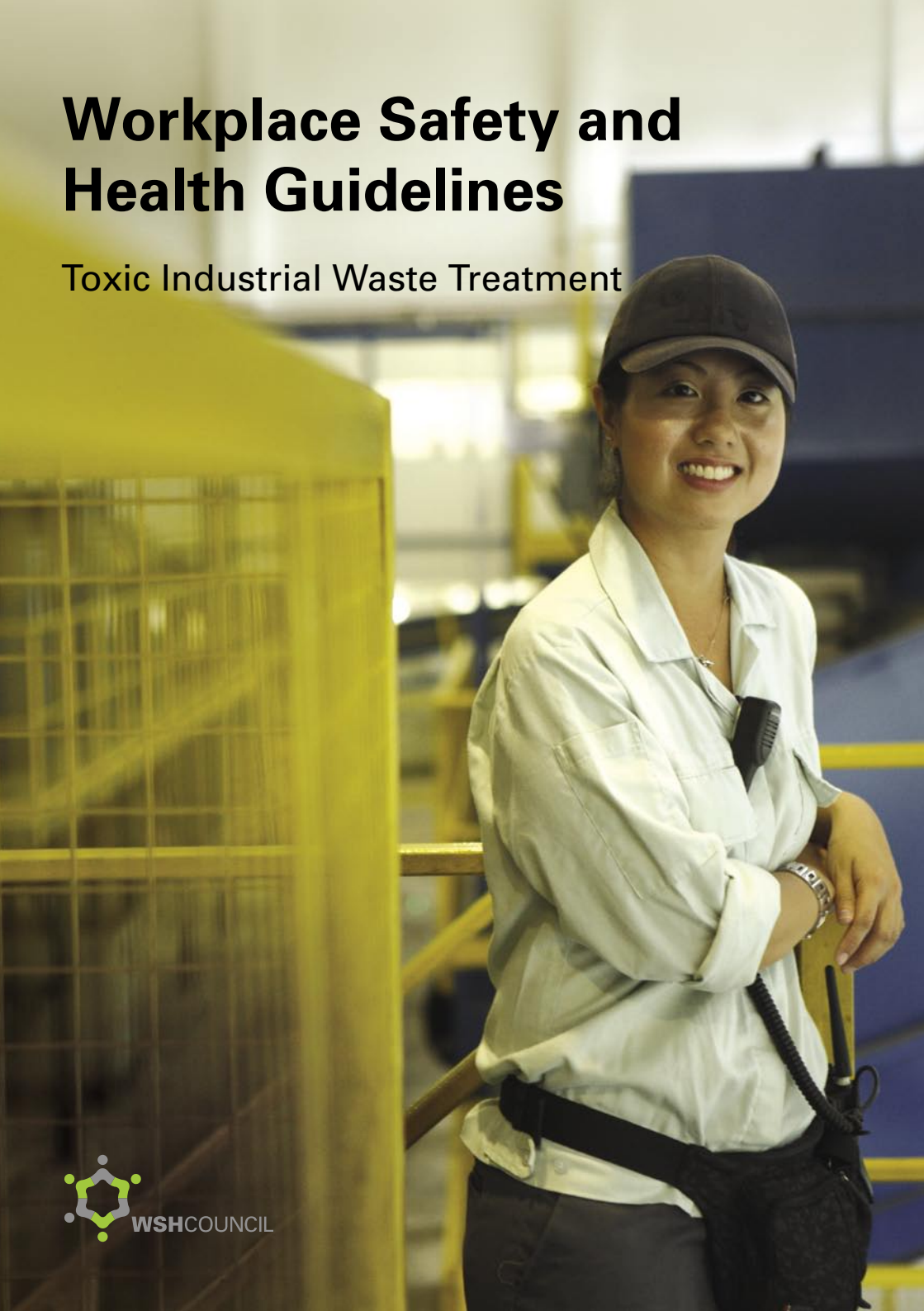
# Workplace Safety and Health Guidelines

## Toxic Industrial Waste Treatment



WSHCOUNCIL

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# Introduction

Industrial waste is unwanted products and by-products resulting from or incidental to the manufacturing process. We should, however, not take industrial waste lightly as it is a mixture of complex substances, thus, creating its potent nature when mishandled.

Improper storing, handling, treating or disposing of industrial waste can jeopardise workplace safety and health; these translate into costs in terms of compensation, clean-up and lost time due to illnesses and accidents.

# Scope

The primary objective of this document is to provide guidance on minimising workplace safety and health risks in the waste treatment industry.

The scope of the guidelines covers workplace safety and health in waste treatment facilities that store, treat and dispose of toxic industrial waste commercially.

The guidelines should be read together with the Singapore Standard CP 100: 2004 *"Code of Practice on Hazardous Waste Management"* * as well as MOM's Guidelines on "Prevention and Control of Chemical Hazards"†.

These guidelines are not meant for facilities that treat biological and/or radioactive waste. Please refer to the website of the National Environment Agency (NEA)‡ for details on the proper treatment and disposal of biological and radioactive waste.

** Published by SPRING Singapore and can be purchased at their website: http://www.spring.gov.sg*

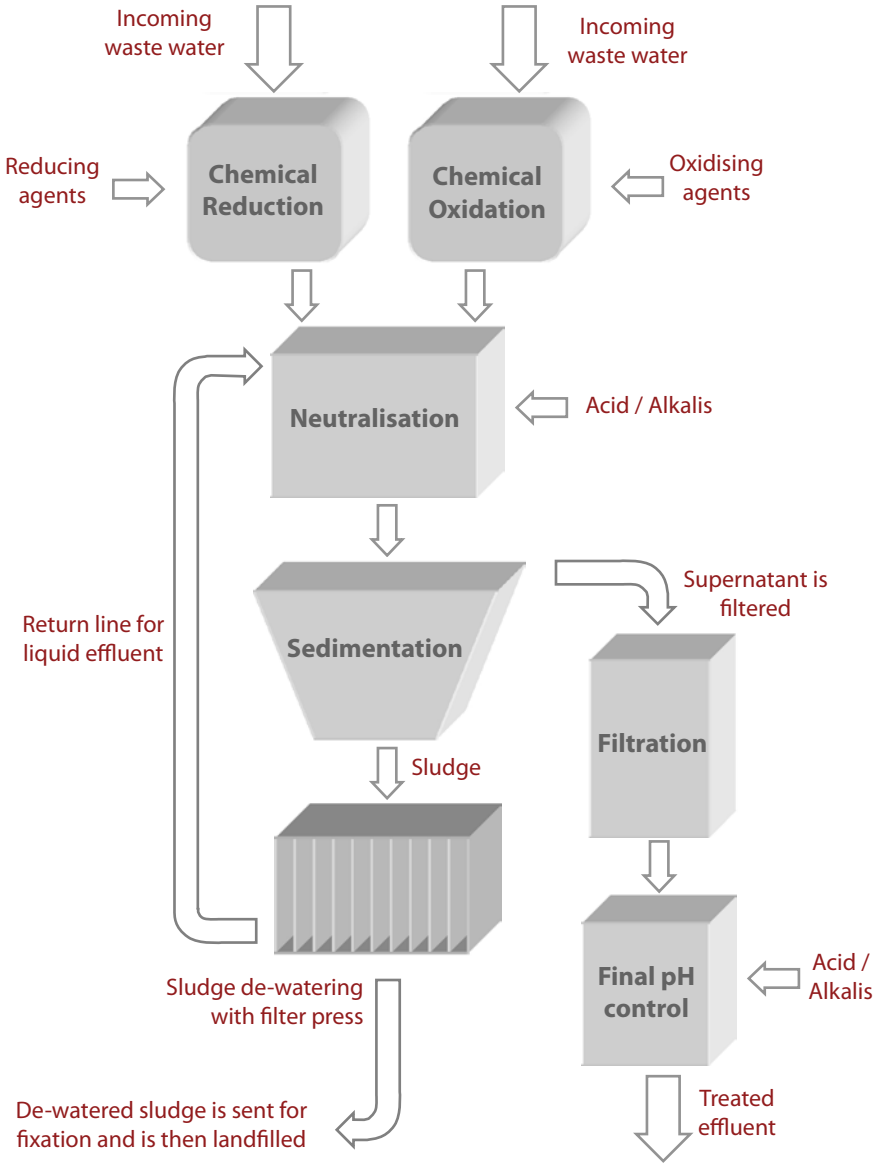
*† http://www.mom.gov.sg/oshd*

*‡ http://www.nea.gov.sg*

# typical waste treatment processes

# Typical Waste Treatment Process

A typical wastewater treatment process consists of these various unit operations:



The various unit operations are explained briefly in the following section.

