
- Agriculture–garden pest control operators, farmers;
- Vector control operators;
- Formulation and manufacture of organophosphates, e.g., insecticide sprays;
- Laboratory workers analysing organophosphates; and
- Packing and redistribution of organophosphates.

Note: OP may be commonly used in the homes.

Common OP used in Singapore are:

- Basudin 60
- Dichlorvos
- Dimethoate
- Dipterex
- Diazinon
- DDVP (2,2, Dichlorovinyl 0, 0-Dimethyl Phosphate)
- Fenthion
- Malathion
- Parathion
- Rogor
- Tamaron
- Temephos

11.11.3 Medical Examinations

Indications:
Any occupational exposure to organophosphates

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on the central and autonomic nervous systems
  - Tests:
    i. Red blood cell acetylcholinesterase (RBC AChE) estimation; and
    ii. Plasma cholinesterase estimation.
- Periodic medical examinations: every 6 months
  - Clinical examination shall include a detailed medical and work history with emphasis on the central and autonomic nervous systems
  - Tests:

    i. Red blood cell acetylcholinesterase (RBC AChE) estimation

    Action Level = Less than 70% of preplacement (baseline) RBC AChE level. If the result is not available, then action level is less than 70% of the laboratory's lower limit of normal

Actions to take based on clinical examinations and investigation findings:

Findings	Actions	Suspension
If RBC AChE between 51 - 70% of baseline	• Examine • Reduce risk • Notify • Update MOM	Yes, if further reduction of 10% in repeat test
If RBC AChE <50% of baseline	• Examine • Reduce risk • Notify • Update MOM • Refer immediately to hospital if symptomatic	Yes

Description of Actions to Take:

Actions to Take	Description
Examine	• Clinical examination for signs and symptoms of OP poisoning • Take detailed occupational history to determine reason for high exposure e.g. non-usage of personal protective equipment, accidental contact, wrong handling technique, etc • Repeat rbc cholinesterase test • Check past serial results
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review Risk assessment evaluating adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Monitor worker closely by repeating rbc cholinesterase monthly till results are above the Action Level • Visit workplace if necessary

Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Suspension includes suspension from work with carbamates • Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • If indicated, usually temporary suspension. When rbc cholinesterase results are above BTLV, worker is fit to return to OP exposure. Submit *Certificate of Fitness* to employer, MOM and worker.
Refer	• Referral to Emergency Department of hospital for treatment of poisoning and toxicologist for additional tests e.g., butyrylcholinesterase • Where indicated, plasma cholinesterase estimation should be carried out (especially following accidental skin contact or acute high exposures or in suspected acute poisoning cases)
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

11.11.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases of definite or suspected poisoning and excessive absorption.
- Cases with RBC AChE of less than 50% of the baseline or laboratory's lower limit of normal.
- Cases with RBC AChE of between 50 and 70% of the pre-employment level showing a fall of more than 10% in their repeat test results.

Indications for Return to Organophosphate Exposure

- RBC AChE levels above worker's personal baseline level or laboratory's lower limit of normal

11.11.5 Special Instructions

Special instructions for collection of specimen for

1. Baseline RBC and plasma AChE estimation:
    a. Worker should not have worked with OP for at least one month.
    b. Blood for RBC AChE should be collected in an EDTA tube and which should contain at least 3 ml of blood, i.e. tube is full.
    c. Blood for plasma AChE should be collected in a plain tube.
    d. Both specimens should be kept cool (around room temperature) and reach the lab within 1 day of collection.

2. Periodic RBC AChE estimation:
    a. Blood for RBC AChE should be collected in an EDTA tube and which should contain at least 3 ml of blood, i.e., tube is full.
    b. The specimen should be kept cool (around room temperature) and reach the lab within 1 day of collection.

The workers' RBC cholinesterase level following at least one month of suspension can be taken as the workers' baseline levels if higher than the result obtained during the pre-placement medical examination or the laboratory's lower limit of normal.

11.11.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact and inhalation; and
- No likelihood of oral ingestion.

11.11.7 Treatment

All cases of OP poisoning must be immediately removed from exposure. Acute poisoning cases must be referred for hospital treatment. Treatment with atropine and/or glycopyrronium bromide may be considered especially if there are clinical signs and symptoms. Pralidoxime chloride (2-PAM) should be used with caution.

Refer to the Ministry of Health Clinical Practice Guidelines–Management of Drug Overdose and Poisoning for details on treatment of OP poisoning.

Further Reading

1. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Values and Biological Exposure Indices. 7th edition, 2001: Acetylcholinesterase inhibiting Pesticides.
2. National Institute for Occupational Safety and Health: Occupational Health guideline for malathion
   http://cdc.gov/niosh/docs/81-123/pdfs/0375.pdf
2. Guidelines for healthcare providers in Washington State: Cholinesterase monitoring for agricultural pesticide handlers, Department of Labor & Industries, Division of Occupational Safety & Health (DOSH), Jan 2010
3. Occupational Health Tracker 2003
   http://systoc.com/tracker/2003/Aut2003/MedSurv.asp
4. California Environmental Protection Agency: Guidelines for physicians who supervise workers exposed to cholinesterase-inhibiting pesticides. Office of Environmental Health Hazard Assessment, 4th edition, 2002
   http://www.oehha.ca.gov/pesticides/pdf/docguide2002.pdf
5. ACGIH Documentation of the Threshold Limit Values and Biological Exposures Indices. 7th edition, 2001: Parathion
6. Health and Safety Executive. Medical aspects of work-related exposures to organophosphates, 2000. Accessed 27 Sept 2010:
   http://www.aerotoxic.org/about-aerotoxic-syndrome/reports-and-evidence/363-exposures-to-ops-ms17
7. World Health Organization. Recommended Health-based Limits in occupational exposure to pesticides. Report of a WHO Study Group. Technical Report Series 677, Geneva, 1982.
8. Ministry of Health Singapore. Clinical Practice Guidelines–Management of Poisoning Chapter 9: Organophosphates.

11.12 Perchloroethylene (PCE)

CAS NUMBER : **127-18-4**

Synonyms : Tetrachloroethylene
Ethylene tetrachloride
Carbon bichloride
Carbon dichloride
Tetra
Perc
Perchlor
Perclene

11.12.1 Toxic Effects

- Acute effects
  - Irritation of eye, nose and throat.
  - Central Nervous System:
    i. Massive exposure can cause dizziness, headache, nausea, incoordination, coma and death.
- Chronic effects
  - Central Nervous System:
    i. Non-specific complaints like headache, dizziness, fatigue and incoordination.
  - Skin
    i. Prolonged or repeated skin contact with liquid PCE can cause irritation and even burns.
  - Liver
    i. Cirrhosis has been observed in workers exposed to high levels.

Note: When there is mixed exposure to trichloroethylene and other solvents there may be combined effects on target organs.

11.12.2 Main Industries and Occupations at Risk

- Dry cleaning in laundries;
- Degreasing and cleaning of metal parts and equipment in metalworking, automotive, aircraft, aerospace industries and shipyards;
- Cleaning of lenses in the optical industry; and
- Used as a solvent in manufacture and use of printing ink, varnishes, adhesives, polishes, rubber coatings and silicones.

11.12.3 Medical Examinations

Indications:

Any occupational exposure to PCE

Types of Tests and Frequency of Examinations

- Pre-placement medical examinations: within three months of exposure
  - Clinical examination with emphasis on the central nervous system, skin and liver.

- Tests:
  i. Mid of workweek end-of-shift urinary trichloroacetic acid (U-TCA) determination (results to be corrected for specific gravity or urinary creatinine concentration).
  ii. Liver function tests (serum bilirubin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and gamma glutamyl transferase). For exposures that are irregular or intermittent, the test should be done at the end of the exposure period
- Unfit for PCE exposure:
  i. Workers with liver diseases
  ii. Alcoholics and cases of solvent abuse

- Periodic medical examinations: every 12 months
  - Clinical examination with particular emphasis on the central nervous system, skin and liver
  - Mid of workweek end-of-shift urinary trichloroacetic acid (U-TCA) determination (results to be corrected for specific gravity or urinary creatinine concentration)

For exposures that are irregular or intermittent, the test should be done at the end of the exposure period

BTLV for U-TCA = 7 mg/L
Action Level for U-TCA = 5.6 mg/L

- If U-TCA exceeds Action level, to conduct liver function tests (serum bilirubin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and gamma glutamyl transferase)
- Actions to take when there are abnormal clinical findings:

Findings	Actions to Take	
	Abnormal Liver Function Test Results	**Normal Liver Function Test Results**
U-TCA < 5.6 mg/L	• Examine • Suspend (refer to Appendix K) • Refer • Update MOM	• No further action
U-TCA ≥5.6 to 6.9 mg/L	• Examine • Reduce risk • Suspend (refer to Appendix K) • Refer • Update MOM	• Examine • Reduce risk • Update MOM

U-TCA ≥7 mg/L	• Examine • Reduce risk • Suspend (refer to Appendix K – high risk) • Notify • Refer • Update MOM	• Examine • Reduce risk • Suspend • Notify • Update MOM

Description of Actions to Take:

Actions to take	Description
Examine	• Clinical examination for signs and symptoms of PCE poisoning • To determine work-relatedness of condition, obtain detailed occupational history from worker to document PCE exposure (past and present); obtain PCE-in-air levels from company • If U-TCA is above action level: - determine reason for high exposure e.g. non-usage of personal protective equipment, accidental contact, wrong handling technique, absence of exhaust ventilation system, etc • If U-TCA is above BTLV, to conduct liver function test as soon as possible (serum bilirubin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and gamma glutamyl transferase) • If liver function test is abnormal: - refer to Appendix K to determine whether to suspend or not • Check serial U-TCA and liver function test results for deteriorating trend
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review Risk assessment evaluating adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Visit workplace if necessary

Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • For cases on temporary suspension: - monitor worker closely by repeating abnormal test(s) monthly till results are all normal. - when U-TCA and liver function test results are all normal, worker is fit to return to PCE exposure. Submit *Certificate of Fitness* to employer, MOM and worker. - after return to PCE exposure, continue to monitor worker's liver function test every 3-monthly for the next 6 months. • For cases on permanent suspension, monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the *Report of Examinations* form
Refer	• Referral to toxicologist or hepatologist for additional tests e.g. abdominal ultrasound, blood PCE estimation, etc
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

11.12.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases of suspected PCE poisoning; and
- All cases of PCE excessive absorption, i.e., asymptomatic workers with U-TCA levels ≥ 7 mg/L or blood PCE level ≥ 0.5 mg/L.

Indications for Permanent Suspension

- All cases of definite PCE poisoning;
- Workers with persistently abnormal liver function test results of more than 3 months;
- Workers with diagnosed liver disease; and
- Alcoholics and cases of solvent abuse.

*Note: When there is mixed exposure to PCE and trichloroethylene (TCE), BTLV for U-TCA of 50 mg/l should be adopted if the air level for PCE is less than half PEL. Where the air level for PCE is more than half PEL, a BTLV of 7 mg/l should be adopted.

Indications for Return to PCE Exposure

- U-TCA level < Action level or B-PCE level < 0.5 mcg/L;
- Normal liver function test results; and
- No symptoms of PCE poisoning.

11.12.5 Special Instructions

- Workers should abstain from alcohol one week before examination as the test results may be affected.
- To note whether workers are on phenobarbital and chloral hydrate treatment as this may result in increased urinary TCA levels.

11.12.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption by completing Appendix F if all the following conditions are met:

- Air levels are not detectable;
- Workers have undergone at least 1 round of pre-placement and 1 round of periodic medical examinations with U-TCA results within range for normal unexposed population (See Appendix J); and
- No direct physical contact with PCE is required in the work process.

11.12.7 Treatment

All cases of PCE poisoning must be immediately removed from exposure. Acute poisoning cases must be referred for hospital treatment.

Further Reading

1. American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values and Biological Exposure Indices. 7th Edition, 2009: Tetrachloroethylene.
2. Vernon Benignus et al. Long-Term Perchloroethylene Exposure: A Meta-Analysis of Neurobehavioural Deficits in Occupationally and Residentially Exposed Groups. Journal of Toxicology and Environmental Health 2009; 72 : 824-831.
3. Gold LS et al. Systematic Literature Review of Uses and Levels of Occupational Exposure to Tetrachloroethylene. Journal of Occupational and Environmental Hygiene. 2008: 807-839.
4. World Health Organization. Chapter 5.13 Tetrachloroethylene. Air Quality Guidelines. Second Edition. WHO Regional Office for Europe: Copenhagen, Denmark: 2000.
5. World Health Organization. Tetrachloroethylene Environmental Health Criteria 31. Geneva: 1984.

11.13 Free Silica

Silica is silicon dioxide (SiO2), also called "crystalline" silica. Includes quartz, tridymite and cristobalite.

11.13.1 Health Effects

- Acute Silicosis
  - Rare;
  - Due to inhalation of high concentrations of very fine free silica dust particles (e.g., manufacture of abrasive soaps, tunnelling and sandblasting);
  - May develop within a few months with severe dyspnoea, cough, mucoid sputum, fever, weight loss and cyanosis; and
  - Fatal within a year.
- Chronic Silicosis
  - Most of the cases are asymptomatic, presenting after 10 – 20 yrs;
  - Some may have dyspnoea, cough and wheezing; and
  - Silicotics may develop progressive massive fibrosis.
- Cancer
  - Crystalline silica dust is an IARC Group 1 carcinogen–Cancer of lung; and
  - Higher risk of lung cancer especially in smokers.

Note: Silicotics are more prone to developing pulmonary tuberculosis.
There is also an association with scleroderma and chronic renal disease.

11.13.2 Main Industries and Occupations at Risk

- Mining, quarrying and tunnelling of siliceous rocks (e.g. granite, sandstone, slate, mica, silica containing coal or metal ores);
- Abrasive blasting using siliceous grains (e.g., sandstone, sand, quartzite and flint);
- Stone cutting, dressing, polishing, cleaning and monumental masonry (including tombstone engraving) using granite and sandstone;
- Construction (e.g., jack hammering, drilling of silica or silicon dioxide-containing material like sand, sandstone, quartz and granite);
- Maintenance and repair of refractories (furnace linings);
- Manufacture of ceramics (chinaware, porcelain, earthenware) and refractories;
- Foundries (mould breaking and fettling);
- Rubber milling (using calcium carbonate containing silica);
- Enamelling using quartz, feldspar, metal oxides and carbonates; and
- Manufacture of abrasive soaps.

11.13.3 Medical Examinations

Indications:

Any work where workers are exposed to airborne free silica

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within 3 months of exposure

- Clinical examination shall include a detailed medical and work history with emphasis on:
  i. past, present and anticipated future exposure to silica; and
  ii. respiratory system.
- Test:
  i. Full size chest x-ray examination.
- Unfit for exposure to silica:
  i. Workers with history of pulmonary tuberculosis; and
  ii. Workers who are unable to wear respirators.

- Periodic medical examinations: every 36 months
  i. Clinical examination shall include a detailed medical and work history with emphasis on the respiratory system;
  ii. Full size chest x-ray examination; and
  iii. Actions to take based on clinical examinations and investigation findings:

Abnormal Clinical and Radiological Findings	Actions to Take
Abnormal clinical findings of respiratory system	• Examine • Reduce risk • Refer • Suspend (if symptomatic) • Update MOM
Abnormal chest X-ray, suggestive of silicosis	• Examine • Reduce risk • Notify • Refer • Suspend (if symptomatic) • Update MOM
If previously confirmed as silicosis	• Examine • Reduce risk • Update MOM • Suspend – see section below on indications for suspension
If suspected lung cancer	• Examine • Refer • Reduce risk • Notify • Suspend • Update MOM

If contracted tuberculosis	• Refer • Suspend • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of silicosis and lung cancer • Review previous and latest Chest X-rays to look for changes • To determine work-relatedness of condition, obtain detailed occupational history from worker to document silica exposure (past and present) • Conduct lung function test
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review risk assessment, reviewing adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension (if necessary) • Visit workplace if necessary
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • Monitor suspended worker closely by examining worker and repeating abnormal CXR annually to observe for changes
Refer	• When diagnosis is unclear or worker requires further investigation or management • Referral to relevant clinical specialist for additional tests which may include: - Lung function test, e.g., Forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) - Sputum examination for acid fast bacilli - Mantoux test, etc

Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

11.13.4 Special Instructions

Radiologists interpreting the Chest X-rays should compare them against the set of standard films–ILO International Classification of Radiographs of Pneumoconioses.

11.13.5 Suspension From Exposure

Indications For Permanent Suspension

- All cases of pulmonary tuberculosis, active or inactive;
- All symptomatic cases; and
- All cases diagnosed with lung cancer.

11.13.6 Criteria For Exemption

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential exposure;
- Silica-in-air levels are not detectable; and
- Workers have completed at least two rounds of examinations and the Chest X-rays of all workers are normal.

11.13.7 Treatment

There is no definite treatment for silicosis. All pulmonary tuberculosis cases should be referred for treatment and further management in a chest hospital/ clinic. Symptomatic silicotics may require treatment as and when indicated.

