

Guidelines
for
Hazardous waste
PART II

Industry- specific information

**under particular consideration of framework conditions in India and
Vietnam**

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1. Introduction and how to use the following chapter

The second part of these guidelines gives specific information about waste streams, the risks of hazardous substances, and how to handle hazardous waste in the following industries:

- Casting of metals
- Metallurgical industry
- Chemical and agrochemical industry
- Production of paper and cardboard
- Production and application of fibrocement

The main aim of the guidelines is to prevent risks to employees from hazardous waste. Therefore, in addition to information on reducing hazardous fractions, the second part of each chapter devoted to a particular industry also includes general aspects concerning handling, disposal and prevention. In other words, each chapter is completely autonomous and has the following structure.

- A Industry
 - A.1 Economic characteristics
 - A.2 Processes
 - A.3 Hazardous materials
 - A.4 Waste reduction options
 - A.5 Handling, disposal and prevention: general aspects
 - A.6 Further literature and links
 - A.7 Conclusions
 - A.8 Case study

Apart from decreasing risks for employees and the environment, reducing waste has many other advantages:

- Lower waste disposal costs
- Lower expenditure on energy, water and raw materials
- Reduced operating costs
- Improved public image
- Income generated from saleable waste

Finally, the case studies provide several examples of problems involving hazardous compounds in industry, outline ways of preventing risks, and suggest initial steps towards cleaner production. Each chapter closes with a summary.

2. General information on hazardous waste

Did you know that you always remain responsible for the hazardous waste you generate? By learning more about hazardous waste management, you can eliminate some of the worries associated with the liability. Sending your hazardous waste off-site for proper management is expensive. These costs will only increase as time goes on and as regulations become stricter. This means that learning about proper waste management not only helps the environment, but also your budget.

2.1. What is a hazardous waste?

Waste considered as hazardous has chemical, physical or biological characteristics that require precautionary measures for handling, treatment and disposal to avoid dangers and risks to human health and the environment.

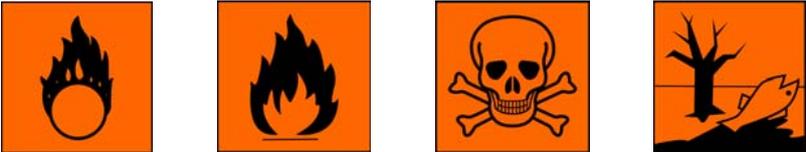
Nevertheless, the definition and exact classification of hazardous waste is laid differently by individual national legal systems and technical requirements.

2.2. Properties of hazardous waste

There is a large variety of waste that can be considered as “hazardous”. Hazardous Waste can be in the form of solids, liquids, contained in gaseous material or sludge. They can be the by-products of manufacturing processes or simply discarded commercial products, like cleaning fluids, battery acid or pesticides.

Table 1: United Nations Classification System for hazardous materials

<p><u>Class 1 Explosives</u></p> <p>With a mass explosion hazard With a projection hazard With predominantly a fire hazard With no significant blast hazard Very insensitive explosives Extremely insensitive explosives</p>	
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<p><u>Class 2 Gases</u> Compressed, liquefied, dissolved and toxic gases</p>	
<p>Examples</p>	<p>Flammable Gas: acetylene, butane, hydrogen, aerosols Non-Flammable Gas: oxygen, nitrogen Poisonous Gas: fluorine, chlorine, hydrogen cyanide, aerosols of low toxicity Sprays</p>
<p>Symbols</p>	
<p>Dangers</p>	<p>Explosion possible through heat, fire or some other ignition source Dangers through leakage or poorly maintained containers Propane/butane is highly inflammable Waste can be water polluting</p>
<p>Safety</p>	<p>Do not crush container</p>

<p><u>Class 3</u> <u>Flammable liquids</u> Possible additional dangers: Toxic, corrosive or explosive</p>	
<p>Examples</p>	<p>Paints, solvents, petrol, used oil, substances from pickling, hardener based on Isocyanate, acetone, ethanol</p>
<p>Symbols</p>	
<p>Dangers</p>	<p>Contain volatile compounds Vapour from solvents are heavier than air Used oil contains often heavy metals Substances from pickling are highly corrosive Hardener based on isocyanate react with paint under production of heat Together with air they form explosive mixtures especially in closed containers and rooms Vapour can be poisonous or dazing Many liquids spoil water and cause thereby damage to the environment</p>

<u>Class 4.1</u> <u>Flammable solids</u>	
Examples	Sulphur, fat, wax, other solid waste containing flammable liquids, hydrocarbons, calcium carbide
Symbols	 
Dangers	Oil contaminated substances can contain heavy metals. Fire through heat, sparks or other ignition source possible, oil contaminated cloth can be self-inflammable waste can spoil water and cause thereby damage to the environment.
<u>Class 4.2</u> <u>Spontaneously combustible materials</u>	
Examples	Phosphorus, chemicals from laboratories
Symbols	 
Dangers	With oxidizing materials strong chemical reaction is possible Often toxic or development of toxic gases Self-inflammable and danger of dust explosion. Waste can spoil water and cause thereby damage to the environment
Safety for all flammable substances	Store in approved safety cans of cabinets Segregate from oxidizing acids and oxidizers Keep away from any source of ignition, such as flames, localized heat, or sparks Safety cans of drums containing flammable liquids should be grounded and bonded when being used. Keep fire-fighting equipment readily available. Have spill cleanup materials handy
<u>Class 4.3</u> <u>Dangerous when wet materials/Water-reactive substances</u>	
Examples	Calcium carbide, sodium, aluminium phosphide, lithium
Symbols	 
Dangers	React together with water explosive Can heat by themselves Evolving gases are often toxic and explosive Waste can spoil water and cause thereby damage to the environment
Safety	Store in a cool and dry place In case of fire keep water away

<p><u>Class 5.1</u> <u>Oxidizing substances</u> and <u>Class 5.2</u> <u>Organic peroxides</u></p>	 
Examples	Ammonium nitrate fertilizer, pool chlorine, hydrogen peroxide and other peroxides, potassium permanganate, chemicals from laboratories, salts of sulphates, chromic acid
Symbols	 
Dangers	<p>Together with flammable materials, they form explosive substances, sometimes-even self-inflammable.</p> <p>Toxic and corrosive</p> <p>Waste can spoil water and cause thereby damage to the environment.</p> <p>Peroxides can produce a lot of oxygen resulting in a potentially explosive situation.</p>
Safety	<p>Keep away from flammable and combustible materials (including paper and wood)</p> <p>Store in a cool and dry place</p> <p>Keep away from reducing agents like zinc, caustics/alkalis and organic acids</p>

<p><u>Class 6.1</u> <u>Toxic substances</u></p>	
Examples	Cyanide, arsenic, mercury and mercury containing waste, pesticides solid and liquids, halogenated solvents, methylene chloride (used as a paint stripper and a degreaser)
Symbols	  
Dangers	<p>Often volatile, toxic vapour</p> <p>Combination with other dangers like flammability or explosive is possible.</p> <p>Even at low dose damage through long term exposure possible</p> <p>Often carcinogen or mutagen</p> <p>Waste can spoil water and cause thereby damage to the environment.</p>

<p><u>Class 7</u> <u>Radioactive Materials</u></p>	
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<p><u>Class 8</u> <u>Corrosive substances</u></p>	
<p>Examples</p>	<p>Battery acids, all acids and bases, mercury, potassium hydroxide, caustic soda, cleaning agents</p>
<p>Symbols</p>	
<p>Dangers</p>	<p>Often volatile, danger of corrosive, irritant or toxic vapor. Through mixture, also with water chemical reactions are possible that cause explosion. Waste can spoil water and cause thereby damage to the environment</p>
<p>Safety</p>	<p>Segregate bases from acids Segregate oxidizing acids from organic acids and flammable and combustible materials Segregate acids from bases and active metals such as sodium, potassium, magnesium Segregate acids from chemicals such as sodium cyanide, iron sulphide etc. which could generate toxic gases upon contact Have neutralizers and solidifiers available in case of acid spills or caustic spills.</p>

<p><u>Class 9</u> <u>Miscellaneous hazardous materials/Products, Substances or Organisms</u></p>	
<p>Examples</p>	<p>Asbestos, electronic waste, batteries</p>
<p>Dangers</p>	<p>Some are carcinogen, Contain often heavy metals</p>

2.3. Sources of hazardous waste

Most hazardous waste is generated by industries; including car repair shops; the construction, ceramics and printing industries; manufacturers of chemicals, paper, leather, cleaning agents, cosmetics, and metals. Mixtures of hazardous and non-hazardous waste are also labelled hazardous. To help you identify some of the waste streams common to your busi-

ness, see the following table to find a list of typical hazardous wastes generated by small- and medium size businesses. If your waste is hazardous, you will need to manage it according to appropriate regulations.

Table 2: Typical hazardous waste generated by small- and medium size businesses

Typical Hazardous Waste Generated by Small- and Medium Size Businesses		
Type of Business	How Generated	Typical Wastes
Dry-cleaning and Laundry Plants	Commercial dry-cleaning processes	Still residues from solvent distillation, spent filter cartridges, cooked powder residue, spent solvents, unused perchloroethylene
Furniture/Wood Manufacturing and Refinishing	Wood cleaning and wax removal, refinishing/stripping, staining, painting, finishing, brush cleaning and spray brush cleaning	Ignitable wastes, toxic wastes, solvent wastes, paint wastes
Construction	Paint preparation and painting, carpentry and floor work, other specialty contracting activities, heavy construction, wrecking and demolition, vehicle and equipment maintenance for construction activities	Ignitable wastes, toxic wastes, solvent wastes, paint wastes, used oil, acids/bases
Vehicle Maintenance	Degreasing, rust removal, paint preparation, spray booth, spray guns, brush cleaning, paint removal, tank cleanout, installing lead-acid, batteries, oil and fluid replacement	Acids/bases, solvents, ignitable wastes, toxic wastes, paint wastes, batteries, used oil, unused cleaning chemicals
Printing and Allied Industries	Plate preparation, stencil preparation for screen printing, photo processing, printing, cleanup	Acids/bases, heavy metal wastes, solvents, toxic wastes, ink, unused chemicals
Equipment Repair	Degreasing, equipment cleaning, rust removal, paint preparation, painting, paint removal, spray booth, spray guns, and brush cleaning.	Acids/bases, toxic wastes, ignitable wastes, paint wastes, solvents
Pesticide End-Users/Application Services	Pesticide application and cleanup	Used/unused pesticides, solvent, wastes, ignitable wastes, contaminated soil (from spills), contaminated rinse water, empty containers
Educational and Vocational Shops	Automobile engine and body repair, metalworking, graphic arts-plate preparation, woodworking	Ignitable wastes, solvent wastes, acids/bases, paint wastes
Photo Processing	Processing and developing negatives / prints, stabilization system cleaning	Acid regenerants, cleaners, ignitable wastes, silver
Leather Manufacturing	Hair removal, bating, soaking, tanning, buffing, and dyeing	Acids/bases, ignitable wastes, toxic wastes, solvent wastes, unused chemicals

2.4. Dangers of hazardous waste

One important objective of this handbook is to inform you of the risks and potential hazards posed by many products used. Whether working in the manufacture, in the garage, in the office, in the kitchen, or out in the yard, important decisions must be made to ensure not only that the proper products are used, but that they are used safely with regard to environmental and human health. The following list shows the main properties of hazardous waste (not all apply at once).

2.4.1. Short term hazards

Short term hazard are sorts of physical hazards and health hazards, especially:

- Corrosive
- High inflammably or risk of explosion
- Water reactive
- Oxidizing
- Toxicity by ingestion, inhalation or skin absorption
- Skin or eye contact hazards, irritant

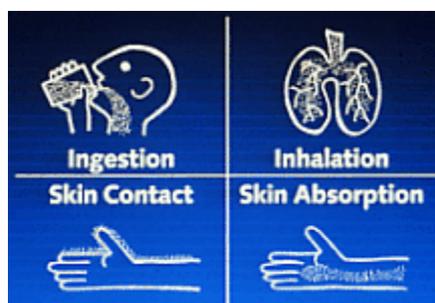


Figure 1: Pathways of toxic entering human and animal bodies¹

Examples of common products are paint cleaners, gasoline, drain cleaners and chlorine bleach. Products may be quite safe when used according to instructions, but still be capable of easy misuse. Carefully examine product labels for written warnings as well as warning symbols.

Definitions below are terms that may be helpful in understanding the mentioned potential dangers.²

¹ Source: Hazardous waste, Purdue University

² Hazardous waste, EPA region 5 and agricultural & biological engineering, Purdue University

Toxicity

Toxicity is the quality, relative degree, or specific degree of being toxic or poisonous, which is capable of causing injury or death through ingestion, inhalation, or absorption. Some toxic substances are known to cause cancer (carcinogens), genetic damage (mutagens), and fetal harm (teratogens).

Acute effects

Effects that are felt soon afterwards exposure, usually within 24 hours and in some cases almost immediately characterized by severe symptoms with a sudden onset. Skin burns and disfigurement from splashing battery acid, fire caused by an exploding aerosol can stored too close to a stove, or an overnight fish kill resulting from dumping toxicants down the storm sewer are examples of acute dangers caused by hazardous products.

Chronic effects

Effects that are gradual and occur through repeated exposure over an extended period of time. Headache and trouble thinking caused by carbon monoxide leaking from an appliance, allergic reactions that occur each time you open the cupboard where aromatic cleaning products are stored, or the slow pollution of ground water resulting from the disposal of small amounts of herbicide down a sinkhole every growing season are examples of chronic dangers caused by hazardous substances. Some of the most common chronic health effects are liver or kidney damage, central nervous system damage, cancer and birth defects.

2.4.2. Long term hazards:

Long term hazards are:

- Risks to the environment, plants, animals and humans through long run or repeated exposure and through accumulation of toxic substances:
Carcinogen, reproductive toxin
- Accumulation of toxic substances in water bodies, groundwater and soil posing a long-run risk to agro- and aquaculture

Toxic compounds enter the environment in many ways and in many forms. Some are poured into sewers or onto the ground, some are carried in exhaust fumes from cars and factories, others may be taken as solids to landfills and dumps. Once in the environment, chemicals may undergo series of reactions forming new products, some of which may be toxic, and some of which may take on a new phase (solid, liquid, or gas). Compounds can also move from one environmental medium to another. Acid rain is an example of airborne toxics mov-

ing from one environmental medium- the air- to another –water. Toxics can thus reach humans and animals through variety of pathways. Toxics enter our bodies through ingestion (the mouth), inhalation (breathing), and dermal absorption (movement through the skin, including the eye tissues).