## Drum Handling and Cleaning

Waste-containing drums, carboys, bottles or tins have to be emptied out for processing either by manual pouring or with the use of a pump. After emptying, these containers are washed and rinsed.

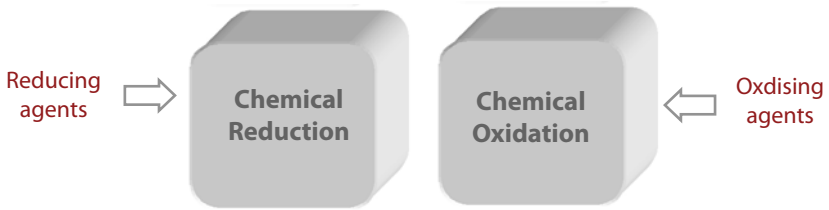
## Reduction / Oxidation (Redox)

Waste is treated according to its chemical contents. Some examples are as follows:

Electroplating waste has to be chemically reduced or oxidised prior to discharge into watercourses and sewers, as required by the National Environment Agency (NEA).

Waste containing chromic acids (where chromium exists in the $Cr^{6+}$ state) are reduced to trivalent chromium ($Cr^{3+}$) using reducing agents / reducers like sodium bisulphite.

Waste containing cyanides ($CN^-$) are oxidised using oxidising agents / oxidisers like hydrogen peroxide ($H_2O_2$).



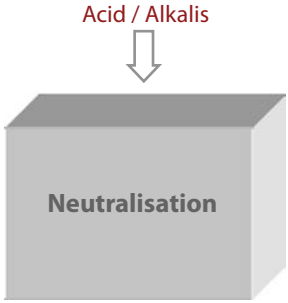
# Neutralisation

Acid-base neutralisation is one of the most common chemical processes used in waste treatment. Neutralisation of an acidic or alkaline waste is the addition of acids or bases to the waste to alter the pH to a more neutral level – in the range of 6 to 9.

Acidic waste may be neutralised with slaked lime [$Ca(OH)_2$], caustic soda (NaOH) or soda ash ($Na_2CO_3$). Alkaline waste may be neutralised with sulphuric acid ($H_2SO_4$) or hydrochloric acid (HCl). Acids/bases are added to the waste in an agitator vessel with a pH sensor to control the feed rate.

The neutralisation reactions are exothermic and care must be taken to avoid excessively high temperatures, which can result in unsafe operating conditions and damage to equipment.

Fumes and mists may be generated due to the increased temperatures from the exothermic neutralisation process.




# Precipitation

Chemical precipitation is a common method for removing heavy metals in wastewater.

Neutralisation of an acidic waste stream can cause precipitation of heavy metals. Hence heavy metals can be removed with the acidic waste stream neutralised in a single process. Depending on the metal and the pH of the wastewater, metals precipitate, forming insoluble hydroxides. The solubility of metal hydroxides is dependent on pH and the optimum pH is unique to each metal hydroxide.

The safety and health considerations for both neutralisation and chemical precipitation are similar as these two processes are usually accomplished simultaneously in the same pit / reactor.

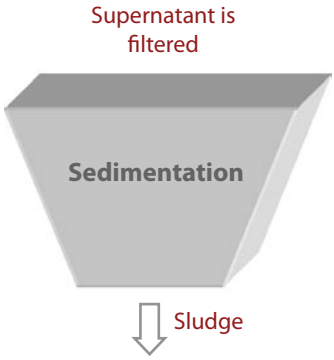
# Coagulation and Flocculation

Precipitation of heavy metals and suspended solids can be greatly enhanced by adding various water-soluble chemicals and polymers that promote coagulation and flocculation.

Coagulation and flocculation are used to settle suspended solids in wastewater when the normal sedimentation rates are too slow to provide effective clarification.

# Sedimentation and Clarification

Sedimentation and clarification induce the separation of solids from liquid waste via gravity and is carried out after precipitation, so that the sludge is allowed to settle at the bottom.

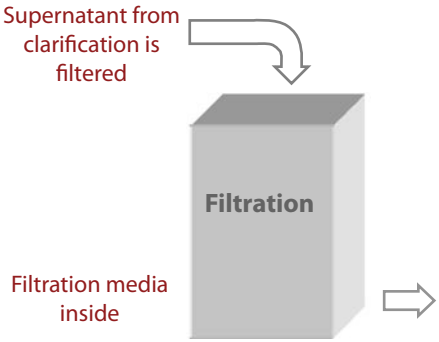



The supernatant continues its treatment at the wastewater plant while the sludge is sent to the filter press for de-watering. Fixation is then carried out on the de-watered sludge to minimise leaching of heavy metals after the stabilised sludge has been landfilled.

Oil and water mixtures are also separated similarly by allowing the mixture to settle over time. The oil will eventually float on top of the water due to their difference in specific gravity. The water can then be drained out and sent to the wastewater treatment plant for treatment prior to discharge.

# Filtration

Suspended solids can be removed from the liquid phase via filtration. A porous medium acts as a filter that traps suspended solids that add to the thickness of the porous medium. When the porous medium becomes saturated, fluid pressure through the medium can become very high. The medium can be recharged by back-washing the filter.

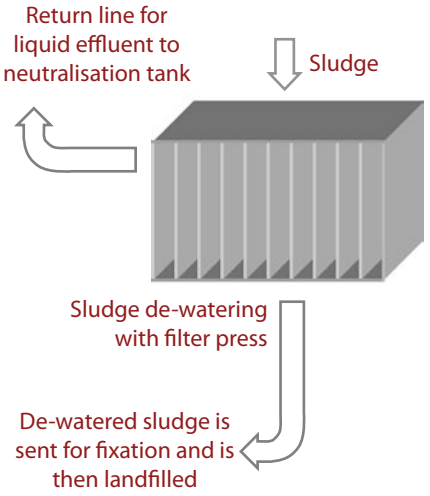



# De-watering / Filter Press

Plate and frame filter presses are commonly used to remove water from the sludge. This process produces filter cakes with solid content as high as 50%.

The filter press is made up of vertical plates held on a frame and between each plate is a filter medium (usually made of woven plastic). Liquids are allowed to pass through the filter medium while solids are collected on the surface of the fabric.

The slurry to be de-watered is fed to the filter press until the flow rate drops significantly. Flow to the filter press is stopped, pressure is relieved and the press is opened to remove the solid filter cake. The solid filter cake will undergo fixation and stabilisation to prevent hazardous substances from leaching out of the cake. The stabilised solid waste is then landfilled.



## Stabilisation and Fixation Systems

Stabilisation and fixation systems are generally designed to reduce the final release of hazardous constituents of the treatment. This is done by:

- Reducing the solubility of the hazardous constituents;
- Reducing the exposed area that may allow migration of the contaminants; or
- Detoxifying the contaminants.

Waste is incorporated into a solid matrix with binding agents or polymers. Some of these common binding agents include: ash, cement, Portland cement (mix of oxides of calcium, silica, aluminium and iron).

Waste is usually de-watered first before solidification to reduce the ultimate volume of stabilised waste for disposal, making it more cost effective to dispose of the hazardous waste.

## Evaporation, Distillation and Condensation (Solvent Recycling)

Evaporation of liquids (usually valuable hydrocarbons) reduces the volume of waste that must ultimately be treated or disposed of. Recycling valuable solvents is also more cost-effective than buying fresh solvents.

Fractional distillation yields solvents of higher purity as compared to simple evaporation and condensation products.

Batch distillation systems are commonly used to recover and recycle volatile liquids.

## Incineration

With complete combustion, incinerators are able to burn off organic waste into mainly, carbon dioxide ($CO_2$) and water. If the organics are nitrogen- or sulphur-containing hydrocarbons, nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$) are produced.

Thermal destruction of hazardous waste is the controlled exposure of waste to elevated temperatures. When properly designed, operated and maintained, thermal destruction systems can destroy hazardous organic waste and significantly reduce their volume.