Further Reading

1. Occupational Safety and Health Administration (OSHA). National Emphasis Program - Crystalline Silica. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=3790
2. International Labour Oganization (ILO). International Classification of Radiographs of Pneumoconioses (revised edtion 2001).
3. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Values and Biological Exposure Indices. 2010: Silica, crystalline: α-Quatz and Cristobalite.
4. National Institute for Occupational Safety and Health. Occupational Respiratory Disease Surveillance. http://www.cdc.gov/niosh/topics/surveillance/ords/WorkerMedicalMonitoring.html
5. World Health Organization: Pneumoconiosis In: Early detection of occupational diseases, Geneva, 1986: 9-25. Harber P, Schenker MB, Balmes JR, editors, Mosby-Year Book, 1996: 373-99.

11.14 Tar, Pitch, Bitumen and Creosote

Tar, pitch and bitumen look alike and can be used for similar purposes. As a result, they have been loosely termed as 'tar'. However, they are toxicologically, chemically and physically different.

Coal tar, pitch, bitumen and creosote are chemically related dense semi-solid carbonaceous materials widely used in construction and metal production such as steel and aluminium.

Coal tar is a by-product of high temperature treatment (destructive distillation) of coal to make coke or natural gas. Distillation of coal tar results in the production of coal tar pitch residues and coal tar creosote. Coal tar pitch is a thick, black or dark-brown liquid or semi-solid with a smoky or aromatic odour. When coal tar pitch is heated, volatile compounds are given off and contain complex mixtures of polycyclic aromatic hydrocarbon compounds (PAHs), phenols, heterocyclic oxygen, sulphur and nitrogen compounds. Coal tar creosotes have an oily liquid consistency and range from yellowish green to dark brown in colour.

PAHs present in extracts of coal tar and coal tar aerosols are thought to be responsible for carcinogenesis. PAHs are formed during incomplete combustion of any fuel. Significant levels occur in coke and gas works, aluminium, iron and steel works, where these materials are handled.

Wood creosote and beechwood creosotes are resins derived from leaves of the creosote bush (Larrea) and beechwood (Fagus) respectively. They are not usually used in the workplace setting.

Bitumen is the residue from the refining of crude petroleum. It also occurs naturally as asphalt pools. It is also known as asphalt in the USA. Asphalt (bitumen) is usually handled hot and workers are exposed to asphalt fumes. There is currently insufficient epidemiological evidence to show association with exposure to asphalt fumes and bitumens with risk of cancer[1,3, 9] Therefore workplaces using petroleum-derived asphalt or bitumen are generally exempted from the Workplace Safety and Health (Medical Examinations) Regulations.

As such, this guideline would focus on medical examinations for coal tar derived products only.

Uses of Coal Tar Products (Coal tar, coal tar pitch, coal tar creosotes, etc)

- Wood preservatives, herbicides, fungicides, insecticides, disinfectants
- Base for coatings, paints
- Roofing and paving of roads
- Contaminant in asphalt products
- Binder for electrodes in aluminium smelting

CAS Number

Coal tar distillation : 8007-45-2
Coal tar pitch volatiles : 65996-93-2

Routes of Exposure

- Dermal
- Inhalation
- Ingestion–rare

11.14.1 Toxic Effects

- Acute effects
  - skin burns;
  - photosensitive reactions of previously exposed areas of skin; and
  - eyes – blepharoconjunctivitis, keratitis.
- Chronic effects
  - Skin & mucous membranes:
    i. irritation–erythema, burning, itching, followed by desquamation (photosensitisation);
    ii. pigmentation changes - usually hyperpigmentation (primarily forearms, wrists, hands, scrotum);
    iii. follicular dermatitis (comedones, acne, sebaceous cysts); and
    iv. benign neoplasms–coarsening and hardening (shagreen appearance), kerato-acanthoma, tar warts or papillomata (tar warts may be pre-malignant).
  - Respiratory:
    i. irritation–congestion, pneumonitis; and
    ii. mild to moderate pulmonary restriction and obstruction.
  - Gastrointestinal tract
    i. burning pain; and
    ii. diarrhoea.
- Cancer
  - Coal tar volatiles
    i. lung cancer in workers in coke and gas manufacture
    ii. lung and bladder cancer in aluminium smelters
    iii. possible increased risk for cancer of the oral cavity, larynx, oesophagus, stomach, skin and leukaemia with exposure.

    Polycyclic aromatic hydrocarbons (PAHs) present in extracts of coal tar and coal tar aerosols are thought to be responsible for carcinogenesis. Some of these PAHs include benz(a)anthracene, benzo(b)fluoranthrene, chrysene, anthraxcene, B(a)P, phenanthrene, acridine or pyrene.
  - Pitch
    i. Squamous cell carcinoma of the skin
    heavy, long term contact, usually in the form of contaminated clothing, rags and poor personal hygiene
    ii. Pre-cancerous epitheliomas also known as "pitch warts"
      - usually on exposed parts such as hands, arms and face
      - also on other parts of the body, particularly the scrotum

11.14.2 Main Industries and Occupations at Risk

- Manufacture of coal tar, pitch, bitumen and creosote (Coke oven industries);
- Coal gasification;
- Coke production;
- Water proofing of wood, making of roofing and insulating materials;
- Lining irrigation canals and reservoirs;
- Manufacture of dyestuff, e.g., carbon black;
- Manufacture of paints;
- Chemical feedstock for the production of benzene, toluene, xylene, phenol;
- Sealing agents, e.g., in battery manufacture; and
- Lubricant for die moulds.

11.14.3 Medical Examinations

Indications:

Any occupational exposure to coal tar, coal tar pitch and coal tar creosote

Types of Tests and Frequency of Examinations:

- Pre-placement medical examination: within 3 months of exposure
  - Clinical examination with emphasis on skin, lungs, gastrointestinal system and bladder.
- Periodic medical examinations: every 12 months
  - Clinical examination with emphasis on the skin, lungs, gastrointestinal system and bladder; and
  - Actions to take based on abnormal clinical examination findings:

Findings from Clinical Examination	Actions	Suspension
Symptoms suggestive of irritative effects	• Examine • Reduce risk • Refer • Notify • Update MOM	No
Benign skin lesions	• Examine • Reduce risk • Refer • Notify • Update MOM	No

Signs and symptoms suggestive of malignancies	• Examine • Reduce risk • Refer • Notify • Update MOM	Yes
Diagnosis of cancer in skin, lung, gastrointestinal or bladder	• Reduce risk • Refer • Notify • Update MOM	Yes

Description for Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of skin, lung, gastrointestinal or bladder cancer • To determine work-relatedness of condition, obtain detailed occupational history from worker to document exposure (past and present)
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review risk assessment and adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension • Visit workplace if necessary
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)
Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension

Refer	• When diagnosis is unclear or worker requires further investigation or management • Referral to relevant clinical specialist for additional tests, e.g., biopsy
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

11.14. 4 Suspension from Exposure

Indications for Temporary Suspension

- All pregnant women

Indications for Permanent Suspension

- All persons diagnosed with skin, lung, gastrointestinal or bladder cancer
- All persons with pre-malignant skin lesions

11.14.5 Special Instructions

Inform all women that they are to inform supervisor as soon as they are found to be pregnant. All pregnant women are to be suspended from exposure to coal tar, coal tar pitch, and coal tar creosote.

11.14.6 Treatment

All cases with cancer must be referred to the appropriate specialist for treatment immediately.

Further Reading

1. International Agency for Research on Cancer. Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 35. Polynuclear Aromatic Comounds, Part 4, Bitumens, Coal-Tars and Derived Products, Shale Oils and Soots. Summary of data reported and evaluation. Also Supplement 7 and Vol. 100F (Pending).
2. International Agency for Research on Cancer. Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 92. Some Non-Heterocyclic Polycyclic Aromatic Hydrocarbons and some related exposures. Also Vol. 100F (Pending).
3. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Values and Biological Exposure Indices. 7th Edition, 2001: Asphalt (Bitumen Fumes).
4. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Values and Biological Exposure Indices. 7th Edition, 2001: Coal Tar Pitch Volatiles.
5. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Wood Creosote, Coal Tar Creosote, Coal Tar, Coal Tar Pitch, and Coal Tar Pitch Volatiles. 2002.
6. Agency for Toxic Substances and Disease Registry (ATSDR). Addendum to the Toxicological Profile for Creosote. 2009.
7. B. Armstrong, E Hutchinson, T. Fletcher. Cancer risk following exposure to polycyclic aromatic hydrocarbons (PAHs): a meta-analysis. London School of Hygiene and Tropical Medicine, 2003. HSE Books. ISBN 07176 2604 0.
8. Health and Safety Executive, United Kingdom. Guidance for appointed doctors on the control of substances hazardous to health regulations 2002 (as amended).
9. Hazard Review: Health Effects of Occupational Exposure to Asphalt. December 2000.

11.15 Trichloroethylene (TCE)

CAS Number : 79-01-6

Synonyms : Acetylene Trichloride
Ethylene Trichloride
Trichloroethene

11.15.1 Toxic Effects

- Acute effects
  - Mucosal Membranes:
    i. Irritation of eye, nose, throat and respiratory tract.
  - Central Nervous System:
    i. Massive exposure can cause excitation, dizziness and euphoria initially. This is followed by a depressive phase of headache, nausea, sleepiness and coma.
  - Respiratory System:
    i. Chemical pneumonitis and death from respiratory failure can occur.
  - Heart:
    i. High exposure levels can sensitise myocardium and cause cardiac arrhythmia and death from cardiac failure.
- Chronic effects
  - Central Nervous System:
    i. Non-specific complaints like headache, irritability, fatigue and insomnia. Impairment in psychomotor and behavioural tests has been reported. Alcohol intolerance characterised by cutaneous vasodilatation, especially in the face, can occur.
  - Skin:
    i. Prolonged or repeated skin contact with liquid TCE can cause irritation and dermatitis.
  - Liver
    i. Few cases of hepatitis-like syndromes and steatosis (fatty liver) have been reported from chronic exposure to trichloroethylene.
  - Kidney
    i. Altered renal function such as proteinuria and raised blood urea may occur from chronic exposure to high levels.
- Severe systemic allergic reaction
  - Presents with triad of generalized rash (Steven Johnson Syndrome or Toxic Epidermal Necrolysis), fever and jaundice; seen within 2 – 3 weeks after starting exposure in sensitive individuals with minimal TCE exposure.
  - May result in fatality; and
- Cancer
  - Prolonged exposure to high concentrations of TCE (hundreds to thousands ppm) increases incidence of renal cancer.

Note: When there is mixed exposure to perchloroethylene and/or other solvents, there may be combined effects on target organs.

11.15.2 Main Industries and Occupations at Risk

- Workers involved in vapour degreasing and cold cleaning of metal parts in metal fabricating, automotive, aircraft and aerospace industries;
- Used for cleaning of lenses in optical industry;
- Used as solvent for extraction of waxes, fats, resins and oils; and
- Used as a solvent or chemical intermediate in printing inks, varnishes, adhesives, paints, lacquers, rug cleaners and disinfectants.

11.15.3 Medical Examinations

Indications:

Any occupational exposure to trichloroethylene

Types of Tests and Frequency of Examinations

- Pre-placement medical examinations: within three months of exposure
  - Clinical examination with emphasis on:
    i. past, present and anticipated future exposure; and
    ii. central nervous system, skin, liver and kidney disorders.
  - Tests:
    i. Mid-week end-of-shift urinary trichloroacetic acid (U-TCA) determination (results to be corrected for specific gravity or urinary creatinine concentration); and
    ii. Liver function tests (serum bilirubin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and gamma glutamyl transferase). For exposures that are irregular or intermittent, the test should be done at the end of the exposure period
  - Unfit for exposure to TCE:
    i. Workers with liver diseases
    ii. Alcoholics and cases of solvent abuse
- Periodic medical examinations: every 12 months
  - Clinical examination with emphasis on the central nervous system, skin, liver and kidney.
  - Tests:
    i. Mid-week end-of-shift urinary trichloroacetic acid (U-TCA) determination (results to be corrected for specific gravity or urinary creatinine concentration)

BTLV for U-TCA = 100 mg/L;
Action Level for U-TCA = 80 mg/L

    ii. If U-TCA exceeds Action level, to conduct liver function tests (serum bilirubin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and gamma glutamyl transferase) For exposures that are irregular or intermittent, the test should be done at the end of the exposure period

Actions to take for abnormal clinical findings:

Findings	Actions to Take	
	Abnormal Liver Function Test Results	**Normal Liver Function Test Results**
U-TCA < 80 mg/L	• Examine • Suspend (refer to Appendix K) • Refer • Update MOM	• No further action
U-TCA ≥80 to 99 mg/L	• Examine • Reduce risk • Suspend (refer to Appendix K) • Refer • Update MOM	• Examine • Reduce risk • Update MOM
U-TCA ≥100 mg/L	• Examine • Reduce risk • Suspend (refer to Appendix K – high risk) • Notify • Refer • Update MOM	• Examine • Reduce risk • Suspend • Notify • Update MOM

Description of Actions to Take:

Actions to Take	Description
Examine	• Clinical examination for signs and symptoms of TCE poisoning • To determine work-relatedness of condition, obtain detailed occupational history from worker to document TCE exposure (past and present); obtain TCE-in-air levels from company • Check serial U-TCA and liver function test results for deteriorating trend • If U-TCA is above Action Level: - determine reason for high exposure e.g. non-usage of personal protective equipment, accidental contact, wrong handling technique, absence of exhaust ventilation system, etc • If U-TCA ≥ BTLV: - conduct liver function test as soon as possible (serum bilirubin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and gamma glutamyl transferase) • If liver function test is abnormal: - refer to Appendix K to determine whether to suspend or not.
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review Risk assessment evaluating adequacy of control measures in workplace - Worker i. Evaluate adequacy of worker's personal protection ii. Counsel worker on preventive measures and suspension (if indicated) • Visit workplace if necessary
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)

Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension • For cases on temporary suspension: - monitor worker closely by repeating abnormal test(s) monthly till results are all normal. - when U-TCA and liver function test results are all normal, worker is fit to return to TCE exposure. Submit *Certificate of Fitness* to employer, MOM and worker. - after return to TCE exposure, continue to monitor worker's liver function test every 3-monthly for the next 6 months. • For cases on permanent suspension, monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the *Report of Examinations* form
Refer	• Referral to toxicologist or hepatologist for additional tests e.g. abdominal ultrasound, etc
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post

11.15.4 Suspension from Exposure

Indications for Temporary Suspension

- All cases of suspected TCE poisoning; and
- All cases of excessive TCE absorption, i.e., asymptomatic cases with U-TCA of more than 100 mg/L.

Indications for Permanent Suspension

- All cases of definite TCE poisoning;
- Workers with persistently abnormal liver function test results of more than 3 months;
- Workers presenting with fever, severe skin rash and/or jaundice. They should be immediately removed and investigated to exclude TCE allergy. These workers may need immediate hospitalisation;
- Workers with diagnosed liver disease; and
- Alcoholics and cases of solvent abuse.

Indications for Return to TCE Exposure

- U-TCA level < Action level;
- Normal liver function test results; and
- No symptoms of TCE poisoning.

11.15.5 Special Instructions

When there is mixed exposure to TCE and perchloroethylene (PCE), BTLV level for U-TCA of 50 mg/L should be adopted if the air level for PCE is less than half PEL. Where the air level for PCE is more than half PEL, a BTLV of 7 mg/L should be adopted.

Workers should abstain from alcohol one week prior to urine collection. Depending on the dose level and the interval between exposure to ethanol and TCE, ethanol may either increase or decrease the level of U-TCA.

Workers on phenobarbital and chloral hydrate treatment may have increased urinary TCA. Those on disulfiram may have lower levels.

Exposure to chlorine-containing ethanes/ethylenes can increase the level of TCA excretion. Other solvents may reduce the level of U-TCA.

11.15.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption by completing Appendix F if all the following conditions are met:

- Air levels are not detectable;
- Workers have undergone at least 1 round of pre-placement and 1 round of periodic medical examinations with U-TCA results within range for normal unexposed population (See Appendix J);
- No direct physical contact with TCE is required in the work process; and
- TCE is handled in an enclosed environment.

11.15.7 Treatment

All cases of TCE poisoning must be immediately removed from exposure. Acute poisoning cases must be referred for hospital treatment.

All cases of severe allergic reaction must be immediately referred for treatment in hospital. They should be advised to ensure that they are never exposed to TCE in future as re-exposure may result in fatality.

Further Reading

1. National Institute for Occupational Safety and Health. Criteria for a Recommended Standard: Occupational exposure to trichloroethylene. US Department of Health, Education and Welfare, USA, (HSM-99-72-129), 1973.
2. World Health Organization. Trichloroethylene: Environmental Health Criteria 50. Geneva 1985.
3. American Conference of Governmental Industrial Hygienists: Documentation of Threshold Limit Values and Biological Exposure Indices, 7th Edition, 2008: Trichloroethylene.
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6. Kim JH et al. A Case of Trichloroethylene Intoxication with Neuropsychiatric Symptoms. Korean J Occup Environ Med. 2008; 20: 54-61.
7. Toxicological Profile for Trichloroethylene (TCE), Agency for Toxic Substances and Disease Registry, Department of Health and Human Services, 1997.
8. Chapter 5.15 Trichloroethylene, Air Quality Guidelines–Second Edition, WHO Regional Office for Europe, Copenhagen, Denmark, 2000.

11.16 Vinyl Chloride Monomer

Vinyl chloride (C_2H_3Cl) is a colourless almost odourless gas at room temperature. It is highly flammable and potentially explosive. It is a liquid at low temperatures and is shipped as a compressed gas. It polymerizes easily in air, sunlight or heat unless stabilised by inhibitors such as phenol.