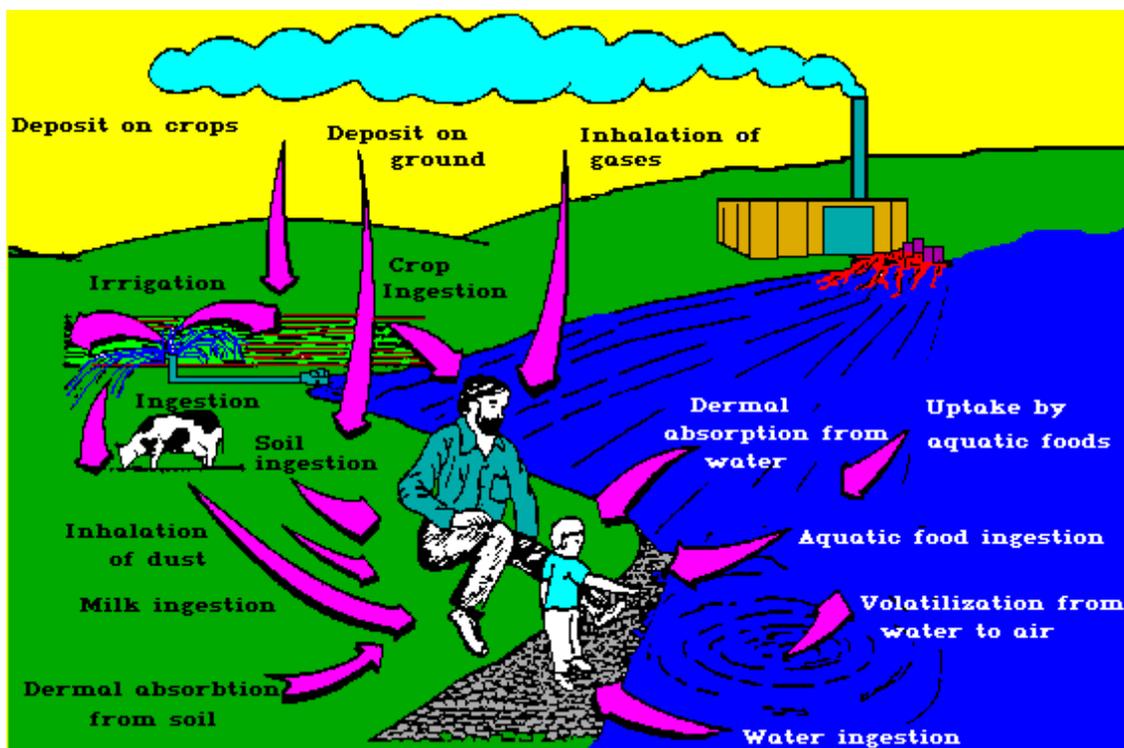


Figure 2: Contamination pathways³

The net accumulation by an organism of a chemical from its combined exposure to water, food, and sediment makes bioaccumulation occurrence. Species higher in the food net can be exposed to all the chemicals that lower-order species accumulate. Being at the top of the food chain, humans are susceptible to high levels of bio accumulated toxins in their diets. Lifelong exposure to even low-level concentrations of contaminants from species lower in the food can cause serious health problems, including cancer, birth defects, birth complications, and nervous and mental disorders. Pesticides and heavy metals are common sources of contamination by bioaccumulation.⁴

The time span in which long-term effects become noticeable pose a great risk to society that have not taken the necessary measures to handle or prevent this problem. Hence, it is important to acknowledge the long and short-term effects of hazardous waste appropriately.

³ (Source: Hazardous waste, Purdue University)

⁴ Hazardous waste, EPA region 5 and agricultural & biological engineering, Purdue University

2.5. Legal framework on hazardous waste

2.5.1. Legal and administrative requirements

An effective and comprehensive disposal system for hazardous waste must be based on some basic requirements and enforced by law. This leads us to identify what are the legislative requirements needed for this purpose. The following general conditions should be considered when elaborating a legal framework for hazardous waste management:

- The basic principles of hazardous waste should be legally binding in the aspects of waste reduction and re-utilization where economically and technically feasible.
- Hazardous waste should be defined by law as to set the scope of the legislation. Such definition should be rather general allowing for detailed listing to stationary regulations or other legal instruments as appropriate.
- The legislation can only set a framework and should refrain from regulating disposal processes in detail unless technical and scientific evidence is sufficient.
- The legislation should give due regard to predisposal options and provide adequate legal instruments for these predisposal options to be enforced.
- The legislation on hazardous waste should not necessarily be specialized legislation but should be incorporated and harmonized with legislation on hazardous substances.
- It is important to attain a comprehensive legislation that considers the “life cycle” of chemicals. Hence, attention should be put on aspects of productions, use, transport, and disposal, for the legislation to provide real protection to the environment and public health.

Nevertheless, no legislation will be effective without a comprehensive control mechanism. There exist three basic groups of measure to control hazardous waste management.

- The control of waste generating processes.
Under this group, waste generating premises are adequate targets of control. The aspects to be considered in these premises are the proper use of materials, processes, operations and maintenance procedures, recycle of waste activities, recovery of valuable material and on-site treatment of waste for mass reduction, dewatering, detoxification or transformation into immobile and/or chemically inert form.

- Licensing procedures for potentially hazardous activities.
Applications for a license prior to any activity involving hazardous waste should be obligatory by law. These licenses could be applied to activities such as transport, storage, treatment and disposal.
- Cradle-to-grave system of notification.
This measure would serve to interlink the control across different activities.

2.5.2. Legislation in India

The legal framework in India dealing with Hazardous Waste consists of the following statutes:

1. Environment (Protection) Act, 1986:
2. Environment (Protection) Rules, 1986:
3. Hazardous Wastes (Management and Handling) Rules, 1989:
4. Hazardous Waste (Management and Handling) Amending Rules, 2000:
5. Hazardous Waste (Management and Handling) Amending Rules, 2003:
6. Batteries (Management and Handling) Rules, 2001:
7. Municipal Solid Wastes (Management and Handling) Rules, 2000:
8. Bio-Medical Waste (Management and Handling) Rules, 1998:
9. Bio-Medical Waste (Management and Handling) Amendment Rules, 2003:
10. Recycled Plastics Manufacture and Usage Rules, 1999:
11. Manufacture, Storage and Import of Hazardous Chemical Rules, 1989:
12. Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996:
13. Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro-Organisms Genetically Engineered Organisms or Cells, 1989:
14. Public Liability Insurance Act, 1991:

Other relevant legislation:

1. Water (Prevention and Control of Pollution) Act, 1974:
2. Atomic Energy Act, 1962:
3. Customs Act, 1962

2.6. Classification of hazardous waste

2.6.1. Introduction to the Basel convention

Adopted in 1989, the Basel convention followed increasing international attention to the problem of hazardous waste handling and disposal. It aims mainly at two parallel objectives. The first one is the reduction of hazardous waste through the implementation of environmentally friendly technologies and methods. The second one is to prevent imports and exports of hazardous waste, in particular those with destination to developing countries with less rigorous legislations on the issue. The Basel convention also sets the basis for countries to cooperate with one another and in terms of technological and environmental expertise.

The Basel convention acts as a reference point for national legislation providing a definition of Hazardous Waste. This list can be updated and added to by each state under their national legislation. The Basel convention has been a reference point for many national regulations. Such is the case of India, where the Hazardous Waste Amending Rules (2000). It has also been relied upon in the landmark judgment *Research Foundation for Science Technology and Natural Resources Policy v. Union of India*⁵ that became a foundation case for hazardous waste policy in India

2.6.2. Other international schemes on hazardous waste

Rio declaration on Environment and Development: The United Nations Conference on Environment and Development, June 1992

The Rio Declaration constitutes itself as a set of principles that enunciate environmental protection with principles such as sustainable development, which is the central thrust of the Declaration. Among its most important principle, we can highlight Principle 16 (referring to the utmost importance or irreversible damage), Principle 16 (referring to the internalization of environmental costs and use of economic instruments), and Principle 19 (prevention of transboundary environmental effects through closer coordination between states).

The Rio Declaration has been referred to in the judgment *Research Foundation for Science Technology and Natural Resources Policy v. Union of India*⁶ delivered by Y. K. Sabharwal J, especially with regard to the precautionary principle and the polluter pays principle. They

⁵ Writ Petition (Civil) 657 of 1995 [With SLP (C) No.16175 of 1997 and Civil Appeal No.7660 of 1997].

⁶ Writ Petition (Civil) 657 of 1995 [With SLP (C) No.16175 of 1997 and Civil Appeal No.7660 of 1997].

have also been referred to in the case *A.P. Pollution Control Board v. Prof. M.V. Nayudu (Retd.) and Ors*⁷ that cements the above principles and their applicability in India.

Stockholm Convention on Persistent Organic Pollutant, 2001

The Stockholm convention echoes some of the principles of the Rio Declaration and aims towards global cooperation and sustainable development. The most relevant provision is Article 6- Measures to reduce or eliminate releases from stockpiles and wastes. This Article also states that the parties included in this convention must keep the Basel convention in mind and cooperate as closely with one another. This article also deals with the abolition of transboundary movement of wastes and stresses on the need to develop ways of reducing them.

Although this convention has not been specifically referred to in any text of judgment, the fact that it is in relation to the Basel convention and the Rio Declaration grants it some validity in India.

The International Maritime Organization's International Convention on the Prevention of Pollution of Ships (MARPOL), 1973

Adopted on 2 November 1973, MARPOL takes into consideration pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage. The aim of this convention was to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimization of accidental discharge of such substances. A new and important feature of the 1973 Convention was the concept of "special areas" which are considered to be so vulnerable to pollution by oil that oil discharges within them have been completely prohibited, with minor and well defined exceptions. The 1973 Convention identified the Mediterranean Sea, the Black Sea, and the Baltic Sea, the Red Sea and the Gulfs area as special areas. Nevertheless, it must be noted that this legislation applies only to activities in port areas. All other regions of the sea are ignored. Also, the Act is too basic and does not enter into necessary specifications. However, if legislation could be enacted based on MARPOL as well as the above Act, a suitable legislation can be enacted. India is also a party to this treaty, and even though there is no specific legislation made after this treaty, the Indian Ports Act, 1908 is applicable to some extent.

⁷ (1996) 5 SCC 718.

International Convention for the Control and Management of Ships' Ballast Water and Sediments, 13 February 2004

Its objective is to prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments. Parties are given the right to take more stringent measures with respect to the prevention, reduction or elimination of the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments, consistent with international law. Parties should ensure that ballast water management practices do not cause greater harm than they prevent to their environment, human health, property or resources, or those of other States [International Maritime Organization, 2002].

This treaty has not yet been ratified by India; though the National Institute of Oceanography has recognized the health and environmental hazards of ballast water in port areas [Goel, 2006] However, the Indian Ports Act 1908 could be applied for the same purpose as it clearly includes ballast within its ambit.

3. Why hazardous waste is to manage

The levels of dangerous wastes grow. Industries and individuals continue to be largely unaware of this major environmental problem. As a result, many people and industries are failing to prevent the creation of hazardous waste or to limit the negative effects it produces. Individual often throw out goods without realizing that they are headed for a landfill and could be dangerous for the environment. No matter where people put these hazardous waste materials, there is always a chance that they could find their way into the ground, and eventually into our bodies.

Hazardous waste is produced both on a huge scale by major industries and on a relatively tiny scale by individuals. No matter where it comes from, waste can be dangerous. One of the main causes of the abundance of hazardous waste is that people do not realize how large a problem it is. Because it can be simply removed and sent to a landfill, it is often assumed that the problem ends there. Industries have often displayed an unwillingness to find ways to deal with hazardous waste because of the expenses associated with it.

Many industries and governments create crude landfills to store waste, and often just dump waste chemicals into nearby bodies of water. Chemicals used for industrial processes often create dangerous forms of waste. The amount of these chemicals has risen heavily in the past, as more areas of the world industrialize and new products are produced. Over 80000 different chemicals are used in industries worldwide. Often, it is difficult and expensive to get rid of these chemicals and to store them in a way that does not endanger human life or the environment. Obviously, not all of these chemicals are dangerous, but many are and they do create serious problems.

Environmental pollution and public health risks due to improper handling, storage and illegal disposal of hazardous waste can be reduced substantially once adequate facilities and procedures for hazardous waste management will be in place. Especially children, women and poor parts of the population are negatively affected by improper disposal and handling of hazardous waste, in particular by small- and medium size companies. Most of the urban poor live in the vicinity of polluted drainage canals, contaminated sites and pollution creating companies. In many cases, the long-term health effects of hazardous waste exposure may not be fully realized, thus meriting precautionary activities. Improperly managed hazardous wastes also threaten ecosystems and limit future availability of our soil, air, groundwater, and surface water resources for meeting agricultural, industrial, commercial, and dwelling needs.

In general, the potential effects of hazardous waste on the environment include:

- Contamination of ground water by infiltration (e.g. from landfill leachate)
- Contamination of surface waters (streams, rivers, lakes, etc.) by direct disposal or run-off
- Short-or long-term contamination of solids and sediments

- Emissions of contaminants into the air from inadequate incineration processes, burning at landfills, and industrial processes

Hazardous waste passes through one or several of the following phases: generation, transport, storage, treatment, and disposal. Hazardous waste can be discharged to the environment during any one of these phases. Any such discharge has the potential to cause an adverse environmental effect and ecosystems, including people and communities. There are three potential exposure routes:

- Permitted discharges from generation/treatment/storage/disposal facilities
- Accidental discharges during transport, or at any point in the hazardous waste life-path
- Illegal discharge

Pollution prevention is the best approach for dealing with hazardous waste for many handlers of hazardous waste for many handlers of hazardous material and generators of hazardous waste. Pollution prevention simply stated involves not creating hazardous waste in the first place. While the elimination or reduction of all wastes may not currently be feasible, making as little hazardous waste as possible in your best interest.