Some design considerations of an incinerator include:

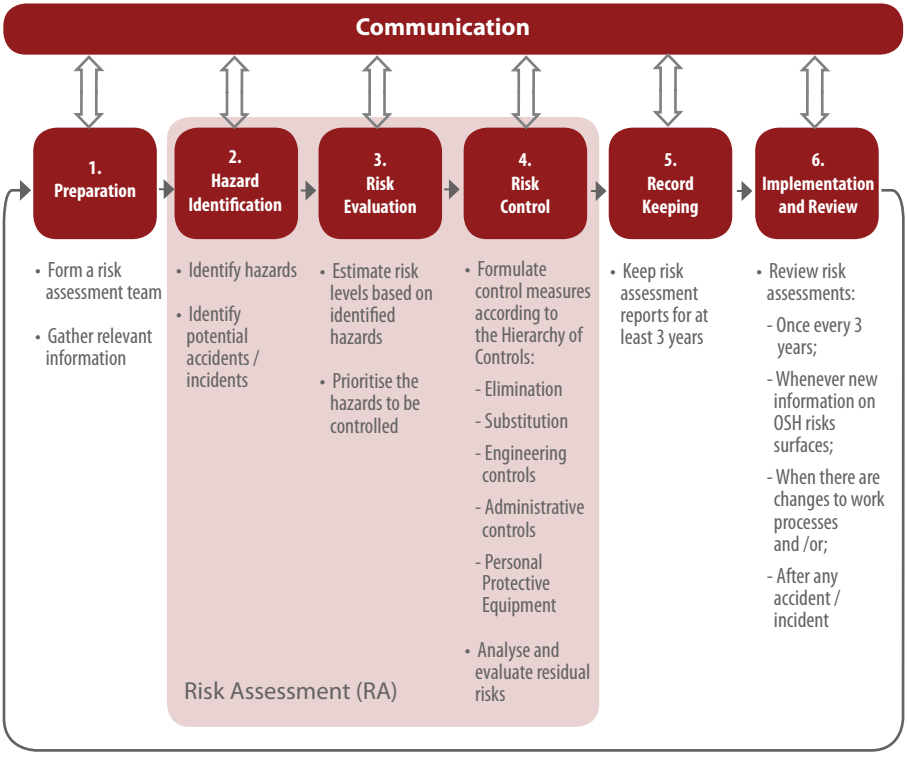
| | |
|---|---|
| **Temperature** | Incinerator temperature is essential in ensuring proper destruction and removal efficiency of hazardous waste. The threshold temperature (temperature of operation to initiate thermal destruction of hazardous waste) must be achieved. |
| **Residence Time** | The volume of the incinerator determines the residence time for any given flow rate. The products of incomplete combustion must remain at the designed incinerator temperature long enough to ensure their conversion to carbon dioxide and water.<br><br>Unless these desirable combustion products are realised, additional downstream processing is necessary. |
| **Turbulence** | Effective use of turbulence can lessen the severity of operating temperature and residence time requirements. The configuration of the incinerator affects its ability to destruct hazardous waste.<br><br>Pumps, blowers and baffles should be selected based on the type of waste to be incinerated. Heat transfer and fluid flow should be considered in the turbulence requirements for the design of the thermal destruction unit. |
| **Pressure** | Incineration should operate in slightly negative pressure or vacuum to reduce fugitive emissions. For incineration systems with positive elevated pressures, non-leaking incinerators are required. |
| **Air Supply** | The reactions of combustible components require air for complete combustion. The incinerator must have sufficient oxygen or air supply to ensure complete combustion. |
| **Materials of Contruction** | The range of chemical and physical properties of the waste to be incinerated should be well defined to ensure proper selection of materials of construction. |
| **Stack Height** | The stack height of the incinerator should be at least 3m above roof level of the factory building or 15m measured from ground level whichever is higher. |
| **Refractory Materials** | Incinerators must be insulated with refractory materials to operate effectively at high temperatures. Refractory materials contain heat released from the incineration within the unit.<br><br>The erosion and abrasion characteristics of waste being incinerated can cause considerable wear on the incinerator refractory. Refractory materials may be subject to chemical reactions between hazardous waste and their destruction products. Hence, they must be versatile and able to withstand physical and chemical attack. Also, they must be capable of maintaining their strength properties under high-temperature conditions. |

# wsh risk management

# WSH Risk Management

Risk management is a process by which the management assesses the risks, determines the control measures, and takes appropriate actions to reduce such risks, through the implementation of sensible health and safety measures. All workplaces must conduct risk assessments to identify the source of risks and should take all reasonably practicable steps to eliminate any foreseeable risk to any person who may be affected by the undertaking in the workplace. Where it is not reasonably practicable to eliminate the risk, other reasonably practicable measures must be taken to minimise the risk.

A schematic diagram of the Risk Management Process is illustrated below:



A key component of risk management is risk assessment, and when carried out appropriately, risk assessment allows better understanding of the risks at a waste treatment facility. The steps in risk assessment in a waste treatment facility are outlined in the following pages.

# Risk Assessment Step 1: Hazard Identification

Hazard identification involves identifying the hazards associated with the activity of each process and type of potential accidents or incidents. 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 to identify the workers who can be potential victims of accidents or ill health.

**Person's-at-risk**

- Persons directly involved in the operation
- Persons not directly involved in the operation
- Visitors to the workplace
- Members of the public

**Types of Accident, Incident and Ill Health**

- Fire and/or explosion
- Release of large amounts of toxic vapours
- Chemical poisoning
- Asphyxiation
- Drowning
- Noise-induced deafness
- Dermatitis
- Person falling from height
- Object falling from height
- Slips or falls on the same level
- Electrocution
- Collapse of structure
- Struck by or against object

**Instances of Hazardous Work**

- Excessive exposure to chemicals e.g. corrosive substances
- Excessive manual material handling e.g. lifting, pulling, pushing
- Method of work e.g. repeated tasks and unsafe work practices
- Electrical and mechanical hazards
- Temporary structures e.g. scaffolds
- Environmental conditions e.g. slippery surfaces, lighting
- Layout and location of equipment, vessels, reactors, sumps, pits

A simple way of identifying hazards for a particular work activity is to divide the work activity into the major steps of carrying out the work and to analyse the steps individually for the presence of hazards. It is also important to differentiate between hazards and accidents or ill-health, which are events caused by inadequate control of hazards. The following chart illustrates the method of identifying hazards systematically and also gives examples for hazards leading up to certain events:

| Work Activity | Divide into Major Steps | Spot the Hazards | Accidents or Ill-health Arising from Hazards |
|---|---|---|---|
| e.g. Neutralisation | 1. Transfer waste to neutralisation tanks using flexible hoses | ---- | ---- |
| | | *Further expansion for step 2:* | |
| | 2. Treat waste by dosing with acid / alkali | - Incompatible mixing of waste leading to runaway / uncontrollable / explosive reactions | - Release of unexpected toxic gases due to uncontrolled side reactions<br>- Deaths, body injuries<br>- Damage to equipment, property |
| | 3. Transfer treated waste out | - Exposure to excessive noise | - Noise-induced deafness (NID) |

# Risk Assessment Step 2: Risk Evaluation

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

Risk is made up of 2 parts:

1. Predicted **Severity** of the hazard and,
2. **Likelihood** of occurrence of the accident, incident or ill health taking into account the existing risk controls

Factors to take into consideration:

**Existing risk controls** must be taken into account when assessing risks. By considering the effectiveness of these controls, and the consequences of their failure, the risk of the activity can be better assessed.

**Severity** is the degree or extent of injury or harm caused by the hazards, or as a result of an accident. The severity is classified into 3 categories: minor, moderate and major.

**Likelihood** of occurrence of an accident, incident or ill health may be defined as the probability that the said incident will happen and is also classified into 3 categories: remote, occasional or frequent. To minimise the subjectivity of estimating likelihood, in addition to looking at existing risk controls, the following sources of information should be considered:

- Past incident and accident records
- Industry practice and experience
- Relevant published literature

**Risk level** may be determined once the severity and likelihood have been established. This may be achieved by using a 3 by 3 matrix. The size of the matrix may vary according to the complexity of the work conditions.