It is used as a precursor in the manufacture of polyvinyl chloride (PVC), a polymer widely used to make a variety of plastic products such as pipes, wire and cable coatings and packaging materials.

CAS NUMBER : **75-01-4**

Common Synonyms

- Chloroethene;
- Chloroethylene;
- 1- Chloroethylene;
- Ethylene monochloride;
- Monochloroethene;
- Monochloroethylene;
- Monovinyl chloride;
- MVC;
- VC; and
- VCM.

Routes of Exposure

Inhalation of vapours–main route of absorption
Dermal contact (vapours or liquid)
Eye contact (liquid VCM)–negligible

11.16.1 Toxic Effects

- Acute Poisoning
  - Depression of the central nervous system (CNS)
    i. Dizziness (~8,000 ppm for 5 minutes);
    ii. Confusion, headache, dizziness (25,000 ppm for 3 minutes);
    iii. Drowsiness, loss of coordination, visual and auditory abnormalities, disorientation, nausea, headache, burning or tingling of extremities (~20,000 ppm); and
    iv. Death (>20,000 ppm) likely due to CNS and respiratory depression.
  - Asphyxiation in poorly ventilated or enclosed spaces as it is heavier than air;
  - Mild respiratory irritation (wheezing and bronchitis) – transient;
  - Skin and mucous membrane irritation;
  - Frostbite injury of skin (redness, blistering, scaling) from contact with escaping compressed vinyl chloride gas or liquid vinyl chloride; and
  - Frostbite injury of eyes (corneal/ conjunctival burns or irritation) from contact with escaping compressed vinyl chloride gas or liquid vinyl chloride.

- Chronic Poisoning at high exposures (100 - 1000 ppm)
  - Neurological
    i. Sensory motor polyneuropathy; and
    ii. Pyramidal, extrapyramidal and cerebellar abnormalities.
  - Imnmunologic
    i. Purpura
    iI. Thrombocytopaenia
  - Vinyl Chloride disease (syndrome)
    i. Raynaud's phenomenon;
    ii. Acro-osteolysis (especially of the hands); and
    iii. Scleroderma-like lesions.
- Cancer
  - liver cancer including angiosarcoma of the liver from cumulative high exposures (>288 ppm-years).
- Others
  - non-cirrhotic portal fibrosis.

11.16.2 Main Industries and Occupations at Risk

- Production of polyvinyl chloride resins (workers who clean and maintain the reactors are especially at risk);
- Production of vinyl chloride- vinyl acetate copolymers;
- Storage of Vinyl Chloride Monomer; and
- Sampling and analysis of Vinyl Chloride Monomer.

11.16.3 Medical Examinations

Indications:

Any occupational exposure to Vinyl Chloride Monomer

Types of Tests and Frequency of Examinations:

- Pre-placement medical examinations: within three months of exposure
  - Clinical examination shall include a detailed medical and work history with emphasis on the skin, liver and hands:
    i. evaluate past, present, and anticipated future exposure to VCM;
    ii. check for history of hepatic disorders, Hepatitis B; and
    iii. determine quantity of alcohol intake.
  - Tests:
    i. Liver function tests (serum bilirubin, alkaline phosphatase, alanine and aspartate transferases and gamma glutamyl transferase estimations); and
    ii. Hepatitis B and C serology.

- Unfit for exposure to VCM:
  i. abnormal liver function test results;
  ii. heavy alcohol ingestion;
  iii. Hepatitis B carrier;
  iv. Hepatitis C serology positive; and
  v. clinical evidence of liver disease e.g. enlarged spleen, liver, spider naevi, etc.

- Periodic medical examinations: every 12 months:
  - Clinical examination with an emphasis on the skin, hands, liver and neurological system;
  - Liver function tests (serum bilirubin, alkaline phosphatase, alanine and aspartate transaminases and gamma glutamyl (transferase estimations)

    Abnormal liver function test = any test result exceeding laboratory upper range of normal by 10%
  - Actions to take when there are abnormal clinical findings:

Abnormal Clinical Findings	Actions	Suspension
Abnormal liver function test	• Examine • Reduce risk • Refer • Update MOM	Refer to Appendix K for indication for suspension
Signs and symptoms of Vinyl chloride disease	• Examine • Reduce risk • Refer • Notify • Update MOM	Yes
Signs and symptoms suggestive of liver malignancy	• Examine • Reduce risk • Refer • Notify • Update MOM	Yes

Description of Actions to Take:

Actions to Take	Description
Examine	• Examine for signs and symptoms of: - Liver cancer including liver angiosarcoma - Liver cirrhosis - Vinyl chloride disease i. Raynaud's phenomenon; ii. Acro-osteolysis (especially of the hands); and iii. Scleroderma-like lesions. - Neurological effects – polyneuropathy or cerebellar abnormalities • Check serial liver function test results for deteriorating trend. • To determine work-relatedness of condition, obtain detailed occupational history from worker to document VCM exposure (past and present); obtain VCM-in-air levels from company. • If worker has abnormal liver function test result, refer to Appendix K to determine whether to suspend worker.
Reduce risk	• To do following within 1 month: - Employer i. Inform employer to review risk assessment and adequacy of control measures in workplace. - Worker i. Evaluate adequacy of worker's personal protection; and ii. Counsel worker on preventive measures and suspension (if indicated). • Visit workplace if necessary.
Notify	• Notify occupational disease to Commissioner for Workplace Safety and Health, Ministry of Manpower (MOM) through iReport (www.mom.gov.sg/iReport) • Provide MOM with basis for diagnosis • Inform employer of diagnosis (in writing)

Suspend	• Submit *Certificate of Suspension* to employer, MOM and worker to inform reason for suspension, date started suspension and period of suspension. • For cases on temporary suspension: - monitor worker closely by repeating abnormal liver function test(s) monthly till results are all normal; and - when liver function test results are all normal, worker is fit to return to VCM exposure. Submit *Certificate of Fitness* to employer, MOM and worker. After return to VCM exposure, continue to monitor worker's liver function test every 3-monthly for the next 6 months. • For cases on permanent suspension, monitor worker at least 6-monthly till advised otherwise by MOM; update MOM using the *Report of Examinations* form.
Refer	• When diagnosis is unclear or worker requires further investigation or management. • Referral to relevant clinical specialist for additional tests, e.g., liver ultrasound, liver biopsy, hand X-ray, platelet count and screening for Hepatitis B and C status, etc.
Update MOM	• Inform MOM on actions taken and investigation findings by submitting *Report of Examinations* by e-mail or post.

11.16.4 Suspension from Exposure

Indications for Temporary Suspension

- All pregnant women;
- Abnormal liver function test result with high risk of VCM poisoning (Refer to Appendix K); and
- All cases of suspected VCM disease.

Indications for Permanent Suspension

- All cases of definite VCM disease;
- All cases of liver cancer;
- Workers with persistently abnormal liver function test results (one or more abnormal result on at least 2 occasions within a 3 month period);
- Has clinical evidence of liver disease, e.g., enlarged spleen, liver, spider naevi, etc;
- Hepatitis B carrier; and / or
- Hepatitis C serology positive
- Heavy drinkers and solvent abusers.

Indications for Return to VCM Exposure

- Normal liver function test results; and
- No symptoms of VCM poisoning.

11.16.5 Special Instructions

Inform all women that they are to inform supervisor as soon as they are found to be pregnant. All pregnant women are to be suspended from exposure to VCM.

Workers undergoing liver function test should abstain from alcohol at least 2 weeks prior to undergoing the test.

11.16.6 Criteria for Exemption from Medical Surveillance

Employer may apply for exemption from medical surveillance by completing Appendix F if all the following conditions are met:

- No potential skin contact; and
- VCM-in-air levels are not detectable.

11.16.7 Treatment

Acute poisoning cases must be referred to hospital for treatment.

Cases with liver cancer and liver angiosarcoma should be referred to the appropriate clinical specialist for treatment.

Further Reading

1. National Institute for Occupational Safety and Health: Occupational Health Guidelines for Vinyl Chloride. Potential Human Carcinogen, 1988.
2. Occupational Safety and Health Administration, US Department of Labor – Regulations (Standards – 29 CFR) Vinyl Chloride – 1910.1017 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10021) accessed on 24 Sept 2010.
3. IPCS International Programme on Chemical Safety. Health and Safety Guide No. 109,1999.
4. International Agency for Research on Cancer. Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 97. 1,3-Butadiene, Ethylene Oxide and Vinyl Halides (Vinyl Fluoride, Vinyl Chloride and Vinyl Bromide), 2008.
5. The National Institute for Occupational Safety and Health (NIOSH). NIOSH Pocket Guide to Chemical Hazards: Vinyl Chloride. Accessed 29 June 2011.
6. Health and Safety Executive, United Kingdom. Guidance for appointed doctors on the control of substances hazardous to health regulations 2002 (as amended). Accessed 30 June 2011.
7. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. Medical management guidelines for Vinyl Chloride. Accessed 30 June 2011.
8. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. Toxicological Profile for Vinyl Chloride.
9. Workplace Safety and Health (General Provisions) Regulations, 2006.
10. American Conference of Governmental Industrial Hygienists (ACGIH). Documentaion of the Threshold Limit Values and Biological Exposure Indices. 7th edition 2001: Vinyl Chloride.

12. Procedures in the Conduct of Statutory Medical Examinations

When you are awarded a contract to look after workers who are working in an occupation where they are exposed to one of the 19 hazards which requires statutory medical examinations, you would be one member of the team which looks after the health of the exposed workers, ensuring that they would not develop adverse outcomes like poisoning, hearing loss or even death.

Upon being awarded the responsibility, some administrative matters would need to be attended to. To prevent any misunderstanding with the company, the contract you sign with the company should enable you to carry out your responsibilities effectively as a DWD. You may want to ensure that the contract itemises all activities which you would be expected to conduct as a DWD, specifying clearly the indications for these activities. Remember, you are responsible for the proper conduct of the medical examinations, not the audiometric service provider or laboratory or the Workplace Safety and Health Officer or the Human Resource officer.

As a DWD you are now responsible for ensuring that the examinations conducted are accurate so that you can make the correct judgement as to whether the workers are fit for further exposure to the hazard or not, and whether the workers have suffered an adverse outcome or not.

To ensure that results are accurate,

- workers should be given correct instructions on the timing for the collection of the specimens or for conduct of the different types of tests e.g. audiometric test. Please refer to Appendix H for a summary of the instructions for workers;
- laboratories used for the toxicological analysis should subscribe to a quality assurance scheme for the analyte assayed; and
- audiometricians conducting the audiometric examination have undergone recognised training. You can check whether the specific audiometrician is listed in the register of trained audiometricians found on the MOM website (www.mom.gov.sg).

12.1 Conducting Medical Examinations

Pre-placement Medical Examinations

Results of these examinations form his baseline results. As many workers move within the same industry, he may have been adversely affected from his exposure in previous workplaces. Hence, information such as the date the worker started exposure to the hazard, both in this workplace and previous ones are very important. Also note the nature of his exposure to the hazard and the type of preventive measures in place in both his previous and current workplaces.

Refer to the specific sub-chapters in Chapter 11 for the types of medical examinations and the medical conditions which renders him unfit for this exposure.

If worker is found to be unfit for exposure to the hazard, complete the ***Certificate of Fitness*** stating that he is unfit for exposure and provide the basis for your certification of unfitness.

Worker's individual examination results should be annotated in the ***Report of Examinations*** form or the audiometric report (for noise hazard).

All results conducted for the round (both pre-placement and periodic examinations) should be included for reporting using the ***Summary Report*** form.

Periodic Medical Examinations

When arranging for the medical examinations, request from the employer the ***Register of exposed*** workers and the workers' individual ***Report of Examinations*** forms or previous audiometric test results (for noise hazard). This is for the purpose of detecting any adverse trends in the results and for you to annotate your findings.

Worker's individual examination results and any other follow-up actions taken e.g. risk reduction, referral, etc should be annotated in the ***Report of Examinations*** form or the audiometric report (for noise hazard). Take the necessary follow-up actions as mentioned in the specific sub-chapter for that hazard in Chapter 11.

If a worker requires suspension, complete the ***Certificate of Suspension***, with copies given to the worker, employer and MOM. The reason(s) and duration for the suspension should be clearly stated.

All results conducted for the round (both pre-placement and periodic examinations) should be included for reporting using the ***Summary Report form***.

12.2 Exemption

If the risk of adverse health outcomes is negligible, you may advise the company to apply for exemption from the medical examinations. See Criteria for exemption in Chapter 9 Biological Monitoring and the individual chapters for the hazards.

To apply for exemption, complete the application form which can be downloaded from www.mom.gov.sg and submit together with relevant supporting documents which must include biological monitoring results. A sample of the exemption form can be found in Appendix F. If the application is successful, a ***Certificate of Exemption*** would be sent by MOM to the company. A copy of the Certificate must be displayed at a prominent area to inform workers of the exemption.

12.3 Documentation

The following are additional points to note about the different forms:

Summary Report Form (Regulation 9)

- This should be completed and submitted to the Commissioner for Work Safety and Health (OSHD, MOM) as soon as possible after completion of the examinations. **One form should be used per hazard per workplace.** DO NOT combine results from different workplaces even if they are the same company.
- For workplaces which have a large number of workers, medical examinations could be conducted in batches. The Summary Report form could be submitted to MOM upon completion of each batch of workers.
- **Summary Report need not be completed for repeat test results**. For individual workers' repeat test results and updating on all follow-up actions taken, update MOM separately using the workers' form.
  - Details of all abnormal cases (whether occupational or not) should be given in the Appendix.
- Workers diagnosed with occupational diseases should separately be notified through iReport (www.mom.gov.sg/iReport) as required under the WSH (Incident Reporting) Regulations.

Report of Examinations (Regulation 9)

- Every worker examined should have their individual Report of Examinations as this serves as their personal case notes. The workers' individual forms should be completed after each round of examinations and whenever repeat tests and other actions e.g. workplace inspection, assessing and reducing risks, referrals, etc are carried out. It gives a chronological record of the medical examination results and interventions, enabling you to detect adverse trends.
- Clinical examination findings and test results should be included.
- **One form should be used per worker per hazard.** If a worker is exposed to more than one hazard, the worker's personal particulars need only be completed once.
- This form may be substituted with any other medical examination form provided it contains all the required information found in the *Report of Examinations* form e.g. audiometric test report may be used instead of the *Report of Examinations* form.

Register of Workers (Regulation 8)

- The company is responsible for maintaining the register of workers exposed to the hazard. Separate registers should be maintained for different hazards.
- Obtain a copy of the register from the company before starting the medical examinations. Confirm with the company that all exposed workers are included, particularly the maintenance and cleaning workers (if exposed).

Certificate of Suspension (Regulation 10)

- When a worker is recommended for suspension from work involving exposure to a certain hazard on a temporary or permanent basis, a copy of the *Certificate of Suspension* is to be issued to the employer, worker and MOM.
- When a suspended worker is subsequently fit for exposure to the hazard, the employer, worker and MOM should be informed by receiving the *Certificate of Fitness*.

Certificate of Fitness (Regulation 4)

- This form is used for certification of fitness for workers returning to work after a period of suspension.
- This form is also used for certification of unfitness e.g. during pre-placement examinations or for workers permanently suspended from exposure.
- When issued, a copy must be completed and submitted to the Commissioner for Workplace Safety and Health, MOM.

Notification of Occupational Diseases through iReport

- Upon diagnosis of an occupational disease (OD):
  - notify MOM within 10 days after diagnosis of OD by submitting online at: www.mom.gov.sg/iReport. The notification should include the following information:
    i. doctor's particulars and clinic details;
    ii. occupational disease details;
    iii. patient's details (e.g., personal particulars, employment, illness, and other pre-existing condition information).
  - inform the employer in writing as this serves to trigger the employer to notify to MOM through iReport and to initiate investigations so as to prevent further cases.
- In situations where you are unsure of the diagnosis, instead of notifying through iReport, you can refer these cases to the available Occupational Health clinics (http://www.mom.gov.sg/workplace-safety-health/resources/accredited-professional-services/Pages/list-of-occupational-health-clinics.aspx).

12.4 Submission of Report

All documents for submission to the Commissioner for Workplace Safety and Health, MOM can be made on-line through http://www.mom.gov.sg/services-forms/workplace-safety-health/Pages/medical-monitoring.aspx Hard copies of the forms can also be downloaded from http://www.mom.gov.sg/services-forms/workplace-safety-health/Pages/medical-monitoring.aspx for submission to the Commissioner for Workplace Safety and Health, 18 Havelock Road #05-01, Singapore 059764.