The hazardous waste you generate could create liabilities for your company in more ways than one.

- Cleanup costs. You remain legally liable for the hazardous waste you generate from “cradle to grave”. This responsibility continues even if the waste was shipped to an approved recycling, treatment, or disposal facility. You may still become a responsible party to a cleanup if your waste contributes to contamination of the environment. Of course, your liability in this situation may be a lot less than if you yourself improperly disposed of the waste.
- Penalties for non-compliance. You may be assessed fines for non-compliance with the hazardous waste regulations.
- Higher production costs. You may literally be throwing money down the drain if the raw materials you purchase end up as waste. You pay for this in two ways by needing to purchase more of the raw materials and by paying increased treatment or disposal costs for waste.

3.1. Examples of Disaster Involving Hazardous Materials

3.1.1. Bhopal Disaster⁸

Many as the worst industrial disaster in history claim the Bhopal Disaster of 1984. It was caused by the accidental release of 40 tons of methyl isocyanate (MIC) from a Union Carbide India, Limited (UCIL, now known as Eveready Industries India, Limited) pesticide plant located in the heart of the city of Bhopal, in the Indian state of Madhya Pradesh.

In the early hours of December 3, 1984, a holding tank with stored MIC overheated and released toxic heavier-than-air MIC gas, which rolled along the ground through the surrounding streets killing thousands outright. The transportation system in the city collapsed and many people were trampled trying to escape. The gases also injured anywhere from 150,000 to 600,000 people, at least 15,000 of whom later died.

The majority of deaths and serious injuries were related to pulmonary but the gas caused a wide variety of other ailments. Signs and symptoms of methyl isocyanate normally include cough, dyspnea, chest pain, lacrimation, eyelid edema, and unconsciousness. These effects might progress over the next 24 to 72 hours to include acute lung injury, cardiac arrest, and death. Because of the hypothesized reactions that took place within the storage tank and in the surrounding atmosphere, it is thought that apart from MIC, phosgene, and hydrogen cyanide along with other poisonous gases all played a significant role in this disaster.

The company never provided information on the exact chemical mixture, but blood and viscera of some victims showed cherry-red color characteristic in acute cyanide poisoning. A series of studies made five years later showed that many of the survivors were still suffering from one or several of the following ailments: partial or complete blindness, gastrointestinal disorders, impaired immune systems, post traumatic stress disorders, and menstrual problems in women. A rise in spontaneous abortions, stillbirths, and offspring with genetic defects was also noted. In addition, a BBC investigation conducted in November 2004 confirmed that contamination is still present.

3.1.1.1. Background of the Disaster

The Union Carbide plant was established in 1969 and had expanded to produce carbaryl in 1979; MIC is an intermediate in carbaryl manufacture. The chemical accident was caused by the introduction of water into MIC holding tank E610, due to slip-bind water isolation plates being excluded from an adjacent tank's maintenance procedure. The resulting reaction generated a major increase in the heat of liquid inside the tank (to over 200°C). The MIC then

⁸ Fact of the story taken from the Wikipedia website (http://en.wikipedia.org/wiki/Bhopal_disaster)

gave off a large volume of toxic gas, forcing the emergency release of pressure. There were many factors that contributed to this accident, all of which were preventable. In chronological order, they were:

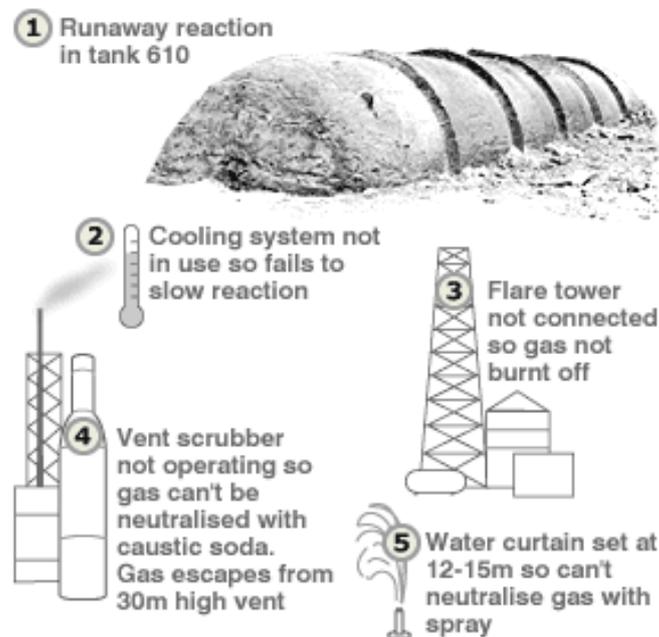


Figure 3: Leakages⁹

- Recent documents, obtained through discovery in the course of a lawsuit against Union Carbide for environmental contamination before a New York Federal District Court revealed that Carbide had exported "untested, unproven technology" to the Indian plant.
- Unlike Union Carbide plants in the USA, its Indian subsidiary plants were not prepared for problems. No action plans had been established to cope with incidents of this magnitude. This included not informing local authorities of the dangers of chemicals used and manufactured at Bhopal.
- Reports issued months before the incident by scientists within the Union Carbide Corporation warned of the possibility of an accident almost identical to that, which occurred in Bhopal. The reports were ignored outright and never made it to senior staff.
- Due to falling sales, staff had been laid off and safety checks became less and less frequent.
- Slip-bind plates that prevent water from pipes being cleaned leaking into the MIC tanks via faulty valves were not installed. Their installation had not been included on the cleaning checklist.
- At the time of the event, the MIC tank refrigeration unit was disabled to save money, and some of its coolant was being used elsewhere. A simple press of a button in the control

⁹ 3 (Source: India Today)

room would have activated it to at least use the remaining coolant, but staff overlooked this.

- The gas scrubber was placed on standby, and therefore did not attempt to clean escaping gases with sodium hydroxide (caustic soda), which may have brought the concentration down to a safe level.
- The water curtain that may have reduced the concentration of the gas was only set to ~13 m and did not reach the gas; it was not designed to contain a leak of such magnitude.
- Though the audible external alarm was activated to warn the residents of Bhopal, it was quickly silenced to avoid causing panic among the residents. Thus, many continued to sleep, unaware of the unfolding drama, and those that had woken assumed any problem had been sorted.
- The flare tower used to burn off gases before they are allowed to escape into the air was in operational pending repairs.
- Doctors and hospitals were not informed of proper treatment methods for MIC gas inhalation. They were told to simply give cough medicine and eye drops to their patients.

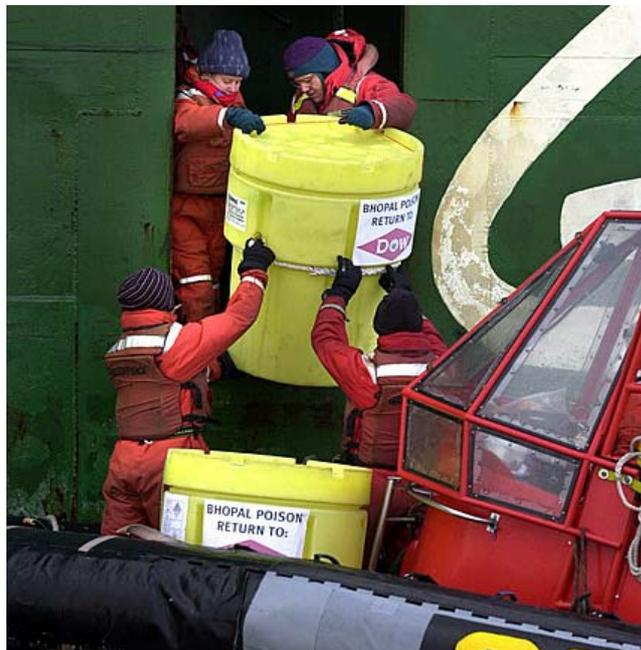


Figure 4: Poisonous waste collected from the Bhopal disaster at the former Union Carbide plant¹⁰

Dow's subsidiary, Union Carbide, denies these allegations on its website (<http://www.bhopal.com>) dedicated to the tragedy. It cites an investigation conducted by the engineering consulting firm Arthur D. Little, which concluded that, a single employee secretly

¹⁰ (Source: Bhopal Disaster, Greenpeace website)

and deliberately introduced a large amount of water into the MIC tank by removing a meter and connecting a water hose directly to the tank through the metering port. Carbide claims such a large amount of water could not have found its way into the tank by accident, and safety systems were not designed to deal with intentional sabotage. UC says that the rest of the plant staff falsified numerous records to distance themselves from the incident, and that the Indian Government impeded its investigation and declined to prosecute the employee responsible, presumably because that would weaken its allegations of negligence against Union Carbide.

3.1.2. Itai- itai Disease¹¹

The itai-itai disease was the first cadmium poisoning in the world in Toyama Prefecture, Japan in 1950. The cadmium poisoning caused softening of the bones and kidney failures. The name of the disease comes from the painful screams due to the severe pain in the joints and the spine. The cadmium was released in the rivers by mining companies in the mountains. The mining companies were successfully sued for the damage. Itai-itai disease is known as one of the Four Big Pollution Disease of Japan.

3.1.2.1. Cause

Itai-itai disease was caused by cadmium poisoning due to mining in Toyama Prefecture. The earliest records of mining for gold in the area dated back to 710. Regular mining for silver started in 1589, and soon thereafter, mining for lead, copper, and zinc began. Increased demand for raw materials during the Russo-Japanese War and World War I, as well as new mining technologies from Europe, increased the output of the mines, putting the Kamioka Mines in Toyama among the world's top mines. Production increased even more before World War II. Starting in 1910 and continuing through 1945, cadmium was released in significant quantities by mining operations, and the disease first appeared around 1912. Prior to World War II, the mining, controlled by the Mitsui Mining and Smelting Co., Ltd., increased to satisfy the wartime demand. This subsequently increased the pollution of the Jinzu River and its tributaries. The river was used mainly for irrigation of rice fields, but also for drinking water, washing, fishing, and other uses by downstream populations.

¹¹ Fact of the case taken from the Wikipedia website (<http://en.wikipedia.org/wiki/itai-itai>)

3.1.2.2. Effect

Due to the cadmium poisoning, the fish in the river started to die, and the rice irrigated with river water did not grow well. The cadmium and other heavy metals accumulated at the bottom of the river and in the water of the river. This water was then used to irrigate the rice fields. The rice absorbed all heavy metals, but especially the cadmium. The cadmium accumulated in the people eating contaminated rice. The population complained to the Mitsui Mining and Smelting Company about the pollution, which subsequently built a basin to store the mining wastewater before leading it into the river. This, however, was too little too late, and many people already were very sick. The causes of the poisoning were not well understood, and up to 1946, it was thought to be simply a regional disease, or possibly a type of bacteria. Medical test started in the 1940s and 1950s, searching for the cause of the disease. Initially, it was expected to be lead poisoning due to the lead mining upstream. Only in 1955 did Dr. Ogino and his colleagues suspect cadmium as the cause of the disease. Dr. Ogino also coined the term itai-itai disease. The Toyama Prefecture also started an investigation in 1961, determining that the Kamioka Mining Station of the Mitsui Mining and Smelting Company caused the cadmium pollution, and that the worst affected areas were 30 km downstream of the mine. In 1968, the Ministry of Health and Welfare issued a statement about the symptoms of the itai-itai disease caused by the cadmium poisoning.

3.1.2.3. Economic Costs

In 1992, the average annual health expense compensation was 743 million yen. Agricultural damage was compensated with 1.75 billion yen per year, or a total of annually 2.518 billion yen. Another 620 million yen were invested annually to reduce further pollution of the river.

3.1.3. Minamata Disaster

Over 3,000 victims have been recognized as having “Minamata Disease”. It has taken some of these people over thirty years to receive compensation for this inconceivable event. In 1993, nearly forty years later, the Japanese courts were still resolving suitable compensation for the victims. Many people have lost their lives, suffered from physical deformities, or have had to live with the physical and emotional pain of “Minamata Disease”. This suffering is all a result of the very wrongful and negligent acts of the Chisso Corporation who dumped mercury into the seawater and poisoned the people of Japan.

Minamata is a small factory town dominated by the Chisso Corporation. The town faces the Shiranui Sea, and Minamata Bay is part of this sea. In Japanese, “Chisso” means nitrogen. The Chisso Corporation was once a fertilizer and carbide company, and gradually advanced to a petrochemical and plastic-maker company. From 1932 to 1968, Chisso Corporation, a

company located in Kumamoto Japan, dumped an estimated 27 tons of mercury compounds into Minamata Bay. Kumamoto is a small town about 570 miles southwest of Tokyo. The town consists of mostly farmers and fisherman. When Chisso Corporation dumped this massive amount of mercury into the bay, thousands of people whose normal diet included fish from the bay, unexpectedly developed symptoms of methyl mercury poisoning. The illness became known as the "Minamata Disease". The mercury poisoning resulted from years of environmental destruction and neglect from Chisso Corporation.

Chisso Corporation started developing plastics, drugs, and perfumes through the use of a chemical called acetaldehyde in 1932. Acetaldehyde is produced using mercury as a compound, and was key component in the production of their products. The company was considered an economic success in Japan, particularly because it was one industry that maintained development despite Japan's suffering throughout and right after W.W.II. As other companies economically ripened during Japan's post-war period, so did the Chisso Corporation. Sales augmented with Japan's economic success. In addition, Chisso Corporation's sale increased dramatically, considering Chisso was the only manufacturer of a primary chemical called D.O.P, a plasticizer (dietyl phthalate), having a monopoly on the chemical enabled Chisso to expand rapidly. Since Chisso Corporation was the main industry in the small Minamata town, the town's growth period from 1952 to 1960 paralleled Chisso's progress.