The following chart on the next page illustrates how severity and likelihood come together to help determine risk level.

# Risk Evaluation

| Determine Severity | |
|---|---|
| **Minor** | No injury, injury or ill-health requiring first aid treatment only (includes minor cuts and bruises, irritation, ill-health with temporary discomfort) |
| **Moderate** | Injury requiring medical treatment or ill-health leading to disability (includes lacerations, burns, sprains, minor fractures, dermatitis, deafness) |
| **Major** | Fatal, serious injury or life-threatening occupational disease (includes amputations, major fractures, multiple injuries, occupational cancer, acute poisoning and fatal diseases) |

| Determine Likelihood | |
|---|---|
| **Remote** | Not likely to occur |
| **Occasional** | Possible or known to occur |
| **Frequent** | Common or repeating occurrence |

Likelihood

Severity

**Determine Risk**

| Likelihood / Severity | **Remote** | **Occasional** | **Frequent** |
|---|---|---|---|
| **Minor** | Low Risk | Low Risk | Medium Risk |
| **Moderate** | Low Risk | Medium Risk | High Risk |
| **Major** | Medium Risk | High Risk | High Risk |

**Example:**
If the consequence of a hazard is identified to have *moderate severity* and *occasional likelihood*, the risk level may be determined to be *medium*.

# Risk Assessment Step 3: Risk Control

## How to establish methods of eliminating or reducing the risks?

Based on the risk level determined in STEP 2, risk controls should be selected to reduce or confine the risk level to an acceptable level. The following table suggests the acceptability of risk for different risk levels.

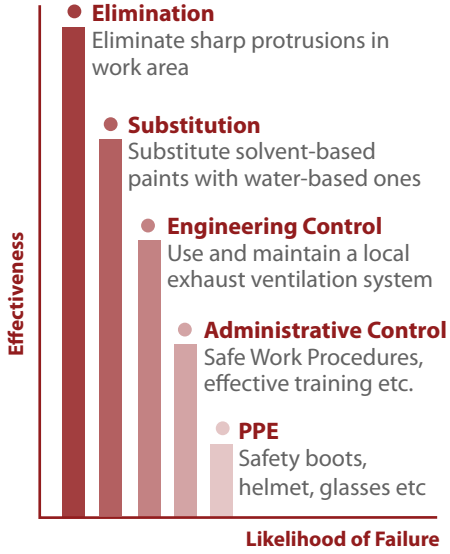
| Risk Level | Acceptability of Risk |
|---|---|
| Low | Acceptable |
| Medium | Moderately Acceptable |
| High | Not Acceptable |

In order to prioritise the risk controls adequately, the formulation of such risk controls can take into consideration the relative risk levels of the different hazards and the cost and benefit of the controls. The residual risk after the implementation of the controls should also be evaluated.

Reasonably practicable measures must be taken to maintain the risk level within the acceptable range. It is essential for risks to be eliminated or reduced 'at source'. If the risk level is high, work cannot commence until the risk level is reduced to the medium level.

## What risk control methods are there?

To ensure that workers are adequately protected from risks posed by the workplace, the following control measures are recommended according to the hierarchy of control: see chart.



## Elimination

Elimination of hazards refers to the total removal of the hazards and hence effectively making all the identified possible accidents, incidents and ill health impossible.

This is a permanent solution and should be attempted in the first instance. If the hazard is eliminated, all the other management controls, such as workplace monitoring and surveillance, training, safety auditing, and record keeping will no longer be required.

## Substitution

Substitution replaces a hazard with a less hazardous alternative. Examples include:

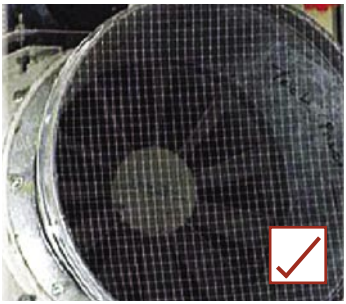
| More Hazardous Chemicals / Materials | Alternative |
|---|---|
| Acidic cleaners, alkaline cleaners | Neutral cleaners |
| Solvent cleaners | Water-based cleaners |
| Organic solvents | Water |
| Chlorinated solvents | Non-chlorinated solvents |
| Lead-based paints, oil-based paints | Water-based paints |
| Asbestos insulation | Fibreglass insulation |

## Engineering Control

**Ventilation**
Ventilation is either local or general in nature and controls exposure by exhausting or supplying air.

Local ventilation directs air movement; general ventilation dilutes the air. Ventilation generally has limited use in uncontrolled hazardous waste treatment processes, but there are some applications.

**Local exhaust ventilation (LEV)**
Under the WSH (General Provisions) Regulations, workers have to be protected from toxic fumes, offensive dust or other contaminants. An LEV system should be installed to extract fumes, airborne chemicals, mists into a scrubber/filter before discharging into the atmosphere. An LEV system usually consists of hoods, ducting, an air cleaning device and a fan.

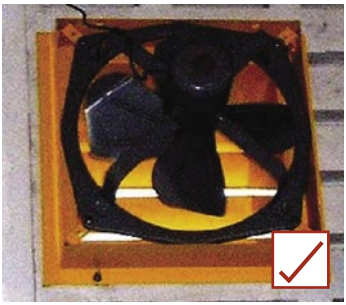


*LEV removes air contaminants at the source of generation.*

LEV would be more effective for covered tanks, sumps and pits rather than uncovered ones. It should be properly designed, fabricated, operated and maintained.

For more details on capture velocities and duct velocities, please refer to the Singapore Standard CP 27 : 1999 *"Code of Practice for Factory Layout - Safety, Health and Welfare Considerations".*

**Dilution ventilation**
Dilution ventilation improves the general airflow in the work area, making the work environment more comfortable. Heat stress on workers is reduced, especially in areas of waste neutralisation and incineration.



*Dilution ventilation increases the air change rate in the work area.*

Dilution ventilation may not effectively reduce workers' exposure to hazards as airborne contaminants are not removed at the source of generation (in comparison with LEV).

Adequate air should be provided to dilute the contaminants to below their Permissible Exposure Levels (PELs).

**Remote-control devices**
Devices that are controlled remotely have been increasingly applied to hazardous waste treatment processes. Remote monitoring can dramatically reduce the need for respiratory protection.

Common techniques include:

- Use of pneumatically operated impact wrenches to open drum bungs; and
- Hydraulic and pneumatic piercers for penetrating drum tops.

**Process design and re-engineering**
The greatest application of process design and re-engineering for operational facilities is during periods of shut-down and maintenance. The earlier safety is considered in the design process, the less it costs to implement and the greater the chance for inherent safety (i.e., designing out potential risks).

However, for existing facilities, safety considerations are manifested extrinsically in the form of devices such as alarms and interlocks and practices such as equipment redundancy.

**Covered tanks, sumps and pits**
Cover all tanks, vessels, structures, pits, sumps that contain any scalding, corrosive or poisonous liquid. This reduces the risk of workers falling into tanks and also, workers' exposure to chemicals that have been generated from the treatment processes.

When a tank is covered, a level sensor is required to indicate the level of liquid in the tank. The liquid level sensor will prevent overflow in the tank and also indicate tell-tale signs of leaks.

If covering the tanks is not possible, barricades and secured fencing should be placed to prevent falls.

*Please refer to the Singapore Standard CP 27 : 1999 "Code of Practice for Factory Layout - Safety, Health and Welfare Considerations" for guidelines in planning the layout of a factory.*


*Barricades and warning signs should be placed to prevent fall into uncovered tanks*

## Administrative Control

**Safe Work Procedures (SWPs)**
SWPs can dramatically improve workers' safety and work efficiency. Written operating procedures should be integrated with safe work.

A multi-disciplinary team should develop the SWPs and SWPs can be developed from an activity-based risk assessment that has been properly conducted. The SWPs should be thoroughly evaluated prior to implementation, monitored during use and modified as working conditions or processes change.

**Lock-out procedures**
Lock-out procedures are procedures to ensure that all energy sources to the relevant plant, machinery or equipment will be isolated, disconnected or discharged. It is to prevent any part of the plant, machinery or equipment from being inadvertently activated or energised.