Responsibility for Submission

Following the conduct of the medical examinations, the persons responsible for the submission of the following documents to MOM, employers and workers are summarised in the table below:

Type of Document	Description	Submission to Employer	Submission to MOM	Submission to Worker
Summary Report form	Summary of examination findings including details of abnormal results	DWD's responsibility	Employer's responsibility	Not applicable
Report of Examinations form	Workers' individual serial results, certification of fitness and follow-up actions	DWD's responsibility	DWD's responsibility (when required to update MOM on actions taken for abnormal cases)	Not applicable
Register of workers form	Register of all workers exposed to the specified hazard	DWD provides toxicological test results to employer	Employer's responsibility	Not applicable
Certificate of Suspension	Certificate to be issued by the DWD to inform worker, employer and MOM of worker's unfitness to continue exposure	DWD's responsibility	DWD's responsibility	DWD's responsibility
Certificate of Fitness	For certification of fitness or certification of unfitness	DWD's responsibility	DWD's responsibility	DWD's responsibility
iReport notification form	Notification of occupational disease under the WSH (Incident Reporting) Regulations	DWD's responsibility to inform employer of diagnosis of occupational disease	DWD's and employer's responsibility	DWD to inform worker of implications of diagnosis

13. Respiratory Protection

The most important route by which toxic chemicals enter our bodies is through inhalation. The best way to protect workers from inhaling such chemicals is to reduce or prevent contamination of the air they breathe through control measures such as elimination or substitution of toxic chemicals, installation of enclosures and implementation of engineering controls such as local exhaust ventilation systems. Where such measures are not feasible or cannot be implemented immediately or are inadequate to control the hazard, then supplementation with personal protective equipment such as respiratory protection would be necessary. Respiratory protection may also have to be used in maintenance operations or during emergencies.

13.1 Indications for Respirator Usage

There are two main indications:

- When exposed to hazardous air contaminants in concentrations which exceed the permissible exposure limits
- When in an oxygen deficient environment (< 19%) e.g. in a confined space such as a storage tank or manhole.

13.2 Effective Respiratory Protection

If respirators are used, they should be used properly so as to ensure effective protection. Otherwise they can give a false sense of security and in fact be a danger to the user.
For respirators to be effective, they must:

- be of the correct type for the situation or hazard;
- fit the persons using them;
- be worn 100% of the time when in the hazardous environment; and
- be properly maintained in good working condition.

13.2.1 Correct Type of Respirator

There is no one all purpose respirator.

It is very important to select the correct type of respirator for the particular hazard or situation. Information on the type of respirator could be found in the Safety Data Sheet or could be provided by the respirator supplier. Basically, there are two types of respirators: air-supplied and air-purifying.

Air-supplied respirators provide a separate supply of air, e.g., air-line respirators and self-contained breathing apparatus (SCBA). These respirators must be used when in an oxygen deficient environment or when the levels of the contaminants are at very high concentrations beyond the protective limits of most air-purifying respirators. Examples of such situations are maintenance operations or emergencies, e.g., fire-fighting, rescue and accidental leakage.

Air-purifying respirators work by filtering or absorbing air contaminants as they pass through the respirator filter or cartridge. There are filters for particulates, e.g., dust, mist and fume and cartridges for vapours and gases. Some of the cartridges are specific for certain types of gases or vapours. Sometimes, a combination of a toxic dust filter and an organic solvent cartridge is required e.g. a worker exposed to both pesticide dust and solvent vapour. The respirators also come with various types of face pieces e.g. full-face mask or half mask. Full-face respirators have the advantage of eye protection and a higher protection level but are heavier and bulkier. There are also disposable respirators which have the advantage of being lighter and being maintenance free. However, these may not be available in different sizes.

In the United States (US) and Europe, the different types of face masks are usually labelled in the following manner – "letter number". In the U.S., the 3 letters used are N, R and P which stands for "not oil resistant", "oil resistant" and "oil proof" respectively. The number that follows indicates the percentage of airborne particles filtered by the mask (Table 1). In Europe, masks are categorized into class 1, 2 and 3 (Tables 2 and 3).

Oil Resistance	Label	Description
Not oil resistant	N95	Filters >95% of airborne particles
	N99	Filters >99% of airborne particles
	N100	Filters >99.97% of airborne particles
Oil resistant	R95	Filters >95% of airborne particles
	R99	Filters >99% of airborne particles
	R100	Filters >99.97% of airborne particles
Oil proof	P95	Filters >95% of airborne particles
	P99	Filters >99% of airborne particles
	P100	Filters >99.97% of airborne particles

Table 1: U.S. nomenclature for face masks

Class	Filter Penetration Limit (at 95L/min air flow)
FFP1	Filters >80% of airborne particles
FFP2	Filters >94% of airborne particles
FFP3	Filters >99% of airborne particles

Table 2: European nomenclature for "filtering face pieces" (FFP; also called "filtering half masks")

Class	Filter Penetration Limit (at 95L/min air flow)
P1	Filters >80% of airborne particles
P2	Filters >94% of airborne particles
P3	Filters >99.5% of airborne particles

Table 3: European nomenclature for the classes of particle filters that can be attached to a face mask.

13.2.2 Proper Fit

There must be a good seal between the edges of the respirator and your face. Otherwise, the air contaminants would leak in through the edges of the respirator. The following may contribute to poor fit:

- wrong size of respirator;
- wrong method of wearing respirator e.g., using single strap only;
- wrong positioning of facepiece or straps;
- straps too loose;
- beard;
- use of handkerchief or towel under the respirator;
- facial deformities; and
- defective respirator.

To ensure proper fit:

- Select the correct size/type of respirator
- Put on the respirator according to the manufacturer's instruction, adjusting the straps and face piece to obtain the best fit
- Carry out a fit test at time of issue of respirator.

  (Fit test: This is based on the ability to taste an aerosol of a substance like saccharin with the respirator worn. With a proper fit, you should not be able to taste it); and
- Carry out user seal checks each time the respirator is used.
  - Seal checks: With the respirator worn, cover the filter or cartridge with the palm of your hands. Breathe in and hold your breath. If there is no obvious leak, the face piece should collapse slightly and remain so.

13.2.3 Consistent Usage

The protection factor is reduced each time the respirator is removed in the presence of contaminated air. Respirators should be worn all the time while in a contaminated environment i.e., worn before entry to the environment and removed only when outside the environment. Workers should not remove the respirators when conversing with other workers.

13.2.4 Proper Maintenance

The cartridges or filters of non-disposable respirators must be regularly changed to ensure continued protection. Particulate filters should be changed once they are clogged up resulting in increased breathing resistance. Gas and vapour cartridges must be changed once they are saturated and can no longer absorb any more of the contaminant. This would be indicated by a "breakthrough" of the chemical into the respirator e.g., smell or irritation by the chemical. The higher the concentration, the more frequent the change. Once there is a breakthrough of the contaminant, the worker must leave the area and change the cartridge immediately. There must be good warning properties of the contaminant in order for a breakthrough to be detected. Otherwise air-supplied respirators are indicated.

13.3 Medical Fitness

Most workers should have no problems breathing through the respirators and working. A few workers with poor cardiovascular function may have difficulty breathing through the respirators. Workers with poor effort tolerance or unstable angina may have difficulty doing strenuous exercise and carrying the heavy air-supplied respirators. Where indicated, lung function tests and stress ECG can be carried out.

13.4 Respiratory Protection Programme

Companies which require their workers to use respirators should implement a self-regulatory and comprehensive respiratory protection programme. This should include the following:

- regular environmental monitoring of the hazard
- engineering control to reduce the hazard where practicable
- selection and provision of suitable respirators
- supervision to ensure proper fit and consistent usage
- proper maintenance of respirators
- training in use and care of respirators
- medical examinations for fitness to use respirators.

For more detailed information on the use and maintenance of respirators, you may refer to the Code of Practice for Selection, use and maintenance of respiratory devices (SS 548:2009) published by SPRING Singapore.

Further Reading

1. Code of Practice for Selection, use and maintenance of respiratory devices (SS 548:2009) published by SPRING Singapore
2. European Standard EN 143 and 149 for the different classes of face masks and particle filters that can be attached to face mask.
3. NIOSH approved particulate filtering facepiece respirators http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/default.html

14. Hearing Protection

Whenever possible, noise should be reduced at source. When this is not possible, or as an interim measure, appropriate, properly fitted and personal hearing protectors should be considered to reduce the sound exposure of the employees. They can be used as additional protection to supplement engineering and administrative controls.

14.1 Indications for Hearing Protector Usage

When noise exceeds the permissible exposure limits (see Chapter on noise)

14.2 Effective Hearing Protection

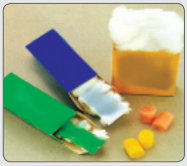
For hearing protectors to be effective, they must:

- Be of the correct type for the exposure situation
- Fit the persons wearing them
- Be worn 100% of the time when in the noisy environment
- Be properly maintained

14.3 Types of Hearing Protectors Available

There are basically two main types of hearing protectors:

Types of Hearing Protectors	Advantages	Disadvantages
Ear Muffs  Ear muffs consist of a pair of cushioned cups that form a seal around the ears. The muffs are designed to cover the entire ear, preventing the entry of noise.	- A single size can fit most employees - Easily worn and taken off - Generally provide better protection compared to ear plugs - More durable - Easily seen at a distance to assist in the monitoring of their usage - Not easily misplaced or lost	- More expensive - Uncomfortable to wear, especially in hot environment - Difficult to use in tight spaces - More inconvenient for use with other personal protective equipment - May interfere with the wearing of safety or prescription glasses: wearing glasses breaks the seal between the ear muff and the skin, reducing hearing protection.

Earplugs  Non-disposable or reusable ear plugs are made of silicone, rubber or plastic and come in various shapes and sizes as the size of the ear canal varies from person to person.  Disposable ear plugs are made of polyurethane foam or glass wool and are used a few times and thrown away.	- Small - Cheap - Convenient to use with other personal protective equipment - More comfortable in hot, humid work areas - Convenient for use in confined work areas	- Requires more time to fit - More difficult to insert and remove - Require good hygiene practices - May irritate the ear canal - Easily misplaced - More difficult to see and monitor usage unless corded - Disposable ones easily soaked with sweat

(Reproduced from: Guidelines on Hearing Conservation Programme, Workplace Safety and Health Council, Singapore)

14.4 Selection of Hearing Protectors

When selecting hearing protectors, one must know the noise exposure level and the noise reduction rating (NRR) of the hearing protectors. NRR is the expected level of noise reduction in the ears when the hearing protectors are properly worn. However, be aware that there may be differences between laboratory-derived attenuation values and the protection obtained by an employee in the real world.

e.g., Noise exposure level = 90 dB(A)
NRR = 25 dB(A)
If properly worn, worker's estimated noise exposure = 90 – 25 = 65 dB(A)

The higher the NRR, the higher is the attenuation for a specific ideal situation. The NRR of the hearing protector is provided by the suppliers and should be taken into consideration when selecting the hearing protector. Most ear muffs have higher NRR than ear plugs. However, do not assume as some may not.

In general, one can use the following table to choose the appropriate hearing protector:

Noise Exposure Level	Choice of Hearing Protectors
≤ 100 dB(A)	ear plugs or ear muffs
> 100 dB(A)	ear plugs and ear muffs

The hearing protector should minimally reduce the effective noise level to the ear to below the permissible exposure limit. For best results, the reduction should preferably be to around 75 - 80 dB(A). In addition, the wearer's comfort and the compatibility of the hearing protector with other headgear e.g., helmet and spectacles, should also be considered.

For more information, refer to the Guidelines on Hearing Conservation Programme published by Workplace Safety and Health Council, Singapore.

14.5 Fitting of Hearing Protectors

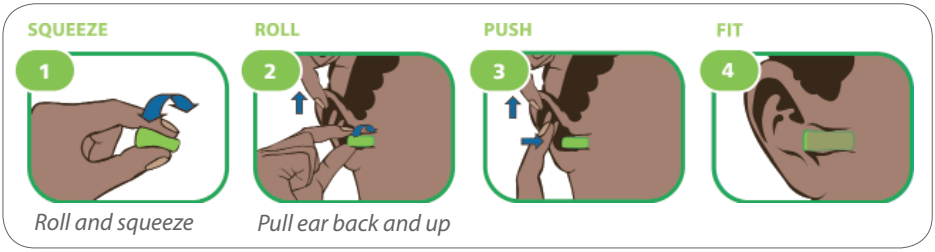
All hearing protectors will have to be properly fitted to ensure adequate protection. To ensure comfort and fit, workers should be able to choose from a variety of hearing protectors. Also, the sizes for both ear canals may not be the same. As such, you may want to advise employers to purchase earplugs which are free-sized.

14.6 Correct Usage

Demonstrate the correct technique for using ear plugs to workers.

Diagram of correct technique for insertion of user formable ear plugs.

Users of re-usable ear plugs start at step 2 of the diagrams.



Roll and squeeze *Pull ear back and up*

Employees should be informed that they should wear the hearing protectors 100% of the time they are exposed to excessive noise, regardless of the duration of exposure. Removal of hearing protectors for even a short period of time can significantly reduce their effectiveness and result in inadequate protection. If hearing protectors are worn for only 50% of the time, a protection of only about 3 dB(A) is obtained. Persons should only take off their hearing protectors when they are away from loud noise.

Case study

In one company, workers inform you that earplugs are stored in cabinets which are located inside the room where the noise level is about 90 dB(A). What would you recommend to the company?

Answer:

Re-locate the cabinet to outside the noisy room as the workers have to be protected before they enter the noisy room, in order to enjoy 100% protection.

14.7 Proper Maintenance

Besides training employees on the proper use of their hearing protectors, employees should also be trained in the care of their hearing protectors to ensure that they work effectively. For personal hygiene, re-usable ear plugs must be washed frequently in warm, soapy water. Disposable ear plugs can also be washed, but should be discarded when they can no longer return to their original shape or are torn.

Wear and tear and hardening of the ear plugs or ear muff cushions can result in cracking and loss of shape, resulting in improper fit. Hearing protectors should be checked regularly and replaced when necessary. They should be kept in a clean place when not in use.

14.8 Role of Employer

Employers should educate all employees on the need for hearing protection and give guidance on the selection of personal hearing protectors. Instructions on their use, fit, care and maintenance should be given regularly. Periodic checks should be conducted to ensure that hearing protectors are used correctly by the employees.

If earplugs are provided, employers should ensure that various types and sizes are available for employees' use and that the earplugs fit the worker.

Employers, DWDs, WSHOs, managers and supervisors should be role models themselves, wearing the hearing protectors at all times when exposed to excessive noise, irrespective of the duration of exposure.

14.9 Hearing Conservation Programme

Companies with a noise hazard should implement an in-house Hearing Conservation Programme (HCP) to control the noise hazard so as to prevent Noise-induced Deafness (NID) among their employees.

The components of the programme include:

- Noise surveys to identify noisy areas or activities;
- Implementation of noise control measures where feasible;
- Putting up signages on hearing protector usage in noisy areas;
- Conducting statutory medical examinations for all workers exposed to excessive noise;
- Providing suitable hearing protectors to all exposed employees; and
- Educating and training all employees on the importance of adequate hearing protector usage, correct fit and proper maintenance.

Further Reading

1. SPRING Singapore. Singapore Standard SS 549:2009: Code of Practice for Selection, use care and maintenance of hearing protectors.
2. iWSH Portal of Workplace Safety and Health Council - Noise Induced Deafness (NID) https://www.wshc.sg/nid

15. Compensable Occupational Diseases

Under the Work Injury Compensation Act (WICA), an employee can claim compensation from his employer if he contracts any of the occupational diseases listed in the Second Schedule of the Act, irrespective of whether any medical leave was given.

15.1 Work Injury Compensation Act (WICA)

WICA allows employees who sustain injuries in a work-related accident or who contracted an occupational disease to claim from their employers for the following:

- medical expenses;
- temporary incapacity compensation, (injured employees are paid medical/ hospitalisation leave wages); and
- permanent incapacity compensation (if any).

Dependants of deceased employees who had sustained work-related injuries or diseases can also claim for death compensation.

The WICA provides a low-cost and expeditious alternative to making a claim. Unlike common law, WICA is a non-fault system. This means the employee does not need to prove that the employer was at fault for his injury. To be eligible for compensation, he only needs to show that the injury arose out of and in the course of his employment. The compensation benefits are computed based on fixed formulae and capped under the Act.

Once an employee decides to pursue his claim under the WICA, he will generally no longer be able to lodge a civil claim against his employer for damages. In other words, he will not be able to double claim from WICA and common law.

15.2 Who are covered under WICA?

The WICA covers all employees except the following:

- Self-employed persons;
- Independent contractors;
- Domestic workers;
- Members of the Singapore Armed Forces; and
- Officers of the Singapore Police Force, the Singapore Civil Defence Force, the Central Narcotics Bureau and the Singapore Prison Service.

15.3 Types and Amount of Compensation

- Medical expenses

For accidents that happened before 1 June 2012	For accidents that happened on and after 1 Jun 2012
Up to $25,000 or 1 year from date of accident, whichever is reached first	**Up to $30,000 or 1 year from date of accident, whichever is reached first**

- Compensation for Temporary Incapacity
  An employee who is unable to work following the accident or contraction of a occupational disease is entitled to claim from his employer the following:
  - full pay up to 14 days of outpatient medical leave and 60 days of hospitalization leave, and
  - two-thirds of his salary for the remaining period of medical/hospitalization leave, up to a maximum of one year. This continues to be payable even after the employment is terminated.
- Compensation for Permanent Incapacity
  Permanent incapacity benefits are payable for injuries or diseases from which complete recovery is not possible, and where there are lasting residual effects. Examples would include amputations of limbs, noise induced deafness and silicosis. The amount payable is computed based on the severity of the injury or disease (as determined by doctors), as well as the employee's age and earnings. The computed amount is subject to the maximum and minimum limits. Please refer to Table 1.

  An additional 25% of compensation is awarded for cases where there is total (i.e., 100%) permanent incapacity.