Figure 5: Pouring its wastes into the air and the waters, the Chisso chemical complex dominates the city of Minamata

Not until the mid-1950 did people begin to notice a "strange disease". Victims were diagnosed as having a degeneration of their nervous systems. Numbness occurred in their limbs and lips. Their speech became slurred, and their vision constricted. Some people had serious brain damage, while others lapsed into unconsciousness or suffered from involuntary movements. Furthermore, some victims were thought to be crazy when they began to uncon-

trollably shout. People thought the cats were going insane when they witnessed "suicides" by the cats. Finally, birds were strangely dropping from the sky. Series of these unexplainable occurrences were bringing panic to Minamata. Dr. Hajime Hosokawa from the Chisso Corporation Hospital, reported on May 1, 1956 that, "an unclarified disease of the central nervous system has broken out". Dr. Hosokawa linked the fish diets to the disease, and soon investigators were promulgating that the sea was being polluted by poisons from the Chisso Corporation. The Chisso Corporation denied the accusations and maintained their production. However, by 1958, Chisso Corporation transferred their dumping from the Minamata Bay to the Minamata River hoping to diminish accusations toward the company.

The Minamata River flows past the town Hachimon, and into the Shiranui Sea. The people of this area also began developing the "strange disease" after a few months. The Kumamoto Prefecture government responded by imposing a ban, which allowed fisherman to "catch" fish, but not to "sell" fish from the bay. Since this was their main food source, the people continued to eat fish at home, but the ban released government officials from any responsibility for those who developed the illness. Finally, in July 1959, researchers from Kumamoto University concluded that organic mercury was the cause of the "Minamata Disease". A number of committees, of which Chisso Corporation employees were members, formed to research the problem. The committees denied this information and refuted the direct link of mercury to the strange disease. Finally, Dr. Hosokawa performed concealed cat experiments in front of the Chisso Corporation management, and illustrated the affects of mercury poisoning by feeding the cats acetaldehyde. Dr. Hosokawa was the first person who made a valiant effort in proving to Chisso Corporation that they were the ones accountable for the mercury poisoning. After the meeting with Chisso officials, Dr. Hosokawa was restricted from conducting any further research or experiments, and his findings were concealed by the corporation.

Chisso Corporation began to make deals with the victims of the "Minamata Disease". People who were desperate and legally ignorant signed contracts which stated that Chisso Corporation would pay them for their misfortunes, but would accept no responsibility. In fact, there was even a clause, which read, "if Chisso Corporation were later proven guilty, the company would not be liable for further compensation". The fishermen began protesting in 1959. They demanded compensation, but soon became intimidated by the threats of Chisso management. The victims feared that if they did not settle, they would never receive any kind of compensation. Chisso paid off some of the people while continuing to profit from increased sales. Chisso installed a "Cyclator" which was designed to treat wastewater. The management however, often ignored this crucial step in their production process. Not until 1968, did Chisso Corporation quit poisoning the waters in Minamata. The company was forced into court in 1969, and the only reason why the polluting stopped was simply because the method of mercury production became outdated. It was later determined in court that Chisso Corpo-

ration consistently polluted the water of Minamata Bay from 1932-1968 [TED Case Studies, 2006].

3.1.4. Seveso Disaster¹²

The Seveso disaster was an industrial accident that occurred on July 10, 1976 around mid-noon in a small chemical manufacturing plant approximately 25 km north of Milan in the Lombardy region in Italy. It resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in residential populations [Eskenazi et al., 2004], which gave rise to numerous scientific studies and standardized industrial safety regulations. The EU industrial safety regulations are known as the Seveso II Directives.

Many things about the exact circumstances of the accident are unknown and perhaps irrelevant. Fortunately, the Seveso disaster was a serious industrial accident that did not have grave consequences and there were no fatalities [Environmental Diseases, 2006]. Nevertheless, TCDD is a known carcinogen and one of the most toxic substances on earth. The accident exposed serious flaw in government response to industrial accidents. No human is known to have died from dioxin poisoning but its toxic effects have been documented in cases such as the Yusho disaster in Japan in 1968, the Yucheng disaster in Taiwan in 1979¹³ as well as in Viet Nam War veterans who processed and sprayed Agent Orange. Most recently, Viktor Yushchenko, the president of Ukraine, was poisoned with TCDD and subsequently suffered from chloracne.

Dioxins are a group of persistent organic pollutants, they do not react easily with other chemicals, that is to say they are lipophilic, they bioaccumulate. Some of them are extremely toxic and fatal when it comes to animal studies but scientific evidence of harmfulness to humans is disputed. A subgroup of polychlorinated dibenzo-p-dioxins (PCDDs) is amongst the most toxic. In humans and other vertebrates, dioxins have been shown to be risk factors for cancer; immune deficiency; reproductive and developmental abnormalities; central nervous system and peripheral nervous system pathology; endocrine disruption, etc.¹⁴

Seveso is a small town with the population of 17000 in 1976, other affected neighborhood communities were Meda (19000), Desio (33000), Caesano Maderno (34000) and to a lesser extent Barlassina (6000) and Bovisio Masciago (11000).¹⁵ The industrial plant was close by Meda, owned by the company ICMESA (Industrie Chimiche Meda Societa), a subsidiary of Givaudan, which in turn was a subsidiary of Hoffmann-La Roche (Roche Group). The factory building was built many years ago and the local population did not perceive it as a potential source of danger. Moreover, although several industrial accidents involving dioxins had oc-

¹² Fact of the story taken from the Wikipedia website (http://en.wikipedia.org/wiki/Seveso_disaster)

¹³ <http://news.bbc.co.uk/1/hi/health/2121976.stm>

¹⁴ <http://www.sciencedirect.com>

¹⁵ <http://www.unu.edu/unupress/upupbooks/uu211e09.htm>

curred before they were of a more limited scale with the exception the use of Agent Orange as a chemical weapon during the Viet Nam War.

The accident occurred in the building where 2,4,5-trichlorophenol (TCP), an herbicide, was being produced from 1,2,4,5-tetrachlorobenzene by the nucleophilic aromatic substitution reaction with sodium hydroxide. It is thought that some 1,2,4,5-tetrachlorobenzene had formed a solid cake on the upper parts of the reaction vessel. As the temperature increased this melted and entered the sodium hydroxide containing mixture. The addition of more 1,2,4,5-tetrachlorobenzene increased the rate of heat production. It is likely that the dioxin formed by either an Ullmann condensation either synthesis (this requires a metal catalyst) or by a simple pair of nucleophilic attacks on the aromatic ring. The 2,4,5-trichlorophenol was intended for use as an intermediate in the production of hexachlorophene, a medical disinfectant. An unintended by product of the manufacture of TCP is TCDD in trace amounts, measured in ppm (parts per million). Due to human error, around 12:37 pm on July 10, 1976 an uncontrolled reaction (thermal runaway) occurred bursting the security disk of the chemical reactor and an aerosol cloud containing sodium hydroxide, ethylene glycol, sodium tri-chlorophenate, and somewhere between a few hundred grams and up to a few kg of TCDD was released over an 18-km² area.



Figure 6: Burst in the security disk of the chemical reactor and an aerosol

The affected area was split into zones A, B and R in decreasing order of surface soil concentrations of TCDD. Zone A was further split into 7 sub-zones. The local population was advised not to touch or eat locally grown fruits or vegetables. Zone A had a TCDD soil concentration of >50 micrograms/m². Zone B had a TCDD soil concentration of between 5-50 micrograms/m². Zone R had negligible or a TCDD soil concentration of <5 micrograms/m². Within days a total of 3300 animals were found dead, mostly poultry and rabbits. Emergency

slaughtering commenced to prevent TCDD from entering the food chain; by 1978, over 80000 animals had been slaughtered. 15 children were quickly hospitalized with skin inflammation. By the end of August Zone A had been completely evacuated and fenced, 1600 people of all ages had been examined and 447 were found to suffer from skin lesions or chloracne. An advice centre was set up for pregnant women of which several opted for an abortion, which was legal in special cases, after consultation. In January 1977 an action plan comprised of scientific analysis, economic aid, medical monitoring and restoration/decontamination was completed shortly after Icmesa began to pay the first compensations to those affected. In 1980 representatives of the Region of Lombardy/Italian Republic and Givaudan/Icmesa signed a compensation agreement in the presence of the prime minister of Italy. The total amount would reach 20 billion liras.

The waste from the clean up of the plant was a mixture of protective clothing and chemical residues for the plant. This waste was packed into waste drums, which had been designed for the storage of nuclear waste. It was agreed that the waste would be disposed of in a legal manner. To this end in 1982 the firm Mannesmann Italiana was contracted to dispose of the contaminated chemicals from Zone A. Mannesmann Italiana made it a condition that Givaudan would not be notified of the disposal site which prompted Givaudan to insist that a notary public certify the disposal. On September 41 barrels of toxic waste left the Icmesa premises. On December, the notary gave a sworn statement that the barrels had been disposed of in an approved way. However, in February 1983 a French/Swiss television programme followed the route of the barrels to St-Quentin in northern France where they disappeared. A public debate ensued in which numerous theories were put forward when it was found out that Mannesmann Italiana hired two subcontractors to get rid of the toxic waste. In May, the 41 barrels were found in an unused abattoir in Anguillcourt-le-Sart, a village in northern France. From there, they were transferred to a French military base near Sissonne. The Roche Group (parent firm of Givaudan) took it upon itself to properly dispose of the waste. In November, over nine years after the disaster, the Roche Group issued a public statement that the toxic waste consisting of 42 barrels (1 was added earlier that year) had all been incinerated in Switzerland. According to New Scientist it was thought that the high chlorine content of the waste might cause damage to the high temperature incinerator used by Roche, but Roche stated that they would burn the waste in the incinerator and repair it afterwards, if it was damaged. They stated that they wanted to take responsibility for the safe destruction of the waste.

All these examples let us know the risks of improper handling of dangerous materials that create serious problems to an environment and human life; thus, we do need hazardous waste management.

3.2. Legal Requirements

A comprehensive system for the hazardous waste management will not develop unless its basic requirements are prescribed and enforced by law. The first step in developing legislation on hazardous waste should be the assessment of existing laws and regulations that have a bearing on the subject. For example, legislation on controlling emissions to the air, the production and transport of goods, water and wastewater management, or health and safety at work might already include basic provisions for hazardous waste management that could be amended or extended. Care is needed to ensure that specific hazardous waste legislation neither duplicates nor contradicts measures already in force [Suess, M.; Huismans, J., 1983].

The nature of the legislation required will depend on the constitution of the individual country; some might require laws in the strict sense of the word, whereas in others statutory or even administrative regulations might be in accordance with constitutional principles. Hazardous waste legislation will have to impose duties on the general public, and this action might call for a law as compared to regulations.

Wherever there is uncertainty, either about the aims and principles of legislation or about technical aspects, guidelines can be used successfully, particularly in periods of transition, but with due regard to their enforcement. See 1.5.1 for the general principles that should be considered when elaborating any legal framework for hazardous waste management.

4. Costs and benefits of hazardous waste management

Hazardous waste management aims to reduce risks to the environment and public health, and to prevent the harmful effects of hazardous substances in order to protect the environment and well being of people and communities so as to enable the maximum benefit. The risks to human health are difficult to calculate, some damages can be more clearly associated with hazardous wastes, such as the loss of value in contaminated land and the loss of productive water supply aquifers. Uncertainty about risks causes uncertainty about regulatory benefits. The current limited knowledge of the chronic health effects of low exposure to many hazardous wastes makes it virtually impossible to estimate the benefits of reducing the impacts [World Bank Group, 1998].

One economic justification of a hazardous waste management program is the benefits in terms of future cleanup costs avoided. However, given the uncertainty about the location and extent of future damage and about the rules for the level of cleanup that might be required, the estimation of benefits is extremely uncertain. It is difficult to compare hazardous wastes with other environmental problems for which it is easier to estimate benefits in terms of overall reduction of risk to public health.

An economics-based approach to managing hazardous wastes takes advantage of incentives to reduce risks while balancing the costs and benefits of doing so. One way of achieving this is to tailor requirements to reflect the wide variations in the risks of different waste types, disposal sites, and exposure conditions, and concentrating resources on the worst risks first.

4.1. Cleaner Production

Cleaner production (CP) minimizes the use of resources and reduces the wastes discharged to the environment. In many cases, the adoption of CP improvements can reduce or even eliminate the need for end-of-pipe investments and can therefore provide both financial and economic net benefits. Cleaner production is also attractive because of concerns about the lack of effectiveness of end-of-pipe solutions: there are numerous examples of poor operation and maintenance of treatment plants, with resulting failure of the system to achieve its objectives.

Cleaner production and related approaches will be increasingly important in environmental management in the future. However, changes will require effort and will be gradual. CP should therefore be seen as part of an overall approach, not as a “costless” alternative to a

comprehensive set of environmental policies and regulations. The introduction of CP is an ongoing process: as resource prices and disposal costs continue to rise, new opportunities arise for pollution prevention and reductions in treatment costs. For this reason, CP can be linked closely with environmental management systems [World Bank Group, 1983].

4.1.1. Definitions

The term cleaner production has come into general use through the efforts of the UNEP Cleaner Production Program, established in 1989. A number of related terms are also used, including low or no-waste technologies; waste minimization (India); waste and emissions prevention (Netherlands); source reduction (United States); eco-efficiency (World Business Council on Sustainable Development) and environmentally sound technology (United Nations Council on Sustainable Development). All these terms essentially refer to the same concept of integrating pollution reduction into the production process and even the design of the product.

4.1.2. Critical Success Factors

Two major issues have to be addressed in developing an effective CP program.

External Incentives

An appropriate government policy and regulatory framework must be in place to provide effective incentives for firms to adopt cleaner production.

Response of the Firms

In many cases, firms are slow or incapable of responding to the incentives, and it may be appropriate to assist the firms to adjust. The approaches adopted will vary considerably, depending on the characteristics of the sector and of the firms involved.

It must be emphasized that CP is only one of a number of possible components of a government industry and environment strategy, and it is only one of the approaches that an enterprise can adopt to improve its environmental and financial performance.

4.1.3. Appropriate Government Framework

A number of key characteristics of the government framework required for the promotion of CP have been identified:

- A broad macroeconomic context that sets real resource prices, encourages investment in new technology, and supports and orientation toward export markets, thus providing strong incentives
- A predictable and flexible regulatory regime under which predictability will encourage investment in pollution management and flexibility will allow enterprises to adopt the most cost-effective solutions
- A credible enforcement system to provide backbone for the regulations
- Targeted measures to assist enterprise in adopting cleaner production.