Under the WSH (General Provisions) Regulations, lock-out procedures should be established and implemented for the inspection, cleaning, repair or maintenance of any plant, machinery or equipment that, if inadvertently activated or energised, is liable to cause bodily injury to any person. Every person carrying the work should be fully instructed on the lock-out procedures for that work before commencing such work.

*Please refer to the Singapore Standard CP 91 : 2001 "Code of Practice for Lockout Procedure" for more details.*

**Permit-to-work systems**
Permit-to-work systems should be implemented for work in any confined space and work involving the application of heat, or the potential generation of any source of ignition, where any explosive or flammable substance is liable to be present.

For guidelines on permit-to-work systems, please refer to:

- Singapore Standard SS 510 : 2005 "Code of Practice for Safety in Welding and Cutting (and other Operations involving the Use of Heat)" or
- Singapore Standard CP 84 : 2000 "Code of Practice for Entry into and Safe Working in Confined Spaces".

**Preventive maintenance**
Regular preventive maintenance should be carried out on all plant, machinery and equipment used in the treatment plants. This will help to prevent any failure of the equipment due to a lack of maintenance or repair, which can result in unsafe situations.

The plant should establish a maintenance programme to ensure that the mechanical integrity of critical plant equipment is maintained. The programme should include, but should not be limited to:

- An appropriate inspection programme to monitor the condition of the equipment and machinery on a continuous basis.
- A corrosion control programme to maintain the integrity of critical equipment and machinery and piping systems.
- Development and documentation of work practices and maintenance procedures, taking into consideration the safety and health exposure of personnel to the work operations and the associated risks to the environment during maintenance work.
- A long-term maintenance plan for periodic maintenance of major and critical equipment. The plan should be reviewed regularly to take into consideration the inspection findings, incident reports and regulatory requirements.
- Relevant training of personnel involved in the work practices and maintenance procedures.

The work practices and maintenance procedures should incorporate safety precautionary measures such as Lockout/Tagout System and Permit-to-Work Systems.

**Management of change**
For any changes to the design, operation or maintenance of plant machinery and equipment, a programme should be implemented to record, schedule, address and monitor hazards that may be introduced by the changes.

Changes can result from feedstock changes, equipment changes, operation changes, technological changes, process changes and mechanical changes. Other changes might be "Not-In-Kind" replacement that may need to be operated in a different manner.

Changes can introduce new complexity into the process. Foresight and planning are most important in this step. This may include risk assessments in advance of the change. In this way, desirable changes are managed safely.

A written procedure for the management of change is required. In this programme, these issues must be addressed:

- Technical basis of the change
- Authorisation requirements
- Time period for change
- Modifications to operating procedures
- Impact of change on safety and health

After the change has been made, affected employees should be informed and trained. Also, process safety information and operating procedures have to be updated according to the changes made.

**Training**
All employees have to be trained to fully understand the safe work procedures within the plant. It is essential to ensure that employees know the need to work safely and the importance of working safely.

It is advised that a chemist be in charge of the treatment of toxic industrial waste. Treatment processes involve chemical reactions and a chemist would know best how to treat toxic industrial waste in a safe manner.

*Employees have to be trained to fully understand safe work procedures*

**Medical surveillance**
Medical surveillance is a system of monitoring the health status of individuals, to determine departures from normal health and to take the necessary corrective actions early.

Under the WSH (Medical Examinations) Regulations, pre-employment and periodic medical examinations are required for persons who are exposed to the following hazards:

- Arsenic and its compounds
- Asbestos
- Benzene
- Cadmium and its compounds
- Compressed air
- Cotton
- Lead and its compounds
- Manganese and its compounds
- Mercury and its compounds
- Excessive noise
- Organophosphates
- Perchloroethylene (PCE)
- Free Silica
- Tar, pitch, bitumen and creosote
- Trichloroethylene (TCE)
- Vinyl Chloride Monomer (VCM)

Under the Regulations, the examinations are to be conducted by a registered designated factory doctor (DFD).

Visit http://www.mom.gov.sg/oshd to obtain the following:

- A list of DFDs;
- Summary of the medical examinations (with frequencies, sampling details and recommended safe levels) required for persons exposed to hazards that may be found in the toxic industrial waste treatment industry; and
- Formats of medical examination records, including summary reports

### Labelling

Labelling aids the identification of waste and wastewaters. Thus, the duty of labelling falls on not only the waste treatment facility but also on the generator of the waste.

It is recommended that hazardous waste labels have the following information:

| | |
|---|---|
| **Title** | A "Hazardous Waste" heading |
| **Identity of Waste** | Chemical name/common names/synonyms, with waste type |
| **Identity of Generator** | Generator's name, address and contact number(s) |
| **Symbol** | Graphical representation of the hazardous waste's nature |
| **Particular Risk(s)** | Inherent/potential harm that the hazardous waste may/can cause |
| **Safety Precaution (s)** | Warnings and instructions in relation to the risk(s) |

### Security and warning signs

Security and warning signs limit worker and third party access to the work areas and site hazards. Security measures can prevent:

- Exposure of unauthorised, unprotected personnel to work-site hazards;
- Spread of contamination;
- Access by thieves, vandals, or persons seeking to abandon other waste on the work-site; and
- Interference with safe work procedures.

**Security**
Site security can be maintained during off-hours by assigning trained in-house personnel for surveillance, using security guards to patrol the plant's boundary, and securing equipment.

**Warning signs**
Physically identifying and posting warning signs are important elements of work-site hazard communication. Site work zones are to be clearly identified with signs at the entrance of each work zone. There should be specific hazard posting requirements for confined spaces, asbestos, noise, carcinogens, corrosive chemicals and flammable storage areas. Signs are to be securely affixed, resist adverse environmental conditions, and reflect changing conditions and hazards at the work-site.

Signs should be spaced to ensure visibility upon approach to the boundary of a work zone or a hazard. At least one sign should be visible on each side of the boundary and from each direction of approach.

Work zone and hazard posting should:

- Identify all types of hazards sufficient to maintain worker recognition and safety;
- Be installed immediately after the work zones are established and the hazards are identified; and
- Be clear and minimise confusion when more than one hazardous condition is present.

For more details and specifications, please refer to:

- Singapore Standard SS 508 : Part 1 : 2004 "Specification for Graphical Symbols - Safety Colours and Safety Signs Part 1: Design Principles for Safety Signs in Workplaces and Public Areas" and
- Singapore Standard SS 508: Part 3 : 2004 "Specification for Graphical Symbols - Safety Colours and Safety Signs Part 3: Safety Signs Used in Workplaces and Public Areas".

**Communication**
Communication of risks at a hazardous waste operation is essential and is either internal or external.

Internal communication
Internal communication is between workers at the various work zones and is used to:

- Alert workers to newly identified hazards or emergencies;
- Provide safety guidance, such as lessons learned or amount of breathing air left;
- Monitor or confirm well-being or exposure, stress, or confusion; and
- Maintain site control and facilitate stop-work actions or work-site evacuation.

A waste treatment log should be maintained to track the different types of waste that has been treated in the facility.

Verbal communication can be impeded by background noise from heavy equipment or by personal protective equipment (PPE). Thus, for effective communication, commands are pre-arranged and include both visual and verbal cues.

A primary and back-up communication system is necessary; both should be checked daily. All communication devices must be spark-free. Communication equipment should be coordinated with explosive experts if explosives are used at the site.

Individual workers should be identified by names placed on their PPE or by color-coding or numbers.

Communication between heavy-equipment operators in enclosed cabs and workers on foot is critical.

External communication
External communication is between onsite and offsite personnel and is used to:

- Coordinate emergency response; and
- Maintain contact with outside personnel such as management.

External communication between generator and toxic industrial waste collector is important. With adequate knowledge of the toxic industrial waste and its composition, the collector is able to know:

- The best way to treat the waste collected
- If there are constituents in the waste that may be incompatible with treatment chemicals

Currently, NEA has an e-tracking system that allows generators to declare the type of toxic industrial waste generated and the licensed collector that will be treating the waste. This system tracks the status of the waste from its point of generation to the receiver's end.

The generator has to declare the composition of the waste accurately and provide correct information. The collector has to ensure that the waste collected is always labelled for proper identification and treatment.

## Personal Protective Equipment (PPE)

PPE controls the degree of worker exposure. PPE should be used as a last resort or as an interim measure:

1. When engineering or administrative controls are not feasible or do not totally eliminate the hazard,
2. While engineering controls are being developed, or
3 During emergencies.