  Doctors are required to refer to 'A Guide to the Assessment of Traumatic Injuries and Occupational Diseases for Work Injury Compensation' when assessing the amount of permanent incapacity (%PI) for the various injuries and diseases.

15.4 Compensation for Death

Compensation is payable to dependants of employees who died in a work-related accident or from an occupational disease. The quantum payable is computed based on the employee's age and earnings, and subject to maximum and minimum limits. Please refer to Table 1.

Table 1

	Permanent Incapacity Compensation	Death Compensation
For accidents that happened on and after 1 Jun 2012		
Minimum limit	$60,000 x % PI*	$47,000
Maximum limit	$180,000 x % PI*	$140,000
For accidents that happened before 1 Jun 2012		
Minimum limit	$73,000 x % PI*	$57,000
Maximum limit	$218,000 x % PI*	$170,000

* % Permanent Incapacity (%PI) is based on doctor's assessment after the employee's medical condition stabilizes

15.5 Notification

Under Regulation 7-(2) of the Workplace Safety and Health (Incident Reporting) Regulations, the doctor who diagnoses an occupational disease is required to notify MOM not later than 10 days after the diagnosis. This can be done online via www.mom.gov.sg/iReport.

The doctor should also inform the employer of the diagnosis in writing. Under Regulation 7-(1), the employer is required to notify MOM not later than 10 days after receipt of the written diagnosis.

If unsure of the diagnosis, the doctor can also refer the case to one of the occupational health clinics listed below:

Suspected Occupational Disease	Occupational Health Clinic	Contact No.
Any work-related illness	Occupational Health Clinic Hougang Polyclinic	6496 6600
	Occupational Health Clinic Geylang Polyclinic	68422440
	Occupational Medicine Specialist Clinic Jurong Polyclinic	6355 3000
Occupational skin disease	Occupational Dermatoses Clinic National Skin Centre	6350 6666
Occupational lung disease	Occupational Lung Disease Clinic Tan Tock Seng Hospital	6357 7000
	Occupational Lung Disease Clinic Singapore General Hospital	6321 4402
Work-related musculoskeletal disorder	Work-related Musculoskeletal Disease (WRMSD) Clinic Tan Tock Seng Hospital	6357 7000
	Work-related Musculoskeletal Disease (WRMSD) Clinic Khoo Teck Phuat Hospital	pending
Occupational chemical exposure or poisoning	Joint Environmental Occupational Toxicology Clinic (JEOTC) Changi General Hospital	6850 3333

Following notification, if the case is admissible, the Work Injury Compensation Department of MOM will work directly with the affected worker and employer to process the compensation claim.

Further Reading

1. Work Injury Compensation Act: A Guide to the Work Injury Compensation Benefits and Claims Process at http://www.mom.gov.sg/legislation/occupational-safety-health/Pages/work-injury-compensation-act.aspx
2. A Guide to the Assessment of Traumatic Injuries and Occupational Diseases for Work Injury Compensation.
3. Occupational Health Clinics - http://www.mom.gov.sg/workplace-safety-health/incident-reporting/Pages/default.aspx

Appendix A: Certificate of Fitness

WORKPLACE SAFETY AND HEALTH (MEDICAL EXAMINATIONS) REGULATIONS

UEN : _____ Workplace Number : _____

Workplace Name : _____

Workplace address : _____

NRIC/ FIN : _____ Employee Name : _____

Date of Birth : _____ Sex : _____

Hazard : _____ Race : _____

Certification of Fitness :

I hereby certify that I have examined the above-named person on_____ and that he/she is *fit / not fit for work which may expose him to_____ (please specify hazard)

Results of medical examination(s)/ test(s) done :

Remarks if any :

_____

*Delete appropriately

Designated Workplace Doctor :

Name : _____ MCR No. : _____

Practice Address : _____

Email : _____ Tel : _____ Fax : _____

_____ _____

Date Signature

Note:
Please attach copies of actual results including laboratory test results, Chest X-ray reports and audiograms.

You may wish to update Singapore Medical Council if there are any changes to your practice and contact information.

Appendix B: Report of Examinations

WORKPLACE SAFETY AND HEALTH (MEDICAL EXAMINATIONS) REGULATIONS

UEN : _____ Workplace Number : _____

Workplace Name : _____

Workplace Address : _____

NRIC/ FIN : _____ Employee Name : _____

Date of Birth : _____ Sex : _____ Race : _____

Summary of medical examinations conducted and actions taken:

Date	Medical Test / Examination done	Result*	Actions taken i.e., examine, reduce risk, suspend, notify, refer**	Fitness to work	Name & Signature of DWD, MCR No.

* For quantitative results (e.g., blood lead), the exact figures and units of measurement must be stated.
For qualitative results (e.g., chest x-ray) state whether normal or abnormal.
For audiometric examinations, state whether within normal limits or abnormal. Audiograms must be attached.
Give diagnosis for **abnormal** results where available.

* *Actions taken to reduce risk if person is not fit may include repeat or additional tests, removal from further occupational exposure using the *Certificate of Suspension*, informing company to review control measures, counseling worker on prevention including PPE, referral to clinical specialists, notification of occupational disease using iReport. For details, please refer to the specific hazard write-up in the Guidelines for Statutory Medical Examinations.

Appendix C: Summary Report Form

WORKPLACE SAFETY AND HEALTH ACT
WORKPLACE SAFETY AND HEALTH (MEDICAL EXAMINATIONS) REGULATIONS, Regulation 9(3)
SUMMARY REPORT FORM

UEN : _____ Workplace Number : _____

Workplace Name : _____

Workplace address : _____

Email (optional) : _____ Tel : _____ Fax: _____

Date of Summary Report : _____

Hazard : _____ Total no. of exposed workers : _____

No. of workers examined : _____ No. with abnormal results : _____

No. with normal results : _____ a. Occupational : _____

b. Not occupational : _____

No. of workers recommended for suspension : _____

For NOISE hazard only

No. of workers examined who use hearing protectors during noise exposure

_____

Name(s) and identification numbers of persons performing the audiometric tests

Name	NRIC/FIN number	Practice Name

For **ARSENIC, CADMIUM, MANGANESE, MERCURY, LEAD, PERCHLOROETHYLENE AND TRICHLOROETHYLENE hazards** only:

The laboratory conducting the analysis *does/ does not participate in the following proficiency testing scheme for the relevant chemical : *NEQAS/ Robens Institute/ Danish EQAS/ NIOSH/

Others, please specify: _____

* Circle appropriately

I certify that the information given above is correct. I confirm that the medical examinations were conducted in accordance with the Guidelines for Statutory Medical Examinations. In the case of audiometric examinations, these were done in a proper booth or test environment and conducted by persons who have undergone a course of training in audiometric screening acceptable to the Commissioner for Workplace Safety and Health. All workers were counselled on the importance of wearing personal protective equipment when exposed to workplace hazards.

Details of the workers with abnormal results are attached.

Designated Workplace Doctor

Name : _____ MCR No. : _____

Practice Address : _____

Email : _____ Tel : _____ Fax: _____

_____ _____

Date Signature

You may wish to update Singapore Medical Council if there are any changes to your practice and contact information.

Please ensure all items in the form are completed. Incomplete forms will be returned.

WORKERS WITH ABNORMAL RESULTS

No.	Name	NRIC/ FIN	Sex	Date of Exam	Clinical Findings (Including auroscopy*)	Diagnosis	Action Taken**

* For quantitative results (e.g., blood lead) give the exact figures and units of measurement. Also state the laboratory normal range. For audiometric examination, attach audiograms. Auroscopy should be done for all newly detected cases of abnormal audiograms which were not notified previously.

** Under the column 'Action Taken', please state the date of notification if case has been notified. Results of such cases need not be re-submitted. Re-notify if there has been significant deterioration as compared to previous results. State actions taken to reduce risk (if applicable).

Appendix D: Certificate of Suspension from Work Involving Exposure to Hazards

WORKPLACE SAFETY AND HEALTH ACT
WORKPLACE SAFETY AND HEALTH (MEDICAL EXAMINATIONS) REGULATIONS
Regulation 10(2)

CERTIFICATE OF SUSPENSION FROM WORK INVOLVING EXPOSURE TO HAZARD

UEN : _____ Workplace Number : _____

Workplace Name : _____

Workplace address : _____

NRIC/ FIN : _____ Employee Name : _____

Date of Birth : _____ Sex: _____ Race: _____

Hazard : _____ Date Started Employmment : _____

I certify that the above named person examined by me on _____ should not continue to work as a _____ in _____ department / section for _____ months, subject to a review on _____.

In the meantime, he/she should be given alternative work in another department / section which does not expose him to _____ (please specify hazard).

The reasons for my recommendations are:

_____

Designated Workplace Doctor:

Name : _____ MCR No. : _____

Practice Address : _____

Email : _____ Tel : _____ Fax: _____

_____ _____

Date Signature

Note:

This certificate should be saved for your records and copies given to the employer, employee and the Commissioner for Workplace Safety and Health.
The copy sent to the Commissioner for Workplace Safety and Health (c/o Ministry of Manpower, 1500 Bendemeer Road #03-02, Singapore 339946, Fax: 65356726) or submitted online at www.mom.gov.sg should be accompanied with a copy of the test results report.

For quantitative results, (e.g., blood lead) the exact figures and units of measurement must be stated.
For qualitative results, (e.g., chest X-ray) attach a copy of the report.
For audiometric examinations, attach audiogram(s).

You may wish to update Singapore Medical Council if there are any changes to your practice and contact information.

Appendix E: Register of Persons Employed in Hazardous Occupations

WORKPLACE SAFETY AND HEALTH ACT
WORKPLACE SAFETY AND HEALTH (MEDICAL EXAMINATIONS) REGULATIONS
Regulation 8(2)
REGISTER OF PERSONS EMPLOYED IN HAZARDOUS OCCUPATIONS

UEN : _____ Workplace Number : _____
Workplace Name : _____
Workplace address : _____
Tel : _____ Fax : _____

Hazard : _____ Date of Register : _____
Test 1 (units) = _____
Test 2 (units) = _____ Laboratory conducting the test : _____

							Exposure			Test Result	
Name	**NRIC/FIN**	**Sex**	**Race**	**Date of Birth**	**Dept/ Section**	**Work involving exposure (Occupation)**	**Date of test**	**Date started exposure**	**Date stopped exposure**	**Test 1**	**Test 2**

Note: Please complete all blanks. Add new employees, if any. For workers who have resigned, indicate with an "R" in the "Date of test" column. For foreign workers, indicate their Foreign Identification Number (FIN)

							Exposure			Test Result	
Name	NRIC/FIN	Sex	Race	Date of Birth	Dept/ Section	Work involving exposure (Occupation)	Date of test	Date started exposure	Date stopped exposure	Test 1	Test 2

Note: Please complete all blanks. Add new employees, if any. For workers who have resigned, indicate with an “R” in the “Date of test” column. For foreign workers, indicate their Foreign Identification Number (FIN)

Appendix F: Application for Exemption from Medical Examinations Required Under the Workplace Safety and Health (Medical Examinations) Regulations

WORKPLACE SAFETY AND HEALTH ACT
SECTION 62(3)

APPLICATION FOR EXEMPTION FROM MEDICAL EXAMINATIONS REQUIRED UNDER THE WORKPLACE SAFETY AND HEALTH (MEDICAL EXAMINATIONS) REGULATIONS

UEN : _____ Workplace Number : _____

Workplace name : _____

Workplace address : _____

Tel : _____ Fax : _____

Email : _____

Part A: To be completed by Management Representative

I would like to apply for exemption from medical examinations of workers exposed to the following hazards:

(Please tick where applicable)

☐ Arsenic	☐ Asbestos	☐ Benzene
☐ Cadmium	☐ Compressed air environment	☐ Lead
☐ Manganese	☐ Mercury	☐ Excessive Noise
☐ Organophosphates	☐ Perchloroethylene	☐ Raw cotton
☐ Silica	Trichloroethylene	Vinyl chloride monomer
Tar, Pitch, Bitumen, Creosote		

To support my application, information in Part B is attached.

Name : _____ Designation : _____

Date of application : _____

Part B:
To be completed by a competent person, e.g. Workplace Safety and Health Officer, Industrial Hygienist or Designated Workplace Doctor.
Use a separate form for each hazard.

Hazard _____

Process or Operation	No. of Workers involved in each process	Max. hours of exposure per day	Exposure level* [State unit of measurement e.g., dB(A), ppm, etc]

*Submit a copy of the assessment reports if available

Other information to support application
(e.g., biological monitoring results, control measures, Safety Data Sheet, etc):

_____

_____

_____

Completed by:

Name :_____

Address :_____

Email : _____ Tel : _____ Fax : _____

_____ _____

Date Signature

Appendix G: Permissible Exposure Levels

Workplace Safety and Health (General Provisions) Regulations 2006

A. Permissible Exposure Levels (PEL) for selected toxic substances

Substance	PEL (Long Term) (ppm)[a]	PEL (Long Term) (mg/m³)[b]	PEL (Short Term) (ppm)	PEL (Short Term) (mg/m³)
• Arsenic, elemental and organic compounds, as As	-	0.01	-	-
• Asbestos (all forms)	-	0.1 (fiber/cc)	-	-
• Benzene	1	3.18	-	-
• Cadmium, as Cd				
- Elemental	-	0.01	-	-
- Compounds	-	0.002	-	-
• Coal tar pitch volatiles (Polycyclic aromatic hydrocarbons), as benzene solubles	-	0.2	-	-
• Cotton dust, raw	-	0.2	-	-
• Lead, inorganic dusts and fumes, as Pb	-	0.15	-	-
• Manganese, as Mn				
- Dust and compounds	-	1	-	-
- Fume	-	1	-	3
- Manganese cyclopentadienyl tricarbonyl, as Mn	-	0.1	-	-
• Mercury				
- Alkyl compounds	-	0.01	-	0.03
- Aryl compounds	-	0.1	-	-
- Inorganic forms including metallic mercury	-	0.025	-	-
• Perchloroethylene (Tetrachloroethylene)	25	170	100	685
• Silica-crystaline				
- Cristobalite, respirable dust	-	0.05	-	-
- Quartz, respirable dust	-	0.1	-	-
- Tridymite, respirable dust	-	0.05	-	-
- Tripoli, respirable dust	-	0.1	-	-

• Trichloroethylene	50	269	100	537
• Vinyl Chloride (Chloroethylene)	5	13	-	-

Notes:

- ppm means parts of the substance per million parts of contaminated air by volume; and
- mg/ m3 means milligrammes of the substance per cubic metre of contaminated air.

B. Permissible Exposure Limits for Noise

Sound Pressure Level dB(A)	Maximum duration per day
82	16 hrs
83	12hrs 42 mins
84	10 hrs 5 mins
85	8 hrs
86	6 hrs 21 mins
87	5 hrs 2 mins
88	4 hrs
89	3 hrs 11 mins
90	2 hrs 31 mins
91	2 hrs
92	1 hr 35 mins
93	1 hr 16 mins
94	1 hr
95	48 mins
96	38 mins
97	30 mins
98	24 mins
99	19 mins
100	15 mins
101	12 mins
102	9 mins
103	7.5 mins
104	6mins
105	5 mins
106	4 mins
107	3 mins
108	2.5 mins

109	2 mins
110	1.5 mins
111	1 min
112	56 secs
113	45 secs
114	35 secs
115	28 secs
116	22 secs
117	18 secs
118	14 secs
119	11 secs
120	9 secs
121	7 secs
122	6 secs
123	5 secs
124	4 secs
125	3 secs
126 to 127	2 secs
128 to 129	1 sec
130 to 140	< 1 sec

Notes:

- The duration of exposure is to be obtained by adding up the total duration of exposure per work day, whether there is one continuous exposure or a number of separate exposures.
- Every continuous, impulsive or impact noise of sound pressure levels from 80 dB(A) to 140 dB(A) must be included in the computation of the noise exposure of the person.
- The permissible exposure limit is exceeded if a person is exposed to noise at a sound pressure level listed in the Table above in excess of the corresponding duration.

* Refer to www.mom.gov.sg for the updated and complete list of PELS of toxic substances.

Appendix H: Useful Information on Biological Monitoring of Some Industrial Chemicals

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Arsenic (As)	• Urine As	• Urine As	- EMU - clean sterile bottle (Results corrected to SG=1.016)	35	Graphite-furnace AAS	300 mcg/L	Abstain from seafood for 3 days before test
	• Liver function test: AST, ALT, SAP, Bil, GGT • Full-sized CXR		- plain tube	5			Abstain from alcohol for at least 2 weeks
Asbestos	• Full-sized CXR	• Full-sized CXR					

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Benzene	• Urine t, t-muconic acid (tt-ma) OR Urine s-phenylm-ercapturic (s-pma) • Full Blood Count (FBC) & peripheral blood film	• Urine t, t-muconic acid (tt-ma) OR Urine s-phenylm-ercapturic (s-pma) • Full Blood Count (FBC) & peripheral blood film	- ESU mid-week - clean sterile bottle - EDTA bottle	20	HPLC	1.6 mg/g Cr 45 mcg/g Cr	
Cadmium (Cd)	• Blood Cd • Urine B_2 microglo-bulin	• Blood Cd • Urine B_2 microglo-bulin	- venous bld - heparinised tube - plain bottle - send sample to laboratory only if pH>5.6 - Specimens to reach laboratory within 2 hrs.	3 50	Graphite-furnace AAS	5 mcg/L <290 mcg/g Cr	Collect specimen 2 hrs after drinking 15 ml Mist. Pot. Cit.