4.1.4. Enterprise Characteristics

Firms respond in different ways to the incentives provided by the government and by the market. It is possible to suggest two extreme types of firm that have different characteristics and require different approaches.

At one end of the spectrum are enterprises that are operating in a highly differentiated market in which product quality is important. Such firms focus on quality, product improvement, and brand and company image. They typically have high-quality management, are responsive to external changes, and concentrate on revenue enhancement. These firms can be characterized as dynamic, in a literal sense, because their processes and methods have to evolve continually if the enterprises are to maintain their positions in competitive markets.

At the other end of the spectrum are firms that can be characterized as static because their processes and markets change very slowly. Included in this category are small firms that are price takers in a mature industry. They use traditional and relatively simple production methods, focus on cost minimization, are often undercapitalized, and lack depth in management. This group includes many of the traditional polluting sectors such as electroplating and training.

The approaches required to introduce and disseminate new processes are very different in dynamic and in static firms. Information and incentives will be most effective in the dynamic enterprises. Static enterprises require a blunter approach because the management is typically much less responsive to incentives.

4.1.4.1. Encouraging Dynamic Firms

Dynamic firms are keen to introduce environmentally sound technology where this gives them a competitive edge, either because of reduced regulatory costs or because of better positioning in the marketplace. They typically have an aggressive management that seeks to improve production performance and has both the motivation and the skills to take advantage of new techniques. They respond to opportunities for technology transfer and manage-

ment upgrading using approaches such as total quality management (TQM) and environmental management systems. The requirement on the government side is to provide incentives, information, and examples, such as demonstration projects or centers of excellence.

4.1.4.2. State-Owned Enterprises

Many state-owned enterprises (SOEs) are static, in the sense used here. They are inefficient, as a result of lack of competition and of hard budget constraints and because management priorities rarely include efficient use of resources. Such enterprises are typically significant polluters, with large opportunities for CP gains. Restructuring or privatization of such SOEs should include audits to identify CP opportunities. Experience demonstrates, however, that new management attitudes are essential if advantage is to be taken of the potential savings.

5. Hazardous waste management in business

5.1. Evaluation of the Current Situation

Does your business generate hazardous waste? Many businesses do. This section will give you a basic understanding of your responsibilities in evaluating hazardous waste generated. The businesses generating hazardous waste must comply with the hazardous waste rules in your country.

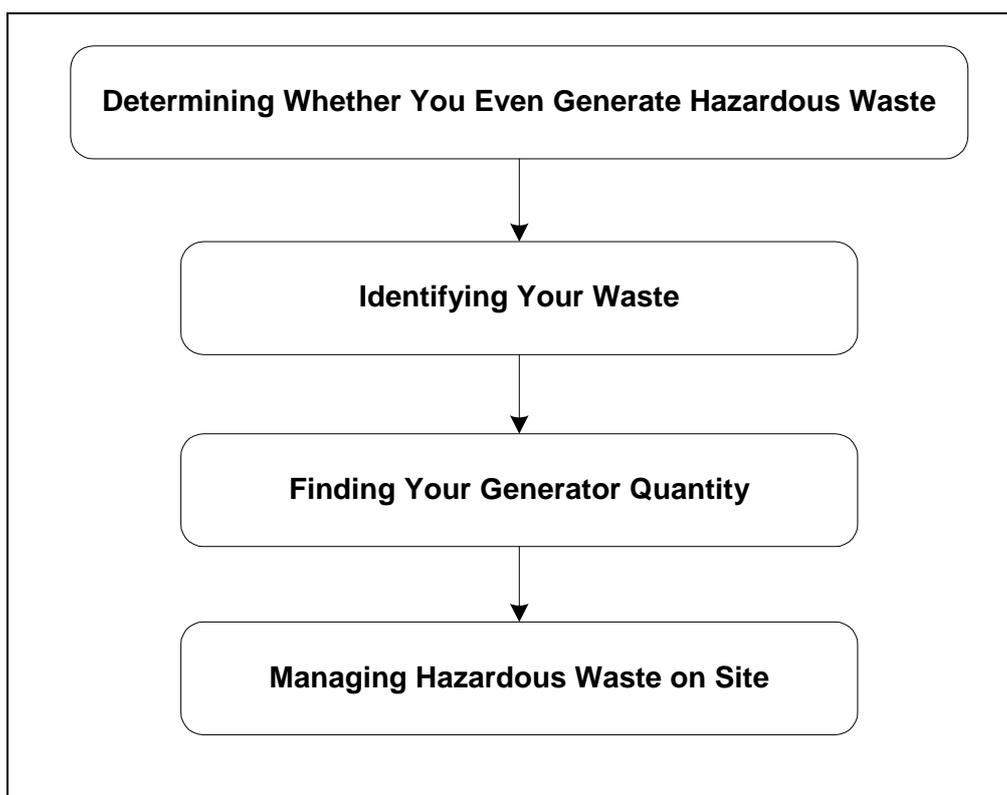


Figure 7: Evaluation of the current situation

5.1.1. Determining whether you even generate hazardous waste

A waste is any solid, liquid, or contained gaseous material that is discarded by being disposed of, burned or incinerated, or recycled. It can be the by-product of a manufacturing process or simply a commercial product that you use in your business - such as a cleaning fluid, battery acid or pesticides. Even materials that are recyclable or can be reused in some way (such as burning solvents for fuel) might be considered waste. Hazardous waste can be one of two types: listed waste or characteristic wastes.¹⁶

¹⁶ Solid Waste and Emergency Response, Environmental Protection Agency, December 2001 (<http://www.epa.gov>)

5.1.1.1. Listed waste

Your waste is considered hazardous if it appears on the list, which is published in environmental regulations. You can also find the listed waste drawn up by the European Commission or by the Environmental Protection Agency as a reference. Wastes are listed as hazardous because they are known to be harmful to human health and the environment when not managed properly. Even when managed properly, some listed wastes are so dangerous that they are called acutely hazardous wastes. Examples of acutely hazardous wastes include wastes generated from some pesticides and that can be fatal to humans even in low doses.

5.1.1.2. Characteristic wastes

If your waste does not appear on one of the hazardous waste lists, it still might be considered hazardous if it demonstrates at least one of these properties:

- It catches fire under certain conditions. This is known as an **ignitable** waste. Examples are paints and certain degreasers and solvents.
- It corrodes metals or has a very high or low pH. This is known as a **corrosive** waste. Examples are rust removers, acid or alkaline cleaning fluids, and battery acid.
- It is unstable and explodes or produces toxic fumes, gases, and vapor when mixed with water or under other conditions such as heat or pressure. This is known as a **reactive** waste. Examples are certain cyanides or sulfide-bearing wastes.
- It is harmful or fatal when ingested or absorbed, or it leaches toxic chemicals into the soil or ground water when disposed of on land. This is known as a **toxic** waste.

Examples are wastes that contain high concentrations of heavy metals, such as cadmium, lead, or mercury.

You can determine if your waste is toxic by having it tested, or by simply knowing that your waste is hazardous or that your processes generate hazardous waste. One way to help determine if your waste exhibits any of the characteristics listed on table 1.1 is to check the Material Safety Data Sheet (MSDS) that comes with all products containing hazardous materials (www.msds-online.com). In addition, your national trade association or its local chapter might be able to help you.

5.1.2. Identifying your waste

To help you identify some of the waste streams common to your business, see the table 1.2 to find a list of typical hazardous wastes generated by small and medium-scale businesses. If

your waste is hazardous, you will need to manage it according to appropriate federal regulations.

5.1.3. Finding your generator quantity

Once you know that you generate hazardous waste, you need to measure the amount of waste you produce per month. You should measure all quantities of listed and characteristic hazardous wastes that are:

- Accumulated on the property for any period of time before disposal or recycling. (Dry-cleaners, for example, must count any residue removed from machines, as well as spent cartridge filters.)
- Packaged and transported away from your business.
- Placed directly in a regulated treatment or disposal unit at your place of business.
- Generated as still bottoms or sludge and removed from product storage tanks.

After measuring the quantity of hazardous waste, you should comply with waste management requirements of your national legislations. First, you must identify all hazardous waste that you generate. Second, you may not store much of hazardous waste on site at any time. Finally, you must ensure delivery of your hazardous waste to an off-site treatment or disposal facility.

Suggestions

It's a good idea to call the appropriate state agency to verify that the treatment, storage, and disposal facility (TDSF) you have selected has any necessary permits, etc.

Most small businesses accumulate some hazardous waste on site for a short period of time and then ship it off site to a treatment, storage, or disposal facility.

5.1.4. Managing hazardous waste on site

Accumulating hazardous waste on site can pose a threat to human health and the environment, so you may keep it only for a short time without a permit. Before shipping the waste for disposal or recycling, you are responsible for its safe management, which includes safe storage, safe treatment, preventing accidents, and responding to emergencies in accordance with federal regulations. Your storage tanks and containers must be managed:

- Label each container with the words “HAZARDOUS WASTE” and the date that the waste was generated.
- Use a container made of, or lined with, a material that is compatible with the hazardous waste to be stored. (This will prevent the waste from reacting with or corroding the container.)



- Keep all containers holding hazardous waste closed during storing storage, except when adding or removing waste. Do not open, handle, or store (e.g., stack) containers in a way that might rupture them, cause them to leak, or other wise fail.
- Inspect areas where containers are stored at least weekly. Look for leaks and for deterioration caused by corrosion or other factors.
- Maintain the containers in good condition. If a container leaks, put the hazardous waste in another container, or contain it in some other way that complies with EPA regulations.
- Do not mix incompatible wastes or materials unless precautions are taken to prevent certain hazards.
- Do not place ignitable or reactive wastes in tanks unless certain precautions are taken.

5.2. Better hazardous waste management

The easiest and most cost-effective way of managing any waste is not to generate it in the first place. You can decrease the amount of hazardous waste your business produces by developing a few “good house keeping” habits. Good housekeeping procedures generally save businesses money, and they prevent accidents and waste. To help reduce the amount of waste you generate, try the following practices at your business.

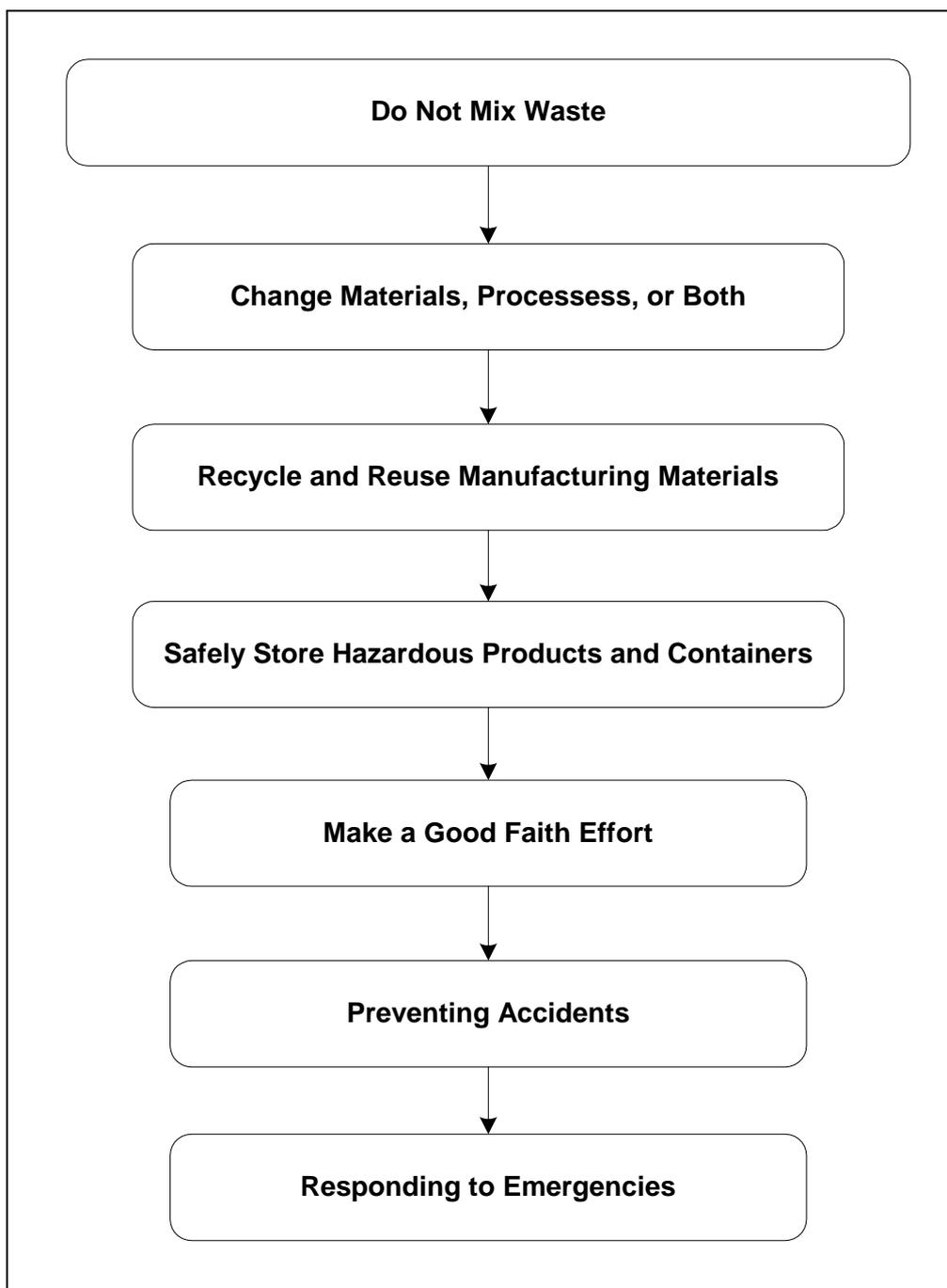


Figure 8: Better Hazardous Waste Management

Mixing waste

Do not mix non-hazardous waste with hazardous waste. Once you mix anything with listed hazardous waste, the whole batch becomes hazardous. Mixing waste can also make recycling very difficult, if not impossible. A typical example of mixing wastes would be putting non-hazardous cleaning agents in a container of used hazardous solvents.