The purpose of PPE is to shield or isolate individuals from the chemical, physical and biological hazards that may be encountered at a waste treatment facility. For any given working condition, PPE should be selected to provide an adequate level of protection to the wearer.

The limitations of PPE should be fully taken into consideration before use. The use of PPE alone creates new problems: heat stress, physical and psychological stress, impaired vision, reduction in mobility and communication. PPE worn should also be appropriate to the hazards exposed to, so that the hazards can be combated effectively with the right PPE.

The type of PPE and the material from which the PPE is made are to protect against the hazards present. No single combination of protective equipment and clothing can guard against all hazards. Thus, it is recommended that PPE should be used together with other risk control measures.

Moreover, because every work-site is different and the degree of known or unknown hazards varies, the PPE ensemble required is likely to change as work progresses.

PPE include respirators, protective clothing, hearing protectors, head protectors, face/eye protectors, hand protectors and foot protectors. Careful selection and proper use of PPE should protect the respiratory system, skin, eyes, face, hands, feet, head, body and hearing.

**Prevention of falls from heights**
Very often, workers in the treatment plants have to access from the top of a trailer container or an ISO-tank to another. They are liable to sustain serious bodily injury or death from a fall. Thus, suitable safety belts or harnesses with sufficient and secured anchorage on a working platform, should be provided for these workers working on the top of the trailer container or ISO-tank.

**Respiratory protection**
Special requirements for respiratory protection include:

- Preparing a written respiratory protection programme;
- Medically evaluating, training, qualifying, and fit-testing workers for specific respirator types; and
- Checking for any special respiratory protection requirements (e.g., for asbestos, lead, nickel or cadmium).

Since the main route of exposure to hazardous substances is via inhalation, care must be taken to select, use and maintain respiratory protection devices.

Respiratory protective devices consist of a facepiece connected to either a clean air source or an air-purifying filter.

For more details on respirators, please refer to Singapore Standard CP 74 : 1998 "Code of Practice for Selection, Use and Maintenance of Respiratory Protective Devices".

| For Further Details : | Topic |
|---|---|
| Ministry of Manpower's Guidelines on *"Prevention and Control of Chemical Hazards"* | Different glove materials and their incompatibilities with chemicals |
| Singapore Standard CP 76 : 1999 *"Code of Practice for Selection, Use, Care and Maintenance of Hearing Protectors"* | Hearing protection |
| Singapore Standard SS 98 : 2005 *"Specification for Industrial Safety Helmets"* | Head protection |
| Singapore Standards SS 473 : Part 1 : 1999 *"Specification for Personal Eye-Protectors Part 1: General Requirements"* | Eye protection |
| Singapore Standards SS 473 : Part 2 : 1999 *"Specification for Personal Eye-Protectors Part 2: Selection, Use and Maintenance"* | Eye protection |
| Singapore Standards SS 513 : Part 1 : 2005 *"Specification for Personal Protective Equipment - Footwear Part 1: Safety Footwear"* | Foot protection |
| Singapore Standards SS 513 : Part 1 : 2005 *"Specification for Personal Protective Equipment - Footwear Part 2: Test Methods for Footwear"* | Foot protection |


# emergency planning

# Emergency Planning

A written emergency response plan should be established to mitigate consequences arising from emergency situations. Procedures should be established to:

- Identify emergency situations and their impacts;
- Implement emergency response plans for each level of the organisation, with clear scope, roles and responsibilities; and
- Maintain an up-to-date emergency response plan.

The emergency response plan should be documented and effectively communicated. The plan should include the following:

- Establishment of the Emergency Team(s) and its duties and responsibilities;
- Appointment of the Emergency Superintendent, who should command the emergency procedures according to the emergency response plan;
- Procedure for notification and raising of alarms;
- Procedure for initial response to emergency situations such as preliminary fire-fighting, first-aid and containment responses;
- Procedure for evacuation and rescue;
- Capability of in-house resources such as rescue and medical facilities; and
- Capability of nearest government response agency, its roles and the response time to the emergency situations.

The waste treatment facility should establish a programme of drills and exercises to assess the preparedness for prompt and effective response to emergency situations.

Effective first aid programmes should be established to provide first-aid and emergency treatment to victims of an accident. This would include provision of adequate first aid facilities and trained first aiders.

In all cases of splashes, inhalation and ingestion of toxic or corrosive chemicals, information on the chemicals can be found in the Safety Data Sheets (SDSs). Thus, SDSs for the chemicals should be available for first aiders and medical personnel to apply proper treatment.


# risk compendium for the waste treatment industry

# Risk Compendium for the Waste Treatment Industry

The work activities stated here are only some typical examples and may vary from workplace to workplace. Customisation to each workplace is required.

The possible hazards, accidents/ill-health and suggested risk control measures supplied here are not exhaustive.

Other possible hazards not indicated should also be controlled to required standards but are not dealt with here.

# Drum Handling and Cleaning

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Empty drums, carboys, bottles by pouring or with a pump | Spills and splashes onto workers' eyes/ skin | Eye injuries<br>Eye irritation<br>Skin burns<br>Skin rash<br>Excessive skin absorption of chemicals | • Build enclosures or curtains around washing area<br>• Use pumps whenever possible to transfer waste<br>• Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants (since gaseous products, fumes and mists are likely to be produced during washing and rinsing)<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Excessive inhalation of toxic vapours or fumes liberated | Chemical poisoning<br>Occupational disease | • Build enclosures or curtains around washing area<br>• Use pumps whenever possible to transfer waste<br>• Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants (since gaseous products, fumes and mists are likely to be produced during washing and rinsing)<br>• Establish and implement safe work procedures |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | | | • Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots)<br>• Regular monitoring of workers' exposure to toxic substances |
| **02** | Wash drums, carboys, bottles | Spills and splashes onto workers' eyes / skin | Eye injuries<br>Eye irritation<br>Skin burns<br>Skin rash<br>Excessive skin absorption of chemicals | • Build enclosures or curtains around washing area<br>• Use pumps whenever possible to transfer waste<br>• Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants (since gaseous products, fumes and mists are likely to be produced during washing and rinsing)<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

# Reduction / Oxidation (Redox)

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | Excessive manual handling of containers | Back injury | • Minimise manual handling through use of mechanical lifting aids / handling devices<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures |
| 03 | Treat waste by dosing with reducing / oxidising agents | Incompatible mixing of waste leading to runaway / uncontrollable / explosive reactions | Release of unexpected toxic gases due to uncontrolled side reactions<br>Explosive reactions<br>Death<br>Body injuries<br>Damage to machines, equipment, property | • Automated closed waste treatment system<br>• Install enclosed system with fixed piping for dosing of reducing / oxidising agents<br>• Conduct laboratory testing prior to treatment<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | Spills and splashes onto workers' eyes / skin | Eye injuries<br>Eye irritation<br>Skin burns<br>Skin rash<br>Excessive skin absorption of chemicals | • Automated closed waste treatment system<br>• Install enclosed system with fixed piping<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Excessive inhalation of toxic vapours or fumes liberated | Chemical poisoning<br>Occupational disease | • Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants<br>• Build enclosures around reactors or cover all reactors<br>• Install an Oxidation / Reduction Potential (ORP) meter linked to the dosing system to monitor the extent of the redox reaction and keep the treatment process within control<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | | | • Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots)<br>• Regular monitoring of workers' exposure to toxic substances |
| | | Exposure to excessive noise | Noise-induced deafness (NID) | • Replace noisy machines and equipment with quieter ones<br>• Build noise-absorbing enclosures around noisy machines and equipment<br>• Install silencers<br>• Implement hearing conservation programme (HCP) |
| **04** | Maintenance work | Insufficient supply of oxygen<br><br>Inhalation of excessive toxic vapours | Death<br><br>Suffocation<br><br>Poisoning by toxic vapours | • Remove residue or sludge before entering tank<br>• Supply continuous forced ventilation into tank<br>• Conduct gas tests by a competent person<br>• Establish and implement safe work procedures<br>• Ensure sufficient lighting in tank<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots)<br>• Provide emergency equipment, rescue equipment<br><br>***Please refer to Singapore Standard CP 84 : 2000 "Code of Practice for Entry into and Safe Working in Confined Spaces"*** |