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Cotton	• Lung function test: FEV1 and FVC	• Lung function test: FEV1 and FVC	For periodic examinations: - Pre shift on 1st day of working week - Post shift after at least 6 hrs of exposure on same day as pre shift test				
Inorganic Lead (Pb)	• Blood Pb • Hb	• Blood Pb • Hb	- venous blood - heparinised tube - EDTA bottle	3 2	Graphite-furnace AAS	i. Blood Pb – BTLV a. for all males and females ≥ 50 years: 50 mcg/dL, b. females < 50 years: 30 mcg/dL ii. Hb-BTLV for males: 11g/dl, females: 10g/dl	

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Lead (Organic)	• Urine Pb	• Urine Pb	- EMU, end of workweek - clean sterile bottle - If intermittent exposure: collect before and after job - (Results corrected to SG-1.016)	30	Graphite-furnace AAS	<150 mcg/L	
Manganese (Mn)	• Urine Mn	• Urine Mn	- EMU - clean sterile bottle - (Results corrected to SG=1.016)	35	Graphite-furnace AAS	50 mcg/L	
Inorganic Mercury (Hg)	• Urine Hg	• Urine Hg	- EMU - clean sterile bottle - (Results corrected to SG=1.016)	35	Graphite-furnace AAS	50 mcg/L	Avoid ingestion of seafood for at least 3 days prior to conduct of the test.
Organic Mercury (Hg)(non-statutory)	• Blood Hg	• Blood Hg	Blood mercury to be collected at end of shift, end of workweek. Use EDTA Trace metal tube for specimen collection	3		25 mcg/L	Change out of work clothes before going to the clinic and avoid seafood at least 3 days before specimen collection.

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Organo–phosphates (OPs)	• RBC acetylcholines-terase (RBC AChE)	• RBC acetylcholines-terase (RBC AChE)	- Venous blood - EDTA tube - Keep cool at room temperature - Send to lab within 1 day of collection	3	Ellmann	70% of baseline or lower limit (LL) of lab normal	No exposure to OP for a month prior to pre-placement examination
	• Plasma acetylcholines-terase		- Venous blood - plain tube - Keep cool at room temperature - Send to lab within 1 day of collection	5			No exposure to OP for a month prior to pre-placement examination
Perchloro-ethylene (PCE)	• Uurine trichloroa-cetic acid (UTCA)	• Urine trichloroa-cetic acid (UTCA)	- ESU mid week - Clean sterile bottle - (Results to be corrected for specific gravity SG=1.016 or urinary creatinine concentration)	35	Colorimetric	7 mg/L or 7 mg/g creatinine	Abstain from alcohol for at least one week
	• Liver function test: AST, ALT, SAP, Bil, GGT		- Plain tube	5			Abstain from alcohol for at least 2 weeks

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Silica	• Full-sized CXR	• Full-sized CXR					
Tar, Pitch, Bitumen and Creosote	Clinical examination only	Clinical examination only					
Toluene (non-statutory)	• Blood toluene	• Blood toluene	- venous blood - prior to last shift of workweek - heparinised tube	5	GC	0.05 mg/L	To go directly to Dr's clinic from home

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Trichloro – ethylene (TCE)	• Urine trichloro-acetic acid (UTCA)	• Urine trichloro-acetic acid (UTCA)	- ESU mid-week - clean sterile bottle - (Results to be corrected for specific gravity SG=1.016 or urinary creatinine concentration)	35	Colorimetric	100 mg/L or mg/g creatinine <u>Mixed Exposures TCE+PCE:</u> a. if PCE in-air levels <50% PEL, use BTLV= 50 mg/L b. if PCE in-air levels >50% PEL, use BTLV=7 mg/L	Abstain from alcohol for at least one week
	• Liver function test: AST, ALT, SAP, Bil, GGT	- Plain tube		5			Abstain from alcohol for at least two weeks

Note: EMU - Early morning urine ESU- End-of-shift urine

Chemical	Pre-placement examination	Periodic examination	Sampling details	Min Vol (ml)	Analytical Method	BTLV	Instruction to workers
Trinitro-toluene (TNT) (non-statutory)	• Urine DNAT • Liver function test: ALT, AST, SAP, Bil, GGT	• Urine DNAT • Liver function test: ALT, AST, SAP, Bil, GGT	- ESU mid-week - clean sterile bottle - Plain tube	35 5	GC	10 mg/L	Abstain from alcohol for at least 2 weeks
Vinyl Chloride Monomer (VCM)	• Liver function test: ALT, AST, SAP, Bil, GGT	• Liver function test: ALT, AST, SAP, Bil, GGT	- plain tube	5			Abstain from alcohol for at least 2 weeks

Note: EMU - Early morning urine ESU- End-of-shift urine

Appendix I: Useful Websites

Website	Remarks
1. http://www.mom.gov.sg/legislation/occupational-safety-health/Pages/default.aspx	For all legislation regarding Workplace Safety and Health
2. http://www.mom.gov.sg/services- forms/Pages/default.aspx	For Workplace Safety and Health e-services and forms
3. http://www.mom.gov.sg/workplace-safety-health/incident-reporting/pages/default.aspx	List of Occupational Health Clinics for referral of suspected cases of occupational diseases
4. https://www.wshc.sg	Singapore Workplace Safety and Health Council. Provides information on WSH guidelines, best practices, other resources and events
5. http://www.mom.gov.sg/iReport	iReport for occupational disease. The report is to be made (1) within 10 days by the doctor who diagnosed the disease; (2) within 10 days of receiving the diagnosis by the employer or person with the disease
6. http://www.atsdr.cdc.gov	Agency for Toxic Substances and Disease Registry (US)

Appendix J: Unexposed Population Levels of Certain Industrial Chemicals

Test	Normal range	Remarks	Remarks
BLOOD Cadmium	0.09-0.11 µg/dL 0.5-1.8 µg/L	- Higher in smokers than non-smokers (subjects: males & females; US) - 20-50 adult female; non-smoker; in urban East and South-east Asia (Cd exposure seems to be higher in Asia than Europe)	- Kowal et al., 1979 - Ikeda etal, 2000
Lead (inorganic)	27 ± 3.3 µg/dL 13.9 µg/dL 14.1 µg/d	- Subjects: 28 males, 9 females; 18-52 years old - 9933 subjects - 5841 subjects; 18-74 years old (males>females: 16.1 µg/dl vs 11.9 µg/dl; 19.2 µg/dl for non-drinkers/ non-smokers; 19.7 µg/dl for drinkers/smokers)	- Meredith et al., 1978 - Annest & Mahaffey, 1984 - Roberts et al., 1985
Manganese	2-8 µg/dL	No correlation with severity of symptoms	INCHEM
Mercury	0-2 µg/dL	Range corresponds to elemental, organic and inorganic mercury	New Jersey State Dept of Health
URINE Arsenic	< 100 µg/L in urine		ATSDR
Cadmium	0.59-0.77 µg/L < 0.5-2.0 µg/L 1.2-3.1 mcg/gCr	- Cd levels increased with age; higher in smokers than non-smokers - Subjects: smokers and non-smokers; Japan, US and Sweden. - 20-50 adult female; non-smoker; in urban East and South-east Asia (Cd exposure seems to be higher in Asia than Europe)	- Kowal et al., 1979 - INCHEM - Ikeda et al., 2000

Lead	2.1-7.5 µg/gCr	20-50 adult female; non-smoker; in urban East and South-east Asia (unspecified)	- Ikeda et al., 2000
Manganese	0.1-0.8 µg/dL	No correlation with severity of symptoms	INCHEM
Mercury	0-20 µg/L	Range corresponds to elemental and inorganic mercury	New Jersey State Dept of Health
ttma	0.24±0.33 mg/gCr 0.14 ± 0.07 mg/gCr 0.12±0.03mg/gCr 0.015 ± 0.05 mg/gCr	- 45 Thai male non-smokers; higher in smokers than non-smokers - 40 male non smokers - 49 male controls. Gas attendants had significantly higher levels of ttMA - 19 males from rural Thailand free from factories	- Wiwanitkit et al., 2005 - Ong et al., 2006 - Wiwanitkit et al., 2001 - Thummachinda et al., 2002
s-pma	1.0 µg/gCr 0.7 ± 0.6 µg/gCr	- 42 non-smokers; higher in smokers than non-smokers - 236 control subjects.	- Ghittor et al., 1999 - Maestri, et al., 2005
Trichloroacetic acid	0-2 mg/L 0-1.03 mg/L 0.6–261 g/24hr in urine 2–292 g/24hr in urine	- 36 male students; corrected to SG = 1.016; Japan - 30 female students; corrected to SG = 1.016; Japan - 94 subjects; Germany - 39 subjects; Croatia	- Ikeda and Ohtsuji, 1969 - Hajimiragha et al., 1986 - Skender et al., 1993

Useful References

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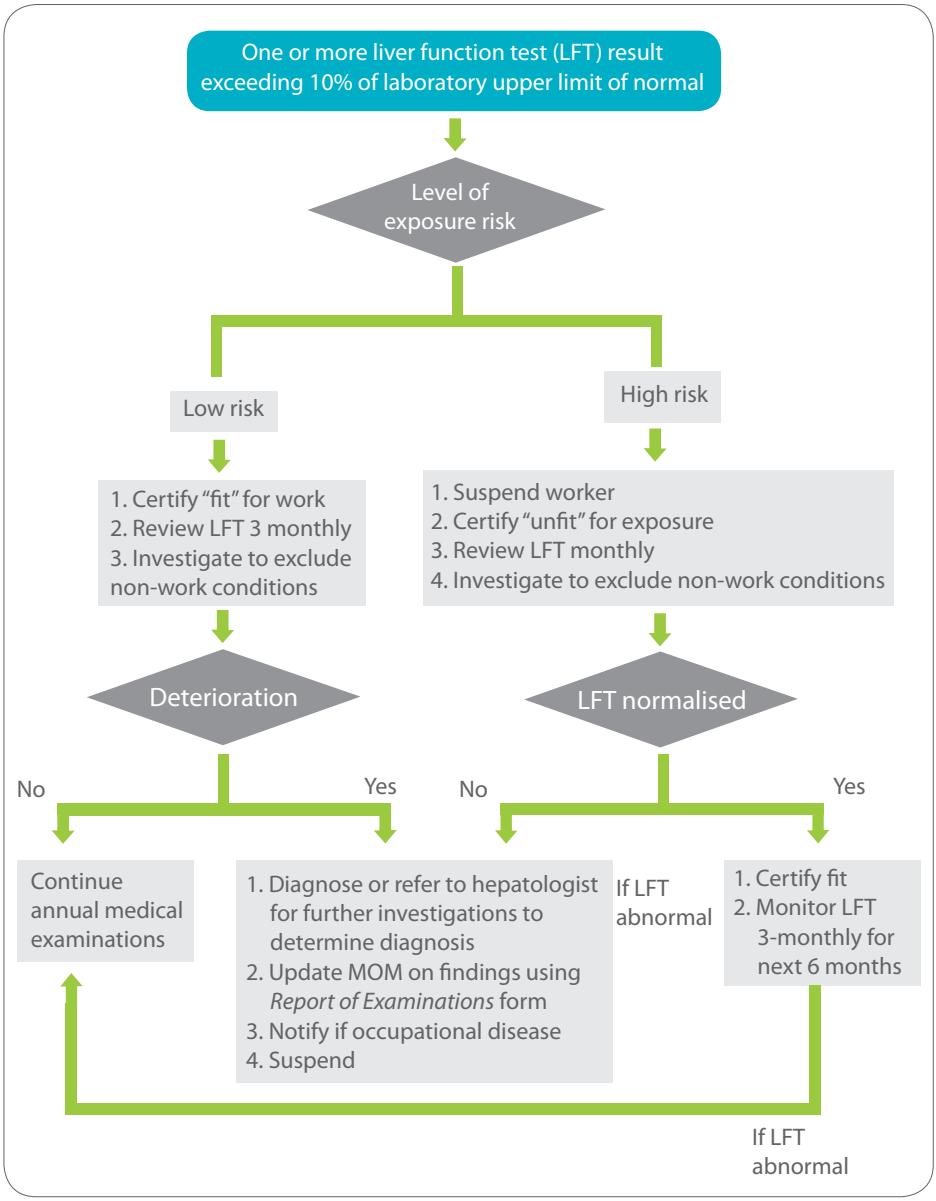
Appendix K: Algorithm for Abnormal Liver Function Test (LFT)



Appendix L: Workplace Monitoring: Methodology and Interpretation of Result

I Airborne Substances

- **Sampling for long term exposure**

  To compare with PEL (Long Term), a full period consecutive sample measurement should be carried out to cover the entire 8-hr period and the samples should be taken consecutively (equal or unequal time duration).

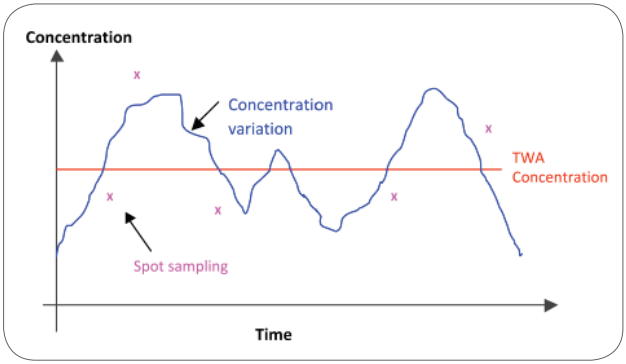
  The minimum sampling duration depends on the concentration of airborne substances, the flow rate and the sensitivity of the analytical method. Essentially, the sampling time must be long enough to allow enough substance to be collected for laboratory analysis.

  It is advantageous to collect more samples as it would better depict concentration variation with time. A desirable number of samples is four to seven, covering the 8-hr work shift. However, for practical reasons and on a cost benefit basis, two consecutive 4-hr samples are optimum.

Example
An employee is exposed to carbon monoxide (CO) at different concentrations during a daily 8-hr work shift as follows: 2 hours at 30 ppm, 1 hour at 40 ppm, 3 hours at 20 ppm, and 2 hours at 50 ppm. The TWA exposure to CO over the 8-hr work shift is:

$$\frac{(30\ ppm \times 2\ hr) + (40\ ppm \times 1\ hr) + (20\ ppm \times 3\ hr) + (50\ ppm \times 2\ hr)}{(2\ hr + 1\ hr + 3\ hr + 2\ hr)} = 32.5\ ppm$$

In this case, the PEL (Long Term) for CO - 25 ppm has been exceeded.



However, many industrial processes, operations or work activities last less than 8 hours or are sporadic. Samples may be taken while the work is carried out and zero exposure is assumed during periods when the work is not performed.

Example

An employee spends the first 4 hours of an 8-hr work shift in dry cleaning areas where the perchloroethylene (PCE) at his breathing zone is measured to be 40 ppm. For the rest of the shift, he works in other areas where his exposure to PCE is virtually zero. The TWA exposure to PCE over the 8-hr work shift is:

$$\frac{(40\ ppm \times 4\ hr) + (0\ ppm \times 4\ hr)}{4\ hr + 4\ hr} = 20\ ppm$$

In this case, the exposure is within the PEL (Long Term) of 25 ppm for PCE.

If long term samples are not feasible, e.g., due to work conditions or equipment limitations, grab samples may be obtained to evaluate the TWA concentration. These would represent samples taken over short periods of time. Typically, four to seven grab samples should be taken randomly throughout the work shift to assess the exposure level.

- **Sampling for short term exposure**

  Sampling for comparison with the PEL (Short Term) is essentially the same as 8-hr time weighted average exposure air sampling except that the sample is collected for a 15-min duration, usually during periods of maximum expected concentrations. As the sampling time is short, the maximum recommended sampling rate should be used to maximise the sampling volume.

Example

The sampling flow-rate range for perchloroethylene (PCE) is 0.02 to 0.2 l/min. To collect a short term sample for PCE, the maximum air sampling rate of 0.2 l/min should be used. This will minimise the possibility of collecting less than the limit of detection mass i.e. the lowest mass that can be detected by a specific analytical procedure used. If less than the limit of detection is reported, the limit of detection concentration can be used to determine whether the PEL (Short Term) is exceeded.

The PEL (Short Term) should be assessed as a 15-min TWA exposure and should not be exceeded at any time during a workday. A direct reading instrument may be used to measure the average concentration during the period of exposure.

Measurements for periods greater than 15 minutes should not be used to compare with the PEL (Short Term). However, if the average exposure over the longer period exceeds the PEL (Short Term), then this exposure standard must have been exceeded over a 15-min period.

- **Exposure to Mixtures**

  Where there is exposure to more than one toxic substance at the same time and the substances have similar harmful effects, the PEL shall be deemed to have been exceeded if the combined exposure index (i.e. sum of the ratios between the TWA concentration and the PEL of each substance) exceeds 1.0 or 100%. The combined exposure index is:

$$\frac{C_1}{PEL_1} + \frac{C_2}{PEL_2} + \frac{\quad}{\quad} + \frac{C_n}{PEL_n} = \Sigma \frac{C_i}{PEL_i}$$

Where there is exposure to more than one toxic substance at the same time and the substances do not have similar harmful effects, the PEL shall be deemed to have been exceeded if the TWA concentration of any one of the substances exceeds the PEL of that substance.