Change Materials, Processes, or Both

Businesses can save money and increase efficiency by replacing a material or a process with another that produces less waste. For example, you could use plastic blast media for paint stripping of metal parts rather than conventional solvent stripping.

Recycle and Reuse Manufacturing Materials

Many companies routinely put useful components back into productive use rather than disposing of them. Items such as oil, solvents, acids, and metals are commonly recycled and used again. In addition, some companies have taken waste minimization actions such as using fewer solvents to do the same job, using solvents that are less toxic, or switching to a detergent solution.

Safely Store Hazardous Products and Containers

You can avoid creating more hazardous waste by preventing spills or leaks. Store hazardous product and waste containers in secure areas, and inspect them frequently for leaks. When leaks or spill occur, materials used to clean them also become hazardous waste.

Make a Good Faith Effort

You should document your waste minimization activities or create a waste minimization plan. You do need to certify on your manifests that you have made a good faith effort to minimize waste generation when you send your waste off site.

Preventing Accidents

Whenever you store hazardous waste on site, you must minimize the potential risks from fires, explosions, or other accidents. What you can do are, for example:

- An internal communications or alarm system capable of providing immediate emergency instruction (voice or signal) to all personnel.
- A device, such as a telephone (immediately available at the scene of operations) or a hand-held, two-way radio, capable of summoning emergency assistance from local police and fire departments or emergency response teams.
- Portable fire extinguishers, fire-control devices (including special extinguishing equipment, such as those using foam, inert gas, or dry chemicals), spill-control materials, and decontamination supplies.
- Water at adequate volume and pressure to supply water-hose streams, foam-producing equipment, automatic sprinklers, or water spray systems.

You must test and maintain all equipment to ensure proper operation. Allow sufficient aisle space to permit the unobstructed movement of personnel, fire protection equipment, spill-control equipment, and decontamination equipment to any area of facility operation. Attempt to secure arrangements with fire departments, police, emergency response teams, equipment suppliers, and local hospitals, as appropriate, to provide services in the event of an emergency. Ensure that personnel handling hazardous waste have immediate access to an alarm or emergency communications device.

You are not required to have a formal personnel-training program, but you must ensure that employees handling hazardous waste are familiar with proper handling and emergency procedures. In addition, you must have an emergency coordinator on the premises or on-call at all times, and has basic facility safety information readily accessible.

Responding to Emergencies

Facility Design and Operation

All facilities need to be designed and constructed and operated minimizing the possibility of fire, explosion or any unplanned release of hazardous waste to the air, soil or surface water.

Minimum facility requirements are:

- Internal communication or alarm system with the capacity to provide immediate emergency instructions to the facility's personnel.
- A telephone or hand-held two-way radio with the capacity to request for emergency assistance from local authorities (police, fire department, emergency response teams, etc)
- Fire extinguisher equipment, fire control equipment (including special equipment such as that using foam, inert gas or dry chemicals), spill control equipment and decontamination equipment
- Water at adequate volume and pressure to apply water hose streams, foam producing equipment, automatic sprinklers, or water spray systems.

These systems should all undergo regular maintenance work to assure its adequate functioning in the case of emergency. Sufficient aisle space should be provided to allow for personnel and equipment unobstructed movement during emergency operations.

Arrangements with Local Authorities

The facility and the local authorities must make the necessary arrangements to be prepared in case of an emergency situation. Authorities such as the police, fire departments and emergency response teams should be made familiar with the premises and the types of haz-

ardous material being treated. Close coordination between the facility and local authorities must be attained, e.g. through agreements, guaranteeing a defined leadership and responsible authority.

At the same time, hospitals must be acknowledged on the types of hazardous waste being treated at the facility and what are the types of illnesses or injuries that could result from fires, explosions or releases at the facility.

Contingency Plan

A contingency planned must be drafted and maintained at each facility, designed to minimize the hazards to human health and the environment in the events of fires, explosions or unexpected release of hazardous waste. The plan should details the procedure to be followed by personnel in case of emergency, the arrangements reached with local authorities (police, fire departments, hospitals, contractors and emergency response teams). The contingency plan must also list the qualified persons to act as emergency coordinators and detail the following aspects of the facility:

- The emergency equipment available at the facility (fire extinguishing system, spill control equipment, communication and alarm system, decontamination equipment)
- The location and physical description of each item and a brief outline of its capabilities
- An evacuation plan for the personnel including description of signals, evacuation routes, alternative evacuation routes.

There must be at least one person, on the premises or available on call at all times, responsible for the coordination emergency response measures. This person must be thoroughly familiar with all aspects of the facility and its contingency plan including all the facility's operation and activities, location and characteristic of waste handled, the location of all records, and the facility's layout. Permanent review of the contingency plan should be carried out to ensure a more practical and effective plan close to real-world situations.

Emergency Response

It is the responsibility of the emergency coordinator to immediately activate the internal facility alarm and communication systems whenever there is an imminent or actual emergency situation. In the case of fire, explosion or release, the emergency coordinator is in charge of identifying the character, source, amount and aerial extend of any release material. The coordinator must also assess the possible hazard on health and environment that may result from the hazardous event. Authorities should be notified immediately in case an evacuation is deemed necessary.

If the facility was to stop its operation due to emergencies, the emergency coordinator should monitor for leaks, pressure build-up, gas generation, or ruptures in valves or equipment. Immediately after an emergency, the coordinator must provide for the treatment, storage and disposal of recovered waste, contaminated soil or surface water, or any material resulting from the event.

For the small businesses, you might not have a written contingency plan. However, you must be prepared for an emergency at your facility. You should also be prepared to answer a set of "what if" questions. For example: "What if there is a fire in the area where hazardous waste is stored? Or "What if I spill hazardous waste, or one of my hazardous waste containers leaks?" In case of a fire, explosion, or toxic release, having such a plan provides an organized and coordinated course of action. You should establish basic safety guidelines and response procedures to follow in the event of an emergency and ensure that employees are familiar with these procedures.

6. Casting of metals

6.1. Economic characteristics

Between 2000 and 2004, the production of steel in Vietnam doubled to 2,929,000 tonnes per year (cf. Table 3). Meanwhile in India, between 2000 and 2005 annual production rose to 5,000,000 tonnes [Statistical Publishing House, 2005]. These figures underline just how rapid development is in this sector. However, this economic growth is accompanied by increasing volumes of waste – particularly of the hazardous variety.

Table 3: Development of the steel production in Vietnam [Statistical Publishing House, 2005]

Industrial sector	Unit	2000	2001	2002	2003	Prel.2004
Steel	Thousand tons	1583	1914	2503	2954	2929

The prevention, substitution and recycling of hazardous materials are often thought to be very expensive, especially by small companies – which make up the vast majority of industrial operations in Vietnam.

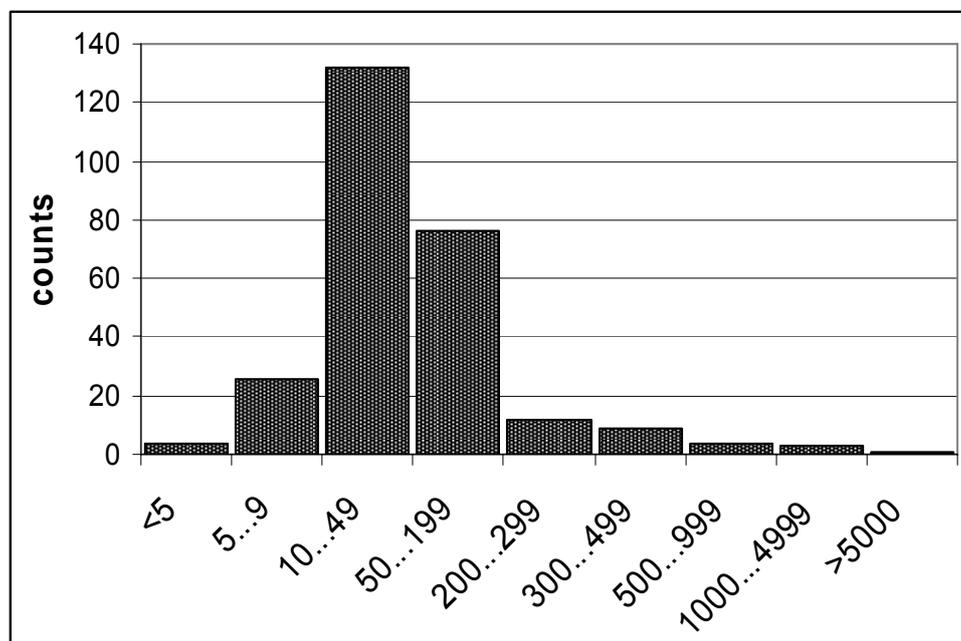


Figure 9: Counts of companies by size of employees in Vietnam



6.2. Processes

The casting of metals takes place in several stages. Firstly, moulds must be made; both temporary and permanent moulds are used. The second process is melting the metal. This can be done in a cupola-melting furnace, an electrical (induction) furnace or a rotary furnace. The next stage is casting. This is followed by separation, sand regeneration, and finishing of the product. Accordingly, the following processes are encountered in the casting industry:

- Pattern making and moulding
- Melting the metal
- Shakeout, cooling and sand treatment
- Quenching, finishing, cleaning and coating
- Die-casting

Figure 12 shows the different steps in the casting of metals.

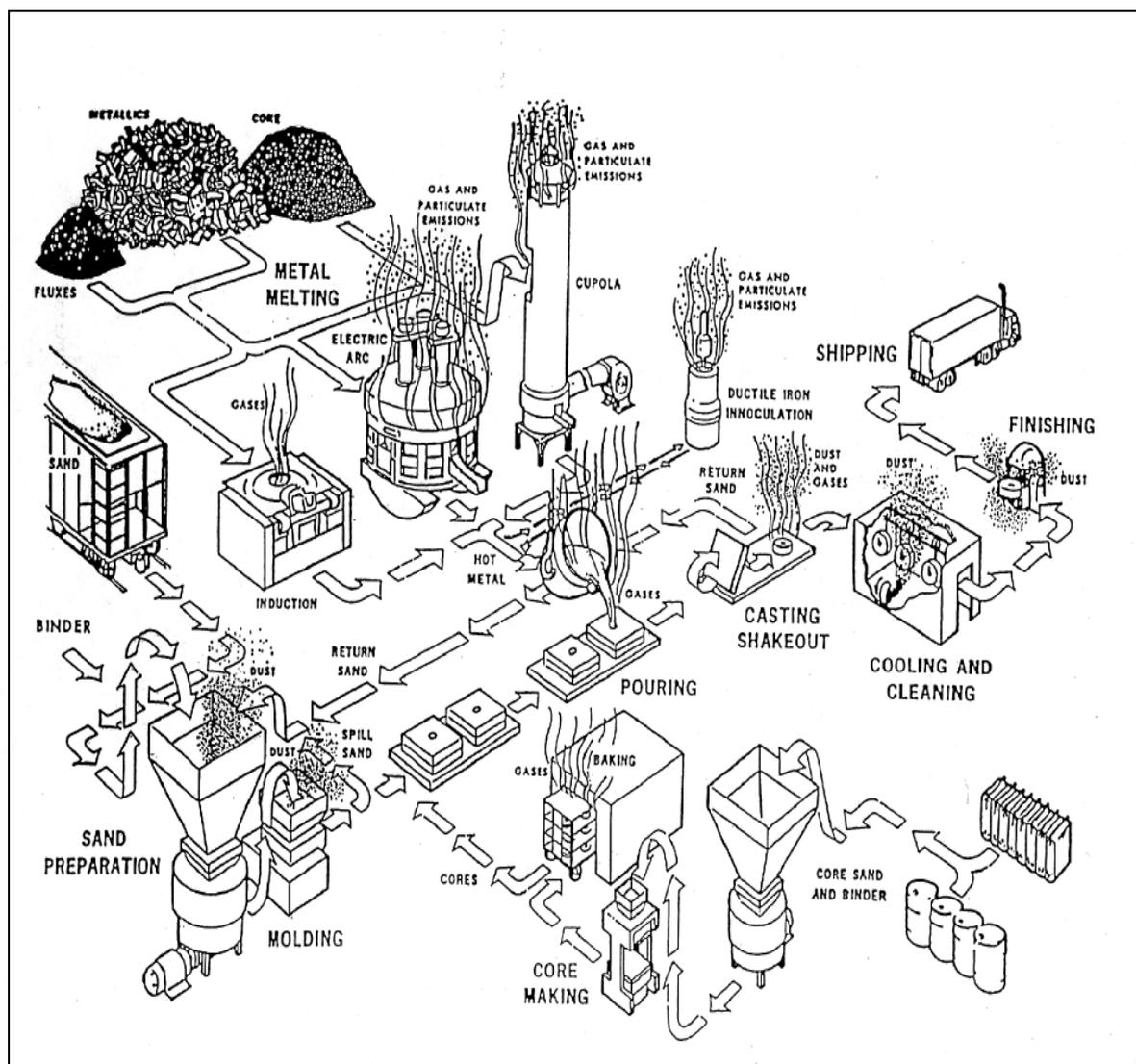


Figure 10: Processes in Casting of Metals [DPPEA, 2006]

Pattern making and mould preparation

The pattern is a replica of an original workpiece. It can be made out of plaster, wood, plastic or wax. Once a pattern has been created, the mould can be made. As well as sand moulds (see Fig. 13), there are also reusable metal moulds, plaster moulds and wax moulds.