# Neutralisation, Precipitation

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Transfer waste to neutralisation tanks with flexible hoses | Incompatible mixing of waste leading to runaway / uncontrollable / explosive reactions | Release of unexpected toxic gases due to uncontrolled side reactions<br><br>Explosive reactions<br><br>Death<br><br>Body injuries<br><br>Damage to machines, equipment, property | • Automated closed waste treatment system<br>• Different hoses for different types of waste<br>• Use hoses of different diameters for different waste types<br>• Conduct laboratory testing prior to treatment<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Spills and splashes onto workers' eyes / skin | Eye injuries<br><br>Eye irritation<br><br>Skin burns<br><br>Skin rash<br><br>Excessive skin absorption of chemicals | • Automated closed waste treatment system<br>• Install enclosed system with fixed piping<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | | | • Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Falls into neutralisation sump / pit | Eye injuries<br>Skin burns<br>Excessive skin absorption of chemicals | • Automated closed waste treatment system<br>• Install barricades or fencing around sumps / pits<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 02 | Treat waste by dosing with acid / alkali | Incompatible mixing of waste leading to runaway / uncontrollable / explosive reactions | Release of unexpected toxic gases due to uncontrolled side reactions<br><br>Explosive reactions<br><br>Death<br><br>Body injuries<br><br>Damage to machines, equipment, property | • Automated closed waste treatment system<br>• Install enclosed system with fixed piping for dosing of acids / alkalis<br>• Install automated dosing systems interlinked with a pH meter to control the extent of dosing<br>• Conduct laboratory testing prior to treatment<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Exposure to excessive noise | Noise-induced deafness (NID) | • Replace noisy machines and equipment with quieter ones<br>• Build noise-absorbing enclosures around noisy machines and equipment<br>• Install silencers<br>• Implement hearing conservation programme (HCP) |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 03 | Maintenance work | Insufficient supply of oxygen<br><br>Inhalation of excessive toxic vapours | Death<br><br>Suffocation<br><br>Poisoning by toxic vapours | • Remove residue or sludge before entering tank<br>• Supply continuous forced ventilation into tank<br>• Conduct gas tests by a competent person<br>• Establish and implement safe work procedures<br>• Ensure sufficient lighting in tank<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots)<br>• Provide emergency equipment, rescue equipment<br><br>*Please refer to Singapore Standard CP 84: 2000 "Code of Practice for Entry into and Safe Working in Confined Spaces"* |

# Coagulation, Flocculation and Sedimentation

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Treat waste by dosing with coagulant / flocculant | Incompatible mixing of waste leading to runaway / uncontrollable / explosive reactions | Release of unexpected toxic gases due to uncontrolled side reactions<br><br>Explosive reactions<br><br>Death<br><br>Body injuries<br><br>Damage to machines, equipment, property | • Automated closed waste treatment system<br><br>• Install enclosed system with fixed piping for dosing of coagulants / flocculants<br><br>• Install automated dosing systems interlinked with a pH meter to control the extent of dosing<br><br>• Conduct laboratory testing prior to treatment<br><br>• Establish and implement safe work procedures<br><br>• Provide and attend training on hazards, safe work procedures, use of control measures<br><br>• Label containers, tanks, carboys etc. clearly<br><br>• Place warning signs in work areas<br><br>• Restrict access to waste treatment areas<br><br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | Spills and splashes onto workers' eyes / skin | Eye injuries<br>Eye irritation<br>Skin burns<br>Skin rash<br>Excessive skin absorption of chemicals | • Automated closed waste treatment system<br>• Install enclosed system with fixed piping<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Falls into neutralisation sump / pit | Eye injuries<br>Skin burns<br>Excessive skin absorption of chemicals | • Automated closed waste treatment system<br>• Install barricades or fencing around sumps / pits<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Label containers, tanks, carboys etc. clearly<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

# Filtration

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Charging of waste liquid into filtration unit | Toxic liquids, vapours or fumes liberated during charging process | Exposure to toxic substances may result in irritation of the skin, eyes or respiratory system, or other ill health | • Install fixed piping system to transfer waste liquid into the filtration unit<br>• Safe work procedures implemented<br>• Wearing of chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges<br>• Regular monitoring of workers' exposure to toxic substances |
| | | Hazardous substances produced due to chemical reactions between different waste types | Exposure to hazardous substances may result in poisoning, or other ill health | • Workers are instructed to carry out the filtration in batches so that supernatants from one type of waste are not mixed with those from another type<br>• Filtration tanks are rinsed after each batch filtration<br>• Conduct laboratory testing prior to treatment to ascertain the types of hazardous substance that may be generated |
| | | Flammable vapours/ mists liberated from supernatant and presence of ignition source (e.g. static build-up) | Fire or explosion, resulting in serious injuries or death of workers | • Safe work procedures implemented<br>• Workers are instructed not to smoke in the work areas<br>• Emergency plan in place<br>• Filtration units to be grounded and inerted to protect against static-electric build-up<br>• Use explosion proof type of fixtures<br>• Provide adequate fire extinguishers |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | Heavy loads | Muscular strain or injury during manual pouring of liquids into filtration unit | • Install fixed piping system so that waste liquids can be charged into the filtration unit directly<br>• Worker to observe proper lifting procedure if manual handling is required |
| 02 | Operation of filtration process | Excessive noise | Noise-induced deafness may result due to prolonged exposure to excessive noise | • Replace noisy machines and equipment with quieter ones<br>• Build noise-absorbing enclosures around noisy machines and equipment<br>• Install silencers<br>• Implement hearing conservation programme (HCP) |
| 03 | Transfer of filtered solids during unit unloading to waste drums | Toxic solids, vapours or fumes. | Contact with toxic substances may result in skin irritation or other ill health | • Provide local exhaust ventilation to control release of toxic vapours or fumes<br>• Conduct regular monitoring of workers' exposure to toxic substances<br>• Safe work procedures implemented<br>• Wear chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges |
| 04 | Rinsing of filtration unit | Toxic liquids, vapours or fumes | Exposure to toxic substances may result in irritation of the skin, eyes or respiratory system, or other ill health, or death | • Use of automated spindle system to rinse tank<br>• Workers' training on confined space hazards and precautions<br>• Safe work procedures<br>• Wear chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | | | • Implementation of Permit-to-work system for confined space, including gas testing with calibrated and well maintained gas meters before and during entry into unit<br>• Emergency procedures in place |
| 05 | Maintenance: Changing of filtration media | High concentrations of hazardous solids, liquids, vapours or fumes | Exposure to hazardous substances may result in ill health, or even death | • Use of pump to pump out the filter medium to reduce worker's contact<br>• Workers' training on confined space hazards and precautions<br>• Safe work procedures<br>• Implementation of Permit-to-work system for confined space, including gas testing with calibrated and well maintained gas meters before and during entry into unit<br>• Emergency procedures in place<br>• Wear chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges |
| | | Heavy loads and awkward angles | Muscular strain when lifting heavy filtration medium into waste drums | • Use pump to pump out the filter medium to reduce manual handling<br>• Worker to observe proper lifting procedure |