Example

A worker is exposed to 20 ppm of trichloroethylene {TCE, PEL (Long Term) = 50 ppm}, 10 ppm of perchloroethylene {PEL, PEL (Long Term) = 100 ppm} and 20 ppm of carbon monoxide (CO, PEL (Long Term) = 25 ppm} over an 8 hr work-shift. Is the combined exposure excessive?

TCE and PCE have similar effects, the combined exposure index is:

$$= \frac{20}{50} + \frac{10}{100} = 0.8 < 1.0$$

Exposure to CO is within its PEL, and its effects are independent of TCE and PCE. Therefore, the combined exposure is not excessive.

- **Sampling Strategies**

  Air sampling strategies in terms of the location, duration and frequency of sampling as well as the number of samples to be taken must meet the objective of monitoring and fulfill the requirements that samples to be taken represent workers' exposures or environmental conditions, and that measurements are efficient, accurate and economical.

  - **Location of Sampling**
    The choice of the monitoring location depends on the objective of sampling or the type of information required. There are two approaches: personal monitoring and area monitoring.

  - **Personal Monitoring**
    If the objective of monitoring is to determine a worker's exposure level, it is necessary to conduct personal monitoring by attaching a sampling device at or near the breathing zone of the worker. The sampling device can be either active, which requires air to be drawn through it by a pump, or passive, which is based on diffusion principle and requiring no sampling pump.

  - **Area Monitoring**
    If the objective is to assess the contaminant concentration at selected locations or to evaluate the adequacy or effectiveness of engineering control measures, area monitoring is required by settling the sampling equipment in fixed positions in the

work area. Fixed monitoring stations can also be used to measure emissions from sources or to measure background concentrations.

- **Grouping of Personal Sampling**
  To maximise the effectiveness of monitoring for assessing exposure hazard, it is necessary to group workers in a plant based on their job tasks and the similarity of the physical conditions (e.g., equipment, process and ventilation) of the workplace or the environment in which they work. Workers in the same group can be randomly selected for monitoring. The sample size should be at least 3 to 5 per group or from 25% to 50% of those in the group for groups of 10 or more.

- **Duration and Volume of Sampling**
  The total volume of air sampled depends on flow rate and duration of sampling. For a certain flow rate, the duration of sampling will determine the total volume of the sample.

  The minimum duration of sampling is directly proportional to the sensitivity of the analytical method but is inversely proportional to the expected concentration.

  The total volume of air sampled must yield a measurable amount of contaminant for accurate analysis.

- **Number of Samples**
  To minimise error associated with fluctuations in exposure, full-shift sampling for air contaminants should be conducted for at least 7 hours.

  A single sample or several consecutive samples covering the whole of the period of the shift should be taken to determine the time-weighted average concentrations of exposure.

  If the worker is exposed to contaminants for less than 7 hours, a partial period or less than full-shift sampling could be conducted. In this case, the un-sampled time should be calculated as zero exposure.

  If technology has not been developed to allow full-shift sampling, a series of "grab" or "spot" samples taken randomly throughout the work shift is acceptable. The acceptable number of samples is 4 to 7.

- **Frequency of Sampling**
  The frequency of air monitoring depends on the exposure level:

  Where workers are exposed to contaminants between 10% and 50% of the permissible exposure level, monitoring should be carried out at least once a year.

  Where the exposure is between 50% and 100% PEL, monitoring should be conducted at least twice a year.

Where the exposure exceeds PEL, monitoring should be done at least 4 times a year until the exposure is reduced to below the PEL by appropriate control measures.

- **Monitoring or Sampling Methods**
  The method of sampling will depend on the chemical being monitored. In general, sampling and analytical methods are divided into those for gases or vapours and those for aerosols. The common air sampling methods are briefly mentioned below:

- **Sampling of Gases and Vapours**
  Gases and vapours may be sampled or collected by any of the four methods:
  - Collection in an inert plastic bag or an evacuated container;
  - Active sampling by drawing a measured volume of air through a collecting medium which may be either solid (sorbents) or liquid (impinger);
  - Passive sampling with a badge that attract gas or vapour molecules by diffusion; and
  - Direct measurement using direct-reading instruments specific or sensitive to one or more gases or vapours.

  - **Sample Bag and Evacuated Container Method**
    Air sample bags are used to collect gases and vapours when the concentration is above the detection limits of common analytical or direct reading instruments. These bags are made of inert plastic film. Air is pumped into the bag and analysed directly from the bag by detector tubes, gas chromatography or other instruments. Evacuated containers such as glass bottles and stainless steel containers can also be used to collect gases and vapours for subsequent analysis, e.g., by infrared spectrometry.

  - **Sorbent Tube Method**
    Sorbent tubes are used for sampling of many gases and hydrocarbon vapours. The tube contains a bed of adsorbent such as charcoal (for volatile or low molecular weight hydrocarbons), silica gel (for oxygenated hydrocarbon species) and Tenax (for higher-molecular-weight species). When air is pulled through the tube by a pump, airborne chemicals are trapped by the adsorbent. After sampling, the sorbent is removed and the trapped chemicals are extracted with a solvent (often carbon disulfide), identified and quantified using gas chromatography or other analytical methods.

  - **Impinger or Bubbler Method**
    Impingers are glass bubble tubes used to collect certain inorganic chemicals (e.g., chlorine, ozone, hydrogen peroxide) and some organic chemicals (e.g., formaldehyde, phenol). A known volume of air is bubbled through the impinger which contains a liquid medium. The liquid will physically dissolve or chemically react with the chemical of interest. The liquid is then analysed by colorimetric, volumetric or other analytical methods to determine the airborne contaminant concentration.

- **Badge Method**

  Many gases and hydrocarbon vapours can be sampled passively, i.e., without a pump, using gas monitoring badges. Badges are available with a variety of collection media including solid adsorbents and reagent-filled tubes. The air sample comes into contact with the adsorbent by diffusion. Analysis methods vary with the badge type or chemical sampled and include colour change and gas chromatography.

- **Direct-reading Instruments**

  There are many types of direct-reading instruments available for measuring gases, vapours using different detection principles. Some of the instruments are specific for a particular contaminant, others are non-specific. Most direct-reading instruments allow for a continuous monitoring of the contaminant level, some have data logging features and alarm settings to warn users of hazardous conditions.

  Detector tubes are commonly used for detecting toxic gases and vapours. Other specific direct-reading instruments for measuring toxic gases include electrochemical sensors (e.g., oxygen meter, carbon monoxide meter, hydrogen sulfide meter) and solid state gas detectors. Photoionizers and infrared analysers are the most versatile direct-reading instruments for measuring many gases and vapours. However both are non-specific and can only be used for measuring known compounds.

  i. Detector Tubes

  A known volume of air is drawn through a small glass tube at a fixed flow rate by a hand-pump. The tube contains solid granules impregnated with a reagent, which reacts with the gas or vapour contaminant and changes colour. The length of the colour stain indicates the airborne contaminant concentration. These tubes are versatile, portable, and useful for field activities such as screening, leak detection, initial site characterizations, and other applications. They are available for a wide range of gases, vapours and mists, both organic and inorganic; the results are typically accurate within 25%.

  Long-term chemical detector tubes are also available to test conformity to the 8-hour time-weighted average concentration. A battery-operated pump is required to provide continuous sampling.

  ii. Passive Dosimeters

  Passive dosimeters are calorimetric indicators based on diffusion principle. These devices do not require a sampling pump or power supply. The dosimeters are used for personal monitoring and provide a cumulative index of exposure. The sampling period is usually 8-hr so that results may be compared with the time-weighted average exposure limit. Dosimeters of various types are available for measuring carbon monoxide, carbon dioxide, ammonia, hydrogen sulphide, sulphur dioxide, oxides of nitrogen and certain organic vapours.

  iii. Electrochemical Analysers

  Electrochemical analysers are well known in applications for the measurement of oxygen, carbon monoxide, chlorine and hydrogen sulphide in atmosphere. The gas

sample is oxidised or reduced at an electrode, which is immersed in an electrolyte and maintained at a fixed potential. The transfer of electrons between the electrodes generates a current, which is proportional to the partial pressure of the gas in the sample.

iv. *Photo-ionisation Analysers*
Photo-ionisation is the absorption of ultra-violet light by a gas molecule resulting in ionisation. Photo-ionisation detectors or analysers can be used to measure a wide range of toxic gases and vapours. The sensor is an ultra-violet light source that emits photons with sufficient energy (usually 10.2 eV) to ionise many compounds. A chamber adjacent to the UV-light source contains a pair of electrodes. The ions formed by absorption of the UV-light are driven to the negative electrode, and the current, which is proportional to the gas concentration, is measured.

v. *Infrared Analysers*
Most gases and vapour absorb infrared radiation. If infrared radiation is passed through a sample of gas, then part of the radiation will be absorbed and the intensity of the radiation emerging from the gas sample will be reduced. An infrared gas analyser consists of infrared radiation source, a chamber in which the gas sample can be drawn in for testing and a detector placed at the opposite end of the chamber to the source. The analyser measures the absorbance, which is proportional to the gas concentration.

vi. *Portable Gas Chromatograph*
A portable gas chromatograph (GC) is an analytical instrument that can be taken to a location to provide an analysis of the volatile organic compounds of an atmosphere and their concentrations. Samples are introduced either by a syringe or through a gas sampling loop. The sample is carried by moving gas (nitrogen or helium) through a column of granular solid impregnated with a non-volatile liquid. Separation of components is due to their different partition coefficients between the gas and solid or liquid phase. Individual components are eluted at different times from the end of the column. A detector detects them and a recorder prints out the peaks.

- **Sampling of Aerosols**

The main objective of aerosol sampling is to assess the magnitude of health hazards resulting from exposure to airborne particulates. The hazards caused by inhaled particulates depend on the nature of the particles and on the site at which they deposit within the respiratory system. It has been established that particles of different sizes will deposit in different regions of the respiratory system. Dust samples collected for hazard evaluation must therefore reflect the airborne concentration and particle size distribution.

In terms of deposition of aerosols, the respiratory system can be divided into three regions: nasopharyngeal (NP) region which includes the nose, pharynx and larynx; the tracheobronchial (TB) region which includes the airways from the larynx to the terminal bronchioles; and the alveolar or pulmonary (P) region where the gas exchange takes place.

The aerodynamic particle size distribution will determine the mass fraction of dust that will deposit in the NP, TB or P regions of the respiratory system. Particle size-selective

sampling is thus necessary to determine the actual quantity of dust that will be deposited in the three regions of the respiratory system.

- **Deposition of Particles**

  At rest, about 700 cc of tidal air is inhaled and exhaled with each breath. During inhalation, the incoming air must negotiate a series of direction changes as it flows from the nose down through the trachea and a sequence of branching before reaching the alveolar surfaces. There are five mechanisms by which inhaled particles can be deposited in the various regions of the respiratory system: inertial impaction, sedimentation, Brownian diffusion, interception and electrostatic attraction. The effectiveness of these mechanisms depends on many factors, including airway geometry, breathing rate, particle size, shape, density and charge.

  - **Nasopharyngeal (NP) Deposition**

    Particles with aerodynamic diameters greater than 10 µm are trapped in the NP region. The largest particles are removed by sedimentation and by impaction on the nasal hairs and at bends in the air path. For nose breathing, 70% of 5 µm particles and 100% of 10 µm particles are trapped in the nose.

  - **Tracheobronchial (TB) Deposition**

    Impaction is the dominant mechanism for the deposition of particles larger than 3 µm in the TB region. Particles of 5 µm and 10 µm aerodynamic diameter that reach the TB region are deposited there with approximately 50 and 90% efficiency, respectively. For particles smaller than 3 µm, sedimentation is the predominant mechanism of deposition, although the overall TB deposition for particles in this size range is quite small. Very small particles with aerodynamic diameter less than 0.1 µm, have enhanced deposition in the TB region due to their rapid Brownian motion.

  - **Pulmonary (P) Deposition**

    Because of size-selective deposition of particles in the TB region, particles larger than 10 µm generally do not reach the P region. For particles smaller than 10 µm, deposition in the P region increases with decreasing particle size. The particle size having the greatest deposition in the P region is about 2 to 2.5 µm, with about 25% of these particles being captured. Lung deposition decreases with particle size below 2.5 µm and reaches a minimum for particles of about 0.5 µm (these particles are stable as they are too big to diffuse and too small to settle). Below 0.5 µm, the deposition in the P region rises due to the increase in Brownian diffusion.

- **Filtration Method**

  Filters are used to collect aerosols or particulate matters such as dusts, fumes and mists. Air is pulled through a filter of a specific type and pore size. The flow rates for sampling of particulates are usually above 1,000 cc/min. Different types of samplers are used for particulate sampling depending on the particle size and the health effects associated with material deposited in particular regions of the respiratory tract.

A number of filter media and sizes are available for dust sampling. The common ones are mixed cellulose ester for metallic dust and polyvinyl chloride (PVC) for gravimetric analysis. Other filters include glass fibre, Teflon and silver membrane. Filtration of particles depends on the following mechanisms: direct interception, inertial impaction, diffusion, gravitational settling and electrostatic attraction.

The collected contaminants can be analysed by various methods, e.g., gravimetric analysis for non-specific dust, atomic absorption and atomic emission spectroscopy for metal dusts, microscopic method for asbestos fibers and infrared spectrophotometry for silica.

The dust concentrations determined are then compared with the relevant particulate exposure standards.

- **Size-selective Particulate Mass Fractions**

  In evaluating inhalation hazard associated with material deposited in particular regions of the respiratory system, four types of particulate exposure standards corresponding to the following particulate mass fractions have been developed.

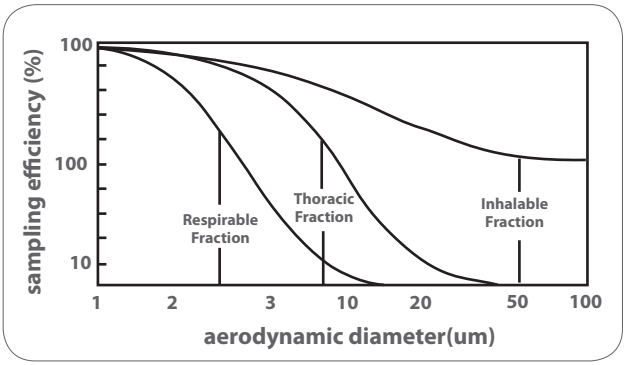
  - ***Total Particulate Mass*** refers to airborne material sampled with the 37 mm closed face cassette used for aerosol sampling. Traditionally, total dust concentration is determined as an index of exposure to most metallic dusts and many nuisance dusts. However, total dust samplers have poorly defined and variable particle size selection characteristics and they do not represent the respiratory characteristics.

  - ***Inhalable Particulate Mass*** refers to those materials (e.g., cadmium and nickel) which can be inhaled and which are hazardous when deposited anywhere in the respiratory system. Inhalable dust samplers are designed to capture those particles with the following collection efficiency: $E = 50\ (1 + \exp\{-0.06\ Da\}) \pm 10$ for particles with aerodynamic diameter (Da) less than 100 µm.

  - ***Thoracic Particulate Mass*** refers to those materials, which are hazardous when, deposited anywhere within the lung airways and the gas-exchange region. Thoracic particulate samplers are designed to collect those particles that penetrate a separator whose size collection efficiency is described by a cumulative lognormal function with a median aerodynamic diameter of 10 µm.

  - ***Respirable Particulate Mass*** refers to those materials (e.g., silica and coal dust) which are hazardous when deposited in the alveolar or gas-exchange region of the lungs. Respirable dust samplers are designed to collect those particles that penetrate a separator whose size collection efficiency is described by a cumulative lognormal function with a median aerodynamic diameter of 4.0 µm.

    The collection efficiencies representative of several sizes of particles in each of the respective mass fractions are shown below.



- **Respirable Particulate Samplers**

  Respirable particulate sampling uses a mechanical device or pre-collector to aerodynamically separate the non-respirable particles before the air stream reaches the filter. Common pre-collectors are cyclones, impactors and elutriators.

  - **Cyclones**

    Cyclones make use of centrifugal settlement to remove the non-respirable fraction of an aerosol stream. In a cyclone, the dusty air enters tangentially at its side and spins around inside several times before exiting to the filter at the top of the cyclone. During spinning, large particles above a certain aerodynamic size are thrown to the cyclone walls by centrifugal force and collected at its base. The cyclone design determines the particle size fraction removed from the air stream. The fraction that remains in the air stream will be collected and determined usually as respirable dust.

  - **Impactors**

    When an aerosol is directed at a high velocity against a flat surface, the particles are separated from the air as a result of the sudden change in the direction of the air flow because of the inertial or momentum of the particles. In an impactor, the air-steam is passed through a nozzle or jet and directed against a flat plate. Particles with sufficient inertial are unable to follow the streamlines, and are therefore removed by impacting on the plate. Smaller particles having less momentum are able to follow the streamlines, and are carried away with the airflow.

    An impactor separates an aerosol into two size ranges; particles larger than a certain aerodynamic size are removed from the air-steam, and those smaller than that size remain airborne and pass through the impactor. The efficiency of removal by impaction is a function of the density and diameter of the particle and the velocity of the air stream. A downstream filter can be used to collect the undersize fraction. The mass of particles collected on the impaction plate and the filter can be determined by weighing them before and after sampling. This cuts the distribution of mass into two size ranges.