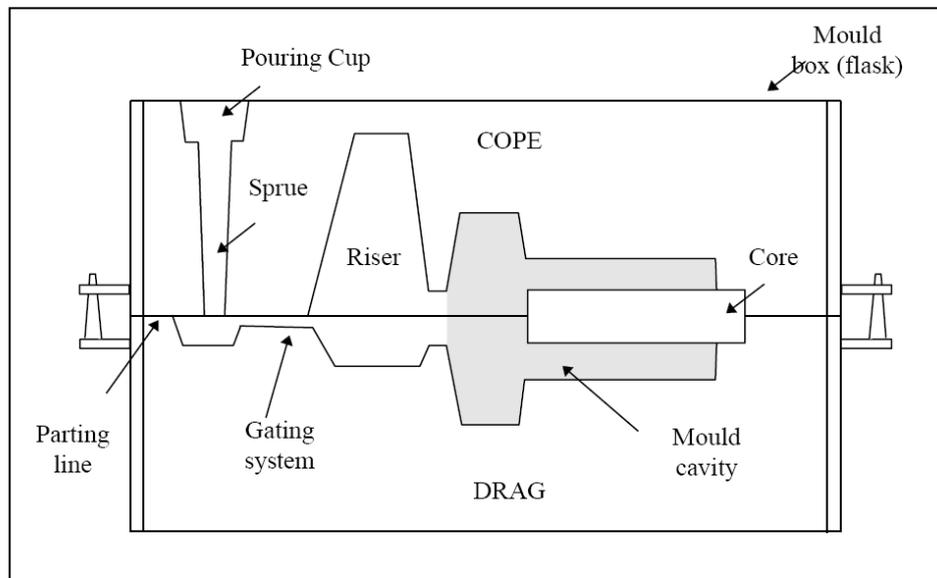


Figure 11: Example of a typical sand mould [Energy Manager Trainer, 1999]

Metal melting

The melting process starts with the preparation of the scrap material. This often involves the cutting, cleaning and degreasing of recycled scrap with solvents being used. Besides the metal, flux and alloys may be added into the furnace. The function of the flux, especially chloride or fluoride salts, is to remove impurities. However, one drawback of adding flux is the formation of acid gases during the melting process. Mainly the following types of furnaces are used:

- Cupola
- Electric arc
- Reverberatory
- Induction
- Crucible

Cupola

Similar to the blast furnace, the cupola is a refractory-lined steel stack 6–11 metres (20–35 feet) tall resting on a cast-iron base plate with four steel legs. The bottom of the cupola furnace has two hinged doors supported in the closed position by a centre prop. Moulding sand is rammed over the closed bottom doors to support the coke bed, molten metal, and suc-

ceeding charges. Forced air for combustion enters the cupola through the openings (tuyeres) spaced around the rim of the lower portion of the cupola.

Iron, coke, and limestone flux are placed on a bed of coke high enough to hold the iron above the tuyere openings, where the temperature is the highest. Melting is continuous, and molten metal may be allowed to flow continuously through an open tapping spout at the base of the cupola, or it may be tapped intermittently. Intermittent tapping is accomplished by piercing a clay bott, or plug, in the tapping spout with a pointed steel rod to create a passageway called the breast of the cupola. The tapping spout can be plugged with a fresh clay bott. Waste flows out in the form of slag when the slag spout is tapped. At the end of the operation, the prop is knocked out from beneath the bottom doors and the remaining contents are discharged.

Electric arc

This apparatus is a type of electric furnace in which heat is generated by an arc between carbon electrodes above the surface of the metal being melted.

Reverberatory

The reverberatory furnace is used for melting or refining, in which the burning fuel is not in direct contact with the contents but heats it by a flame blown over it from another chamber. In steelmaking, this process (now largely obsolete) is called the open-hearth process. The heat passes over the hearth and then radiates back (reverberates) onto the contents. The roof is arched, with the highest point over the firebox. It slopes downward toward a bridge of flues that deflects the flame so that it reverberates.

Induction

Induction is used in induction furnaces for melting and processing metals. The principle of the induction-heating process resembles that of the transformer. A water-cooled coil (inductor), acting as the primary winding of a transformer, surrounds the material to be heated (the workpiece), which acts as the secondary winding. Alternating current flowing in the primary coil induces eddy currents in the workpiece, causing it to become heated. The depth to which the eddy currents penetrate, and therefore the distribution of heat within the object, depend on the frequency of the primary alternating current and the magnetic permeability, as well as the resistivity, of the material.

Crucible

This is an 18th-century technique for producing cast or tool steel, and was the first process where temperatures of 1600°C were reached to melt steel, producing a homogeneous metal of uniform composition. In the 20th century it was replaced by the electric furnace in coun-

tries with inexpensive electric power. For a long time, all high-quality tool steel and high-speed steel was made by the crucible process.

Shakeout, cooling and sand handling

After the melting process, the molten metal is ladled into the mould. Cooling starts immediately, and the moulds complete with molten metal are transported to cooling areas. Large foundries use cooling tunnels to transport the material directly to the shakeout area. In contrast, in smaller companies cooling takes place on the shop floor. The mould is replaced in what is known as the shakeout area. Typically, vibrating grids, conveyors or manual systems are used. Often the waste sand can be treated and used several times. One simple way of reconditioning it is to sieve the waste sand in order to remove lumps stemming from the casting process. In a second step, smaller ferrous parts can be extracted by magnetic separation. If the waste sand cannot be treated, it can still be used as construction material.

Quenching, finishing, cleaning and coating

Apart from slow cooling, the quenching (rapid cooling) of hot castings in a water bath is also practised in order to speed up the process. This is especially attractive for larger companies. However, one drawback of quenching is the increased amount of wastewater containing chemicals which therefore has to be treated. After cooling and shakeout, the casting process concludes with operations to remove risers, runners and sprues by band saws, air-carbon arc devices, hammers, abrasive cutting wheels and flame-cutting equipment. In addition, blasting with sand or steel shot is used to remove residual refractory material and oxides.

Die-Casting

One special type of casting is pressure die-casting. In this process the molten metal is poured into a permanent die (metal mould) consisting of two blocks of steel. In die-casting, the metal is kept under pressure until the metal is cold and solid. Two types of die-casting are distinguished depending on the pressure reached: hot-chamber die-casting (up to 345 bar) and cold-chamber die-casting (up to 690 bar). In the case of cold-chamber die-casting, the temperature of the melting metal is only slightly above melting point. The following figure summarizes the different processes during the casting of metals and possible sources of waste [DPPEA, 2006].

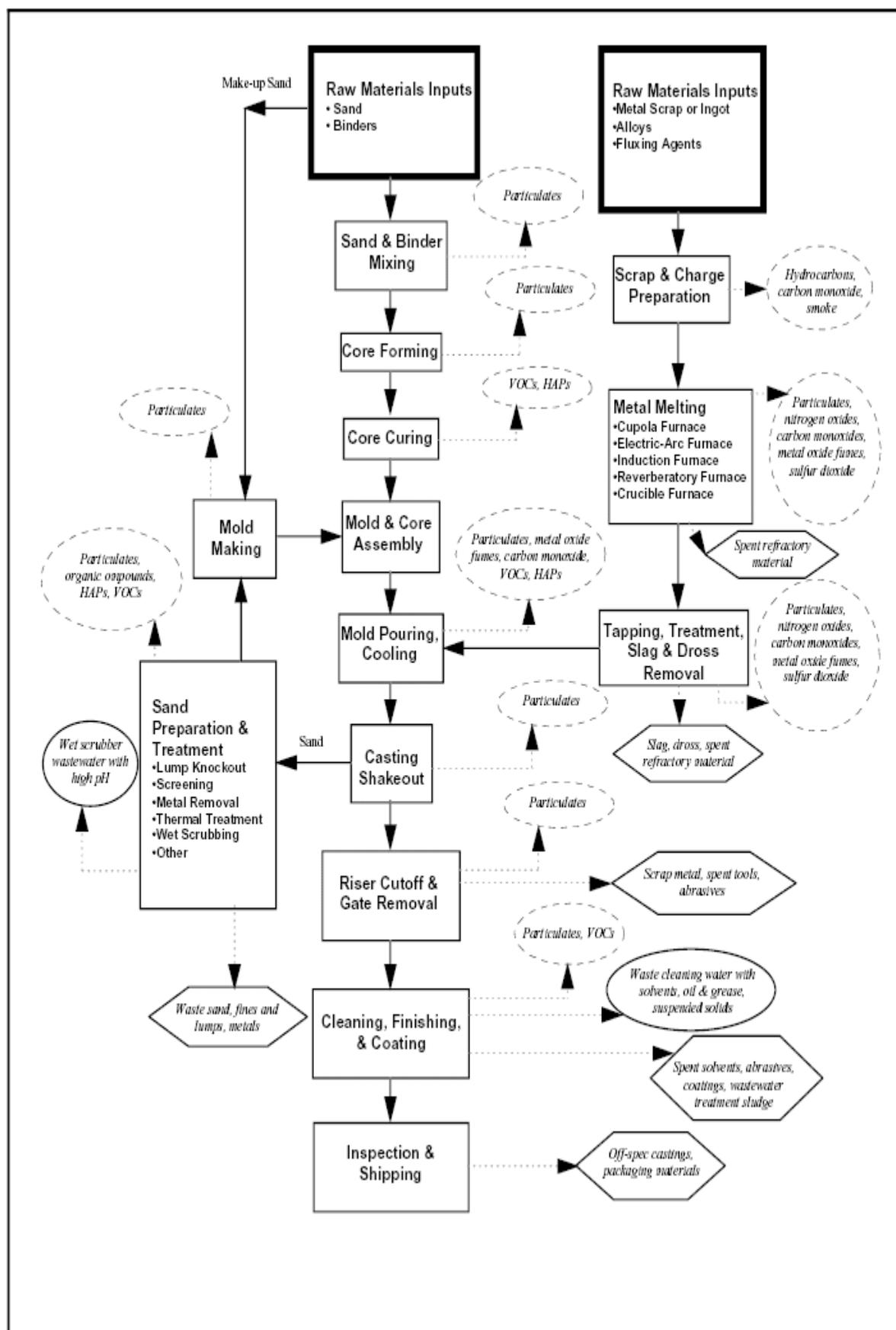


Figure 12: Process Flow and Potential Pollutant Outputs for Typical Green Sand Foundry [Anonymous, 2006]



6.3. Hazardous materials

The hazardous emissions of the casting industry can be categorized into air emissions, wastewater and solids.

Air emissions

Air emissions comprise combustion products and harmful dust. Fly ash, metallic dust containing lead, nickel, chromium, cadmium and zinc, fumes and carbon are frequently encountered near furnaces, the exact levels depending on for instance furnace type and melting temperature. In the nonferrous metal industry, aluminium, copper and tin are also used – and hence found in air emissions. In addition, harmful emissions are caused during mould-making, shakeout, finishing, sand handling and die-casting, too.

Liquid emissions

There are two different types of wastewater: cooling water and sometimes wet scrubber effluent. Normally, cooling water need not be purified and can be safely discharged into surface water. By contrast, wet scrubber effluent contains alkalis and acids, and needs to be neutralized. Moreover, during quenching, wastewater containing oil and suspended solids is produced.

Solids

The solid hazardous fractions produced by the casting industry include dust from air cleaning, slag containing toxic metals (e.g. heavy metals such as lead) from the melting process, and in some cases sludge containing corrosive substances. Beside this, casting sand may contain cadmium or lead. During the die-casting process, waste oil, lubricants and other hydraulics may be produced [Ravenswaay, 1997].



6.4. Waste reduction options

Good operation practices

One first step towards waste reduction is to employ reusable moulds lasting several years. Another possibility is to minimize the addition of harmful substances by introducing continuous monitoring. In larger foundries, expensive automatic dosing systems are conceivable. However, monitoring must be conducted by well-trained personnel, meaning training courses are required to ensure good operating practice. Furthermore, optimizing the mixing temperature can cut emissions and also minimize additional hazardous compounds.

Regeneration of sand

Foundry sand that has been in contact with molten melting metal often contains high levels of heavy metals and other hazardous organic compounds, and should not be disposed of without being first cleaned up. The following types of treatment are known:

- Cooling
- Crushing and sieving
- Cleaning by mechanical friction
- Wind sifting
- High-pressure washing
- Incineration

Sand can also be reclaimed by using wet washing and scrubbing techniques. These methods produce high-quality sand but are rarely employed because they generate a significant liquid waste stream and require additional energy input for sand drying.

Thermal reclamation has become increasingly common in recent years. This process heats the sand to the point where organic materials, including the binders, are driven off. This process can return the sand to an 'as new' state, allowing it to be used for core-making. However, thermal reclamation is more expensive than mechanical systems.

Because of the high costs, the above-mentioned processes are mainly used in large foundries. Special small-scale mechanical regeneration options are in the pipeline. Examples include the "Öko-Sandsanierungssystem" for small and medium-sized plants with a throughput of 1–5 tons/h and a mechanical removal system by the company GEMCO. However, it makes sense for foundries with waste sand amounting to less than 5,000 MG/y, to have their sand treated in a central regeneration unit.

Recycling of dust

Because of the high levels of dust, especially near mould-making and the separation of castings and moulds, the emissions need to be trapped in ventilation systems comprising hoods and ducts. Afterwards, foundry dust can be separated by using bag houses, electrostatic precipitators or wet scrubbers, and then recycled [European Commission, 1998].

6.5. Handling/ Disposal/ Prevention- general aspects

General information about the disposal, prevention and handling of hazardous compounds and waste is contained in Chapter 3.6 (“Handling, disposal and prevention” in the metallurgical industry). Moreover, other areas covered in detail include labelling, specially adapted container systems depending on the substances for which they are intended, protective clothing, the segregation of all of waste streams, and the transportation of harmful substances in special transport systems.



6.6. Further literature and links

- **Specific information about hazardous materials**

<http://www.epa.gov/ispd/pdf/2006/metalcasting.pdf>

<http://www.deh.gov.au/settlements/chemicals/hazardous-waste/salt-slag.html>

http://www.environmentaldefense.org/documents/883_GC_pamp.htm

- **Specific information about waste reduction options**

<http://glrppr.org/contacts/gltopicub.cfm?sectorid=15>

<http://p2pays.org/ref/07/06137.pdf>

<http://www.cwc.org/industry/ibp951fs.pdf>

<http://www.deq.state.mi.us/documents/deq-ead-tas-metalwrk.pdf>

<http://es.epa.gov/techinfo/facts/jwlry-fs.html>

<http://www.sepa.org.uk/wastemin/sector/casting.htm>

http://www.uwex.edu/ces/ag/sus/sbdc/pdftocdt/S4_11_3.pdf



6.7. Summary

Process steps:

- *Pattern-making and mould preparation*
 - A pattern is a replica of an original piece of work. Plaster, wood, plastic and wax can be used. After pattern creation, a mould is made.
- *Metal-making*
 - Firstly, the scrap metal is prepared by being cut, cleaned and degreased. The following types of furnace are used: cupola, electric arc, reverberatory, induction and crucible.
- *Shakeout, cooling and sand handling*

- After melting, the metal is poured into the mould and cooled. The material is then taken to the shakeout area, where the mould is replaced. The waste sand can be reused several times; it is sieved first to remove lumps of metal and then subjected to magnetic separation to extract ferrous items.
- If the sand cannot be treated, it can still be used in construction.
- *Quenching, finishing, cooling and coating*
 - Quenching (rapid cooling) in a bath is practised. After cooling and shake-out; the casting process is concluded by cleaning, using sand or steel shot blasting if necessary. One drawback of quenching is that it increases the amount of wastewater.
- *Die casting*
 - The dies consist of two blocks of steel. Die-casting can be hot (345 bar) or cold (690 bar).