# De-watering / Filter Press

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Charging of sludge into de-watering unit | Toxic solids, liquids, vapours or fumes | Exposure to toxic substances may result in irritation of the skin, eyes or respiratory system, or other ill health | • Install fixed piping system to transfer sludge into the filtration unit<br>• Safe work procedures implemented<br>• Wearing of chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges<br>• Conduct regular monitoring of workers' exposure to toxic substances |
| | | Hazardous substances produced due to chemical reactions between different waste types | Exposure to hazardous substances may result in irritation of the skin, eyes or respiratory system, or other ill health | • Workers are instructed to carry out de-watering in batches so that sludge from one type of waste is not mixed with those from another type.<br>• Conduct laboratory testing prior to treatment to ascertain the types of hazardous substance that may be generated |
| | | Flammable vapours/ mists liberated from sludge and presence of ignition source (e.g. static build-up) | Fire or explosion, resulting in serious injuries or death of workers | • Safe work procedures implemented<br>• Workers are instructed not to smoke in the work areas<br>• Emergency plan in place<br>• Filtration units to be grounded and inerted to protect against static-electric build-up<br>• Use explosion proof type of fixtures<br>• Provide adequate fire extinguishers |
| | | Heavy loads | Muscular strain or injury during manual pouring of sludge into de-watering unit | • Install fixed piping system so that sludge can be charged into the de-watering unit directly.<br>• Worker to observe proper lifting procedure if manual handling is required |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 02 | Operation of filter press | Excessive noise | Noise-induced deafness may result due to prolonged exposure to excessive noise | • Replace noisy machines and equipment with quieter ones<br>• Build noise-absorbing enclosures around noisy machines and equipment<br>• Install silencers<br>• Implement hearing conservation programme (HCP) |
| | | Moving parts | Injury due to limbs caught between moving parts | • Use of safety device to stop operation when operator's limbs are within danger area<br>• Guarding installed around filter press<br>• Safe work procedures implemented |
| 03 | Removal of filter cake | Toxic heavy metal dust released from filter cake | Exposure to toxic substances may result in irritation of the skin, eyes or respiratory system, or other ill health | • Provide local exhaust ventilation to control dust exposure<br>• Conduct regular monitoring of workers' exposure to toxic substances<br>• Solid filter cake is allowed to drop directly into disposal bins with assistance of gravity or via mechanical scrapping |
| | | Awkward limb position | Muscular strains due to awkward angles and overreaching | • Solid filter cake is allowed to drop directly into disposal bins with assistance of gravity or via mechanical scrapping<br>• Workers' training on good work practices |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 04 | Addition of binder reagent to stabilise and fix the filter cake | Toxic dust generated when reagents are added to filter cake | Exposure to toxic substances may result in irritation of the skin, eyes or respiratory system, or other ill health | • Provide local exhaust ventilation to control dust exposure<br>• Conduct regular monitoring of workers' exposure to toxic substances |
| 05 | Replace filled disposal bin with empty one | Toxic vapours and heavy metal dust released from filter cakes | Exposure to toxic substances may result in irritation of the skin, eyes or respiratory system, or other ill health | • Filled disposal bins are covered to minimise evaporation of toxic vapours and dust<br>• Blowers are installed to increase airflow in work area and reduce odours<br>• Wearing of chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges<br>• Conduct regular monitoring of workers' exposure to toxic substances |
| 06 | Repair and Maintenance: Worker separates filter plates for cleaning and resetting of press | Moving parts | Limbs caught between moving parts | • De-energise the filter press before working on it<br>• Implementation of Lock-out and Tag Out (LOTO) procedures for maintenance work |
| | | Toxic solvent vapours | Exposure to toxic solvent vapours can result in ill health | • Wearing of chemical resistant and impervious gloves, overalls and boots, safety goggles or face shields, and respirators fitted with the appropriate cartridges |

# Stabilisation and Fixation Systems

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Add binding agent or polymer to de-watered sludge | Excessive exposure to hazardous substances generated from reactions among different types of waste | Release of unexpected toxic gases due to uncontrolled side reactions<br>Explosive reactions<br>Death<br>Body injuries<br>Damage to machines, equipment, property<br>Eye injuries, irritation<br>Skin burns, rash<br>Excessive skin absorption of chemicals | • Automated closed waste treatment system<br>• Install enclosed system with fixed piping<br>• Conduct laboratory testing prior to treatment<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Excessive inhalation of dust particulates and powders generated during mixing of binding agents with sludge cakes | Occupational lung diseases<br>Respiratory illnesses<br>Respiratory discomfort | • Add water to powders instead of powders to water<br>• Install a sprinkler system to wet powders<br>• Avoid manual mixing of the powders with water<br>• Do the mixing in an enclosed area with adequate and effective local exhaust ventilation (LEV)<br>• Use chemical resistant overalls, chemical goggles and /or faceshields (as appropriate), impervious gloves and chemical boots<br>• Use respirators with cartridges / canisters that protect against dust particles and particulates |

# Evaporation, Distillation and Condensation (Solvent Recycling)

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Solvent recycling | Flammable vapours in the explosive range with an ignition source | Fire / explosion<br><br>Deaths<br><br>Bodily injuries<br><br>Burns | • Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants like organic vapours, volatile hydrocarbons<br><br>• Install blowers to increase airflow in the work area<br><br>• Enclose the entire evaporation and condensation unit in a closed loop system<br><br>• Install flammable vapour monitors / detectors<br><br>• For the drumming process, provide displaced vapour control equipment. Displaced vapour control equipment may include:<br>- A return line to the condenser unit or,<br>- Ducting to direct displaced vapours to an exhaust with an activated carbon filter<br><br>• Establish and implement safe work procedures<br><br>• Provide and attend training on hazards, safe work procedures, use of control measures<br><br>• Place warning signs in work areas<br><br>• Restrict access to waste treatment areas<br><br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| | | Excessive exposure to organic vapours generated during solvent recycling | Chemical poisoning<br><br>Occupational diseases | • Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants like organic vapours, volatile hydrocarbons<br><br>• Install blowers to increase airflow in the work area<br><br>• Enclose the entire evaporation and condensation unit in a closed loop system<br><br>• For the drumming process, provide displaced vapour control equipment. Displaced vapour control equipment may include:<br>- A return line to the condenser unit or,<br>- Ducting to direct displaced vapours to an exhaust with an activated carbon filter<br><br>• Establish and implement safe work procedures<br><br>• Conduct regular monitoring of employees' exposures to airborne organic vapours<br><br>• Conduct regular medical examinations of employees' health<br><br>• Provide and attend training on hazards, safe work procedures, use of control measures<br><br>• Place warning signs in work areas<br><br>• Restrict access to waste treatment areas<br><br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

# Incineration

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 01 | Mixing of waste prior to incineration | Flammable vapours in the explosive range with an ignition source | Fire / explosion<br>Deaths<br>Bodily injuries<br>Burns | • Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants like organic vapours and volatile hydrocarbons<br>• Install blowers to increase airflow in the work area<br>• Install flammable vapour monitors / detectors<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Excessive exposure to organic vapours from organic vapours mists generated during mixing | Chemical poisoning<br>Occupational diseases | • Install blender tanks instead of mixing manually<br>• Install effective local exhaust ventilation (LEV) systems to remove airborne contaminants like organic vapours and volatile hydrocarbons<br>• Install blowers to increase airflow in the work area<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

| No. | Work Activity | Possible Hazards | Possible Accidents / Ill Health | Possible Risk Control Measures |
|---|---|---|---|---|
| 02 | Incineration of waste | Flammable vapours in the explosive range with an ignition source | Fire / explosion<br>Deaths<br>Bodily injuries<br>Burns | • Install a flame failure detection system<br>• In the event of flame failure, purge any flammable gas mixture in the furnace and combustion spaces before re-lighting<br>• Install blowers to increase airflow in the work area<br>• Install flammable vapour monitors / detectors<br>• Establish and implement safe work procedures<br>• Provide and attend training on hazards, safe work procedures, use of control measures<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |
| | | Excessive heat stress | Heat stroke<br>Heat exhaustion | • Install blowers to increase airflow in the work area<br>• Establish and implement safe work procedures<br>• Establish adequate rest / breaks in work schedule<br>• Provide adequate supply of drinking water<br>• Provide and attend training on heat stress hazards, symptoms of heat stress, safe work procedures, use of control measures<br>• Place warning signs in work areas<br>• Restrict access to waste treatment areas<br>• Provide, use and maintain PPE (impervious gloves, aprons, face shield, goggles, respirators, safety boots) |

This material is not intended to be an exhaustive list of hazards and control measures for the activities listed below. Companies are to conduct risk assessment on the work activities specific to their workplaces by identifying the hazards, evaluating the risk and determining suitable control measures where appropriate. References should be made to the relevant regulations and code of practices when in doubt.

# References

**Ministry of Manpower, Occupational Safety and Health Division**
http://www.mom.gov.sg/oshd

**National Environment Agency**
http://www.nea.gov.sg

**Singapore Civil Defence Force**
http://www.scdf.gov.sg

**SPRING Singapore**
http://www.spring.gov.sg

**Workplace Safety and Health Act (WSHA)**
http://statutes.agc.gov.sg

**NIOSH Pocket Guide to Chemical Hazards**
http://www.cdc.gov/niosh/npg/npg

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