- **Cascade impactors**

  In a cascade impactor, the same volumetric flow is passed through a series of impaction jets, with each successive stage having a smaller jet cross section and particle cut-off size. The cascade impactor therefore sorts the aerosol into a series of fractions according to aerodynamic particle sizes.

  Each stage is fitted with a removable impaction plate for gravimetric or chemical determination of the collected particles. A filter usually follows the last stage, where it captures all particles less than the cut-off size of the last stage. From the gravimetric measurement of each stage, the fraction of the total mass in each aerodynamic size range can be determined.

- **Elutriators**

  Elutriators rely on particle settling to separate particles according to aerodynamic sizes. Elutriators can be vertical or horizontal.

  A vertical elutriator is a device used to remove particles larger than a certain aerodynamic diameter from an aerosol stream. The aerosol flows upwards at a low velocity in a vertical chamber. Particles having a terminal settling velocity greater than the air velocity cannot be carried out of the chamber, and are thereby removed from the aerosol stream.

  The horizontal elutriator can be used to separate particles larger than certain pre-established sizes. The dust-laden air is passed at low velocity through a rectangular chamber in which the particles above certain sizes settle out of the air stream. The smaller sizes with lower falling speeds are carried through and are collected by a filter at the elutriator outlet. The horizontal elutriator can be so designed for respirable mass sampling.

- **Direct-reading Aerosol Monitors**

  Direct-reading instruments are available for measuring the mass concentration of aerosols or airborne particulates. These instruments are usually based on piezobalance or optical light scattering principle. Direct-reading instruments that measure mass concentration require a means of collecting the particles and a sensitive means of determining the mass. The Respirable Aerosol Mass Monitor separates aerosols by an impactor, and collects respirable aerosol particles by electrostatic precipitation onto a piezoelectric quartz crystal, which oscillates at its resonant frequency. The net change in resonant frequency due to deposition of aerosols during a short sampling period, is measured, and converted to mass concentration. The result is displayed on a digital indicator. Other direct-reading aerosol monitors use light scattering techniques for continuous monitoring of aerosol concentration.

- **Selection of Instruments**

  The choice of sampling instruments depends on a number of factors:

  - the portability and ease of use;

- the type of analysis or information required;
- the collection efficiency of the instrument; and
- the sensitivity, precision and accuracy of the instrument or analytical techniques.

Selection of instruments and equipment best capable of providing the data required in a given survey or study, is ultimately a matter of judgment on the part of the industrial hygiene professionals.

Precautions in Sampling and Monitoring

1. **Follow the recommended sampling protocols**
   When collecting an air sample, always follow recommended protocols on the preparation, handling and storage of collection media, sampling flow rate, minimum and maximum sample volumes, and analytical techniques.
2. **Obtain data that are useful for hazard evaluation**
   The method of sampling must be sensitive enough for quantifying the exposure level of interest. Long-term sampling is required to assess exposure to a substance having a PEL (Long Term). Short-term sampling is needed to evaluate exposure to a substance with a PEL (Short Term). Respirable aerosol samples should be collected for substances having a respirable particulate mass PEL.
3. **Consider the physical state of the contaminant**
   If an airborne contaminant can exist simultaneously in particulate and vapour phase, choose the sampling media to collect both phases of the contaminant of interest, e.g., a pre-filter can be used with a sorbent tube to collect particulate and vapour phases of a contaminant.
4. **Determine the minimum sample volume**
   Collect a sample with sufficient volume to obtain a minimum quantity of contaminate that is required for reliable laboratory quantisation.
5. **Clean sampling devices before use**
   Always wash or clean the sampling devices, e.g., cyclone separators before use. The contaminants deposited on the inner surfaces of these devices can affect the results of sampling. If sampling bags are used for sampling, evacuate and purge with clean air or nitrogen before reuse.
6. **Use EMI or RFI shielded pumps**
   The flow rate of pumps can be affected by electromagnetic interference (EMI) or radio frequency interference (RFI) from devices such as electric motors and high voltage equipment. EMI or RFI shielded pumps are not affected by this interference.
7. **Do not use static samplers to assess personal exposures**
   Measurement of contaminant levels from a static or area sample is typically not related to personal exposure, unless the person is stationary at the area sampled. Personal samples should be collected for persons who are not stationary but move around.
8. **Use constant flow pumps**
   Constant flow pumps will maintain a constant flow even if the flow resistance increases due to filter loading or pinched sampling tubing. Sampling pumps with this feature will introduce less error in sampling volume estimation.

9. **Use validated passive samplers**
   Not all commercially available passive samplers meet the requirements for precision and accuracy. Always ask the supplier of the passive samplers for complete documentation of performance testing.
10. **Collect enough number of samples**
    Sufficient numbers of samples are required to provide a true characteristic of exposure levels. Sample size should be at least 3 to 5 samples for each job classification/ group or from 25% to 50% of those in the group for groups of 10 or more.

    When it is not possible to conduct full-shift sampling throughout the work shift, grab or spot sample (using detector-tubes or other direct reading instruments) can be taken and the sample size should be 4 to 7.
11. **Do not use grab samples to determine 8-hr exposures**
    Grab samples are usually used to determine short-term exposure levels. Long-term integrating samples should be taken to assess full-shift exposures.
12. **Calibrate sampling pumps before and after sampling**
    Sampling pumps should be calibrated before and after sampling to set and verify the flow rate. Calibration should be performed using a primary standard e.g. a soap bubble meter or an electronic film flow meter. If a secondary standard e.g. a rotameter is used, it must be calibrated to a primary standard at regular intervals.
13. **Do not use adapter on the inlet of a filter cassette during calibration**
    Adapters should not be used on the inlet of a filter cassette when calibrating a sampling pump with a filter inline. Since the adapter will not be used for actual sampling, the air flow characteristics during calibration will be different from the actual flow characteristics during sampling.
14. **Misuse of "self-calibrating" pumps**
    Sampling pumps with internal flow indicators should be calibrated frequently with a primary standard. Calibration should be performed with the sampling train or collection medium in-line, as this will be used in the field.
15. **Do not reuse plastic filter cassettes**

    Plastic filter cassettes are designed for one-time use, not for subsequent reloading. Opening and closing cassettes repeatedly can produce deformities, which can cause incomplete sealing and leaks during sampling.
16. **Orientation of sorbent tubes in a vertical position during sampling**
    Airborne contaminants take the least resistance path when sampled through a collection medium. If a sorbent tube is not placed in a vertical position, the collecting medium may fall away from the wall of the tube, forming a small channel through which air flows more readily. This will reduce the collection efficiency.
17. **Orientation of cyclone in a vertical position during sampling**
    The performance of a cyclone is affected by orientation. The device should be held in a vertical position during sampling. The 50% cut-point i.e. the size of particulate removed with 50% efficiency, of a 10-mm cyclone is different at different orientations.

18. **Never invert a cyclone during or after sampling**
    Cyclones separate non-respirable (larger) particles in the grit pot and collect respirable particulate on the filters. If a cyclone is inverted, larger particles will fall from the grit pot onto the filter, resulting in an erroneous high concentration measurement.
19. **Sample the design flow rate when using a cyclone**
    Cyclones are designed to collect the desired respirable particulate at a specific flow rate. A different flow rate will change the 50% cut-point of a cyclone and its collection efficiency.
20. **Sample at the recommended flow rate and collect the recommended volume**
    Always follow the recommended sampling flow rate and sampling volume based on the published sampling and analytical methods. Sampling gases and vapours at higher flow rates through sorbent tubes reduces collection efficiency. Sampling too much air can overload a sorbent tube or filter. Check the filters regularly for signs of excessive loading.
21. **Take notes on work operations or practices during the sampling period**
    Observe the work conditions and operations, which could affect sampling results. Ensure that the sampling devices are not tampered with. Do not attach or place the sampling devices in the morning and collect them in the afternoon.
22. **Determine the sampling time accurately**
    Make an accurate measurement of the sampling time, especially for short-term sampling. The measured concentration depends on the total sampling time.
23. **Do not use passive samplers under stagnant air conditions**
    Passive samplers require air movement across the face of the sampler. This condition is met during personal sampling on a mobile worker, but not area sampling in calm air. Use of passive samplers under stagnant air conditions produces an erroneous low measurement of concentration.
24. **Do not assemble or handle collection materials in contaminated areas**
    Sampling media and collection materials should be assembled, disassembled, processed and packed in clean or uncontaminated areas, before and after sampling. Assembling or processing collection devices in contaminated areas can produce inexplicably significant amounts of analyte on blanks and erratic high exposure measurements.
25. **Document chain-of-custody and store samples properly after collection**
    Sorbent tubes should be stored no longer than 2 to 3 weeks at ambient or refrigerated temperature before analysis. Samples collected in sample bags should be analysed within 48 hours for best results. Samples should not be in the hands of unknown persons. A neat and professional chain-of-custody form should be documented.
26. **Always supply blanks to the analytical laboratory**
    Blank samples are analysed to reduce the errors from background contamination on the sampling media. Always supply blanks to the analytical laboratory when sending samples for analysis.
27. **Use an accredited analytical laboratory**
    Use of an analytical laboratory with accreditation or an effective quality assurance programme will ensure the credibility of the data.

28. **Correct the flow rate for changes in temperature and pressure**
    A mathematical correction of the air volume sampled is necessary if the ambient temperature and pressure at the calibration site is different from those at the sampling site. Some air sampling pumps come with temperature and pressure sensors that automatically correct the flow rate for changes in these environmental conditions.
29. **Document and report pertinent information**
    Record all critical sampling parameters such as sampling duration, temperature, barometric pressure, and details concerning location of sampling, subject monitored, and sample identification. Present sampling data and related information in a neat and organised format.

II Noise

Sound level meter

A sound level meter is designed to measure the sound pressure level in approximately the same way that the human ear responds to sound. The heart of a sound level meter is the microphone, which converts sound pressure into an electrical signal. The tiny signal is amplified by a preamplifier before being processed. It is then passed through a weighting network or an electronic circuit to modify the signal according to standardised frequency weightings.

The A, C and Linear are the standard weighting networks used for sound pressure level measurements. The A-weighting is most commonly used as it responds closer to the way the human ear hears. It attenuates the frequencies below several hundred Hz as well as the high frequencies above several thousand Hz.

C-weighting provides more or less a flat frequency response with only slight attenuation of the very low and very high frequencies. A C-weighted measurement is reported as dBC and is often used as a flat response when Linear-weighting is not available.

Linear-weighting is a flat frequency response over the entire measurement frequency range. It is used in a frequency analyser to perform octave band frequency analysis. This involves the use of electronic filters to remove all sound with frequencies outside the selected band so that the sound pressure level can be determined at different frequency bands.

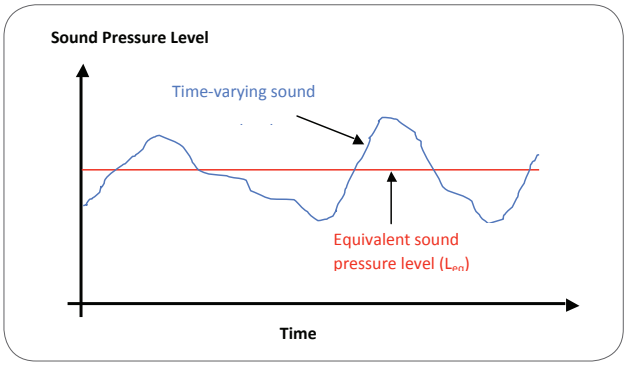
After the signal has been weighted, it is amplified again, and the root mean square value is determined which is directly related to the amount of energy in the sound being measured. The value is then displayed as the sound pressure level either in dB, dBA or dBC depending on the weighting network selected.

- **Equivalent Sound Pressure Level**

The equivalent sound pressure level (Leq) is a constant sound pressure level which has the same acoustic energy as the time-varying sound in question. The relationship between Leq and the varying sound pressure levels (SPL) is:

$$L_{eq} = 10 \log \{\frac{1}{T} (t_1 \times 10\ S^{PL1/10} + t_2 \times 10^{SPL2/10} + \ldots + t_n \times 10^{SPLn/10})\}$$

where SPL is the A-weighted sound pressure level during t period of time and $T = t_1 + t_2 + \ldots + t_n$.



Example
If a person is exposed to 85 dBA for 4 h, 88 dBA for 3 h, and 91 dBA for 1 h, the equivalent sound pressure level over the 8-h period is:

$$L_{eq} = 10\log[\frac{4}{8} \times 10^{\frac{85}{10}} + \frac{3}{8} \times 10^{\frac{88}{10}} + \frac{1}{8} \times 10^{\frac{91}{10}}] = 87\text{dBA}$$

- **Integrating sound level meter**

If the sound level varies in a stepwise manner, the L_{eq} can be calculated using measurements from a sound level meter and a stopwatch. However, if the sound level varies randomly, it is not easy to use manual calculations to compute the L_{eq}. In such cases, an integrating sound level meter is used.

Integrating sound level meters are designed to measure the equivalent sound pressure level over any time period. Some sound level meters also have a 1 min Leq feature which can be used for short term L_{eq} measurements. An alternative energy parameter to the L_{eq} is the sound exposure level or SEL, which is defined as the constant level acting for one second which has the same amount of acoustic energy as the original sound. SEL measurement is often used for describing the noise energy of a single event, such as a vehicle passing by, or an aircraft flying over.

- **Noise dose**

Noise dose (D) may be used as an indication of a percentage of the permissible noise exposure limit. It is defined as the sum of fraction of exposure time at specific sound pressure level (ti) to the permissible exposure time (Ti) at that level.

$$D = \{\frac{t_1}{T_1} + \frac{t_2}{T_2} + \text{-----} + \frac{t_n}{T_n}\} \times 100 = 100 \times \Sigma \frac{t_i}{T_i}$$

Dose is expressed as a percentage of a maximum permissible daily exposure to noise. The sum of the fractions is the noise dose expressed in % with 100% being the permissible criterion sound level.

Example

An employee is exposed to 85 dBA for 4 hours, 88 dBA for 2 hours, and 91 dBA for 1 hour. The permissible exposure durations at 85, 88, and 91 dBA are 8, 4, and 2 hours respectively. The noise dose is:

$$D = \{\frac{4}{8} + \frac{2}{4} + \frac{1}{2}\} \times 100 = 150\,\%$$

In this case, the exposure exceeds the permissible exposure limit.

- **Noise dosimeter**

The dosimeter reading (D) over a specific duration (T) can be converted to an equivalent sound pressure level (Leq) by the following formula:

$$L_{eq} = 85 + 10 \log \frac{D}{12.5 \times T}$$

Example

A noise dosimeter measures 200% noise dose at the hearing zone of an employee, and the measurement is made over an 8-hr work period. The equivalent sound pressure level is:

$$L_{eq} = 85 + 10 \log \frac{200}{12.5 \times 8} = 88 \text{ dBA}$$

In this case, the exposure exceeds the permissible exposure limit.

If in the above example, the measurement time is 4 hours, then the equivalent sound pressure level is:

$$L_{eq} = 85 + 10 \log \frac{200}{12.5 \times 4} = 91 \text{ dBA}$$

A noise dosimeter is designed to monitor noise dose received by a person who moves between different noise environments during the working day. These instruments are portable and can be carried in a person's pocket. The dose is computed using the above formula. The reading is expressed in % with 100% noise dose being the permissible exposure limit at an equivalent noise exposure level of 85 dBA over an 8-hr work shift.

The dosimeter reading (D) over a specific duration (T) can be converted to an equivalent sound pressure level (Leq) by the following formula:

$$L_{eq} = 85 + 10 \log \frac{D}{12.5 \times T}$$

Example
A noise dosimeter measures 200% noise dose at the hearing zone of an employee, and the measurement is made over an 8-hr work period. The equivalent sound pressure level is:

$$L_{eq} = 85 + 10 \log \frac{200}{12.5 \times 8} = 88 \text{ dBA}$$

In this case, the exposure exceeds the permissible exposure limit.

If in the above example, the measurement time is 4 hours, then the equivalent sound pressure level is:

$$L_{eq} = 85 + 10 \log \frac{200}{12.5 \times 4} = 91 \text{ dBA}$$

The noise dosimeters have evolved from simple devices computing single-number % noise dose to highly sophisticated data logging monitors. These instruments store comprehensive data on various parameters, and can provide analysis of variations in the sound level over the period of interest.

Basic Rules for Noise Measurements

The following are some basic rules to follow when making sound measurements using a portable sound level meter:

- Check that the batteries for the measuring instruments are sufficiently charged and take along extra sets of batteries. If the instruments are to be stored for a long time, the batteries should be removed.
- Make sure that the instrument is properly calibrated. Calibration should be made at the start of each measurement session.
- Decide which weighting network should be used. Normally this would be the "A" network but depend on the objective of measurement.
- Select the correct meter response, "F" or "S" to get an accurate reading. Usually the instrument should be set at slow response "S" especially if the sound pressure fluctuates rapidly.
- If required, the equivalent sound level should be made over a specified period of time.
- Make a sketch of the area and perform some orientation measurements before noting actual values.
- When making sound measurements, hold the instrument at arm length or use a remote microphone. This will help to avoid both reflections from your body, and also block sound from certain directions.

- During the measurement, remember to:
  - measure at a suitable distance from the noise source
  - keep away from reflecting surfaces
  - make sure nothing obstructs the noise source
  - use a windshield
  - check the background noise level and make correction if necessary
- Keep a well-documented measurement report.

Appendix M: Acknowledgements

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