Waste reduction options:

Good operating practices

- Reusing moulds for several years
- Minimizing the addition of harmful substances
- Ensuring well-trained personnel

Regeneration of sand

- Since foundry sand is often contaminated by heavy metals and other harmful organic compounds, it needs to be treated. The following methods are used: cooling, crushing and sieving, cleaning by mechanical friction, wind sifting, high-pressure washing and incineration.
- Most of the above forms of treatment are only applied in large factories because they are expensive. However, options for small-scale industries are currently being developed.

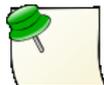
Handling, disposal and prevention: general aspects

Please see Chapter 3.6.

The following table provides an overview of waste characteristics, probable risks and initial steps to minimize them.

Table 4: Overview- casting of metals

	Waste characteristics	Probable risk	Steps to lessen risk
Air Emissions	<ul style="list-style-type: none"> - fly ash, - metallic dust; contains nickel, lead, chromium, cadmium and zinc - air emissions 	<ul style="list-style-type: none"> - associated issues with dust and ash Inhalation 	<ul style="list-style-type: none"> - use of mould for several years - minimisation of adding harmful substances, - well trained personnel, - Improving the mixing temperature, this prevents emissions and minimises hazardous compounds <p>Refer to chapter 3.6 with regard to details about handling, disposal and prevention of such wastes.</p>
Wastewater (Liquid emissions)	<ul style="list-style-type: none"> - cooling water - wet scrubber effluent - water containing oil and suspended solids 	<ul style="list-style-type: none"> - exposure to skin and inhalation risks, - risk of damage to environment 	
Solids	<ul style="list-style-type: none"> - dust from air cleaning, - slag containing heavy metals, - sludge in some cases containing corrosive substances, - casting sands containing cadmium or lead - waste oil, lubricants and other hydraulics 	<ul style="list-style-type: none"> - exposure to heavy metals - exposure to skin and inhalation risks 	



6.8. Case study

6.8.1. Vietnamese mechanical factory:

The Vietnamese Mechanical Factory is a small, privately owned enterprise. It has 20 employees and specializes in producing cylinder linings for combustion engines. The production process for cylinder linings consists of breaking scraps, melting, iron casting and machining.

Breaking scraps

Iron waste, scrap, etc are broken into small pieces by a hydraulic pressing machine prior to melting.

Melting

Broken scraps are heated up to melting point by burning fuel oil. It takes 120 litres of fuel oil to melt one tonne of scrap. Both solid and gaseous waste are produced during melting. Gas containing dust is produced by burning fuel. To reduce dust, a filtering system comprising a cyclone and a water-spraying system is applied, which is very good at trapping dust particles. Using current technology, the output product accounts for about 80 percent of the input material. The input material lost consists of flux and slag. Solid waste is mainly slag and is used for road-building.

Iron casting

Centrifugal casting with metal moulds is often performed at the Vietnamese Mechanical Factory. During casting, it is very hot and dusty in the vicinity. To reduce the temperature and dust, a water-spraying system is applied. Thanks to the improved working environment, productivity has doubled from 5 to 10 tonnes per day.

Machining

After casting, cylinder linings are transferred to the machining department for finishing using turning, drilling and boring equipment. Chips from machining are recycled. Other waste such as cloths soiled with grease or other lubricants is burned on site.

6.8.2. Vietnamese aluminium factory:

This is a medium-sized private enterprise located on a site measuring 4,000 square metres and employing 70 workers. The factory specializes in aluminium products for the home at a rate of 200 tonnes per year which are sold on the domestic market and exported to Cambodia. The production process comprises melting and casting, rolling and cutting, and finally forming and surface treatment.

Melting and casting stage

The factory recycles aluminium waste such as beverage cans and aluminium household appliances amounting to 220 tonnes per year. It is melted by burning fuel oil and then cast to produce aluminium plate. Melting 1 tonne of aluminium scrap requires about 150 litres of fuel oil. Annual fuel consumption is calculated to be about 30,000 litres per year. Gas waste and dust generated from melting aluminium are treated by a water filter system.

Rolling and cutting stage

After casting, the aluminium plate has to be rolled several times to enlarge the surface until it has the thickness required depending on the products to be made. After rolling, aluminium plate is heated up to make it flexible and cut into pre-designed pieces for the next stage.

Forming stage

The purpose of forming is to produce the product shape and is carried out on a simple turning machine with the mould. Most of the products are formed by hand, although machines are used for thicker products requiring more force. This stage does not appear to produce any hazardous waste.

Surface treatment

The final stage is the surface treatment of the product, such as plating the product with non-corrosive metals or polishing. Polishing is performed by cleaning the surface with rotating brushes, which generates a lot of toxic aluminium dust. To control its dispersion, polishing is carried out in a room with a vacuum system, although the problems are still considerable for those working inside this room. Plating is a chemical process which generates wastewater containing chemical residues. This wastewater is not yet treated at all.

7. Metallurgical industry

7.1. Economic characteristics

Table 5 shows the development of the manufacture of metal products in Vietnam between 2000 and 2004. It can be seen that output nearly tripled in this period [Statistical Publishing House, 2005].

Table 5: Development of Fabricated Metal Products in Vietnam

	2000	2001	2002	2003	Prel 2004
Manufacture of fabricated metal products, except machinery and equipment	5768.4	7062.7	8505.5	10645.5	13274.3

Similar to casting in Vietnam, most companies in this sector are fairly small. For example, there are just nine companies with more than 4,000 workers – and none were found in the statistics to employ more than 5,000 [Statistical Publishing House, 2005].

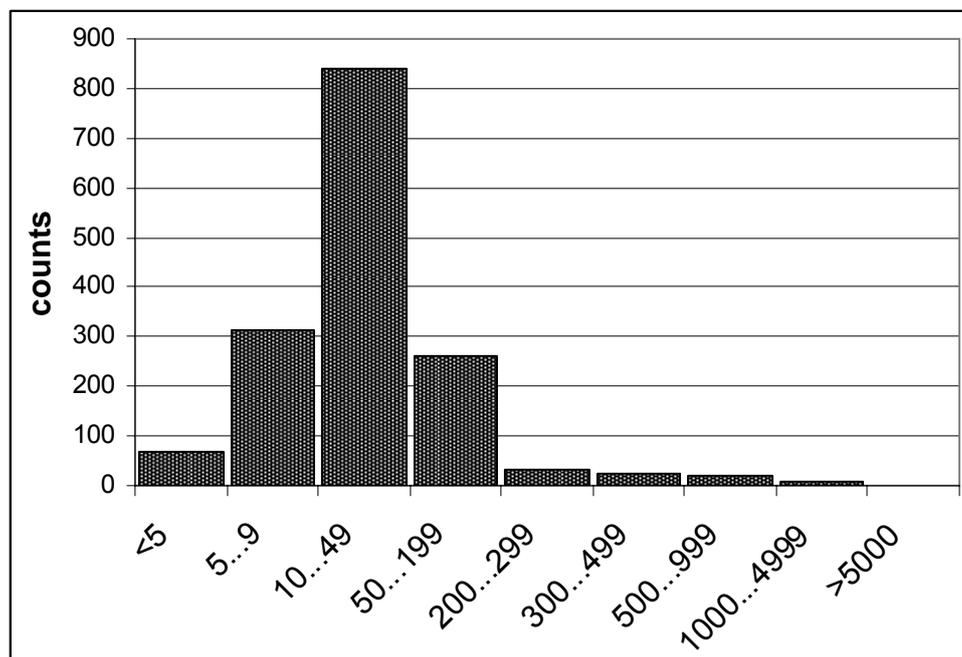


Figure 13: Companies in the metallurgical industry by size of employees

7.1.1. Processes and waste

In metallurgical industry, there exist many different processes. In the following table, most important hazardous waste generating processes are listed. Of course, enterprises can em-

ploy several processes at the same time. Four main processes are discerned. Some of them can be done in a different way whereby they generate different kind of hazardous waste. The column priority refers to the waste issue. The remaining chapter will focus only on processes, which generate hazardous waste of medium or high significance. Waste streams of minor significance are not included in the table [European Commission, 1998].

Table 6: Metal products wastes (source: EC 97)

Process	Waste stream	Priority	Description
Machining operations	Metal working fluids	++	Wastes from shaping
Cleaning and stripping	Halogenated and halogen-free solvent waste	++ +	Wastes from metal degreasing and machinery maintenance
	Contaminated water	0	Wastes from water and steam degreasing processes
	Blasting grit	+	Wastes from mechanical surface treatment processes
Metal surface treatment and plating	Spent process bath solutions	++	Liquid wastes and sludge from metal treatment and coating of metals
	Filter sludge	+	
	Wastewater treatment sludge	++	
	Spent salt bathes Spent quenchants	+ +	Sludge and solids from tempering processes
Paint application	Waste paint and sludge containing halogenated solvents	++	Wastes from MFSU ¹⁷ of paint and varnish
	Waste paint and sludge free of halogenated solvent	+	
	Aqueous waste paint and sludge	0	
Priority: ++ high significance, + medium significance, 0 low significance			

As the table shows, the main sources of hazard are chemicals (halogenated solvents, halogen-free solvents, paint) and metals (in grit, sludge, fluids and wastewater). These different forms of waste are mostly found in liquids, wastewater and sludge. The basic issues are as follows:

- A certain fraction of waste from many metallurgical operations is hazardous.

¹⁷ Manufacture, Formulation, Supply and Use

- Because only a small part of the waste is hazardous, the danger emanating from it is often not fully appreciated.
- The main dangers of hazardous waste are the emission of volatile substances, water pollution by discharge, and soil and groundwater contamination by waste disposal.
- Employees are at immediate risk from volatile chemicals (e.g. solvents) and aggressive liquids.
- Strategies for hazardous waste reduction should centre on recycling metal scrap and residues, reducing the use of chemicals, and substituting dangerous chemicals by less harmful ones.

The following sections describe the waste streams from different processes in detail, provide information about handling hazardous waste, and explain the options available for reducing it. The information about handling and prevention focuses on low-cost technologies suitable for small and medium-sized enterprises and is therefore not exhaustive. In particular, technologies which are very new and unproven as well as those requiring large-scale equipment are excluded.

7.2. Machining operations

7.2.1. Process description



The main kinds of processes are metal-cutting, forging and extrusion. Cutting processes need liquids for lubricating and cooling; extrusion requires lubricants such as grease and graphite. Other processes include forming and grinding.

Metal cutting

Several different cutting processes are used. The most important ones are laser, oxyfuel (flame), plasma arc and water jet cutting.

Laser cutting is characterized by very low tolerance. The laser contains CO₂ mixed with helium, nitrogen and other gases. Although these systems are very precise, they are also very expensive. Besides, they cannot cut material thicker than 1.3 cm and encounter problems when cutting reflective metals.

Oxyfuel cutting entails using a gas-produced flame to cut carbon steel plate. The gases most commonly used are acetylene and oxygen. Following oxyfuel cutting, secondary finishing operations are necessary. Oxygen fuel cutting is less accurate than laser cutting.

- Upsetting
- Squeezing

Common forging processes are open-die forging/hand forging, impression-die forging/precision forging, press forging, upset forging, roll forging, swaging, and net shape/near-net shape forging [Efundu, 2006].

Metal extrusion

In metal extrusion, the metal is also shaped. The material is placed in a die and a ram presses the billet [Bonnell, 2005].



7.2.2. Hazardous materials

7.2.2.1. Metal working fluids

Characteristics

Metalworking fluids are used in industrial machining and grinding operations as coolant as well as to eliminate friction and optimize product quality. They are regarded as hazardous waste because they contain oil and other additives such as emulsifiers, anti-weld agents, corrosion inhibitors, extreme pressure additives, buffers and biocides, not to mention being contaminated by metals, rust and dust. They are also frequently inflammable, endotoxic, exotoxic, mycotoxic and carcinogenic. They have different characteristics ranging from water-based fluids to pure oil, which is nearly insoluble. Semi-synthetic and synthetic fluids are used, too.

As far as employees' health is concerned, long-term exposure to metalworking fluids can cause hypersensitivity pneumonitis, chronic bronchitis, impaired lung function and asthma [European Commission, 1998].



7.2.3. Waste reduction options

This section looks at ways of waste reduction. The possible options include:

- Drawing up a working fluid management programme
- Avoiding working fluids
- Careful selection of working fluids
- Recycling working fluids

Working fluids management program

Working fluid management programmes are considered good operating practice leading to moderate prevention. One of their major advantages is that little is required in the way of time and resources. The options include:

- Setting up training courses
- Creating awareness for the importance of preventive measures
- Data collection on fluids as the first step towards assessment and waste prevention
- Appointing a person in charge of data collection and industrial safety
- Regular inspection of work processes
- Continuous fluid analysis

Avoidance of working fluids

The most effective way to reduce the usage of metalworking fluids is to avoid using them in the first place wherever possible. In some cases fluids can be replaced by air – for example cooling workpieces during the cutting process.

Careful selection of working fluids

Another way of cutting waste is to use synthetic oils. These substances often have greater thermal stability and resist oxidation. Furthermore, they are less contaminated. However, users need to check whether they are composed of harmful chemicals.

Recycling

Two approaches are used to recycle working fluids. Chemical operations are used for the treatment of wastewater with a high level of dissolved contamination. Physical methods used to separate oil and water include skimming, flocculation, flotation, filtration, centrifugation and ultra-filtration. The various techniques are specified in Chapter 1 of these guidelines [European Commission, 1998].

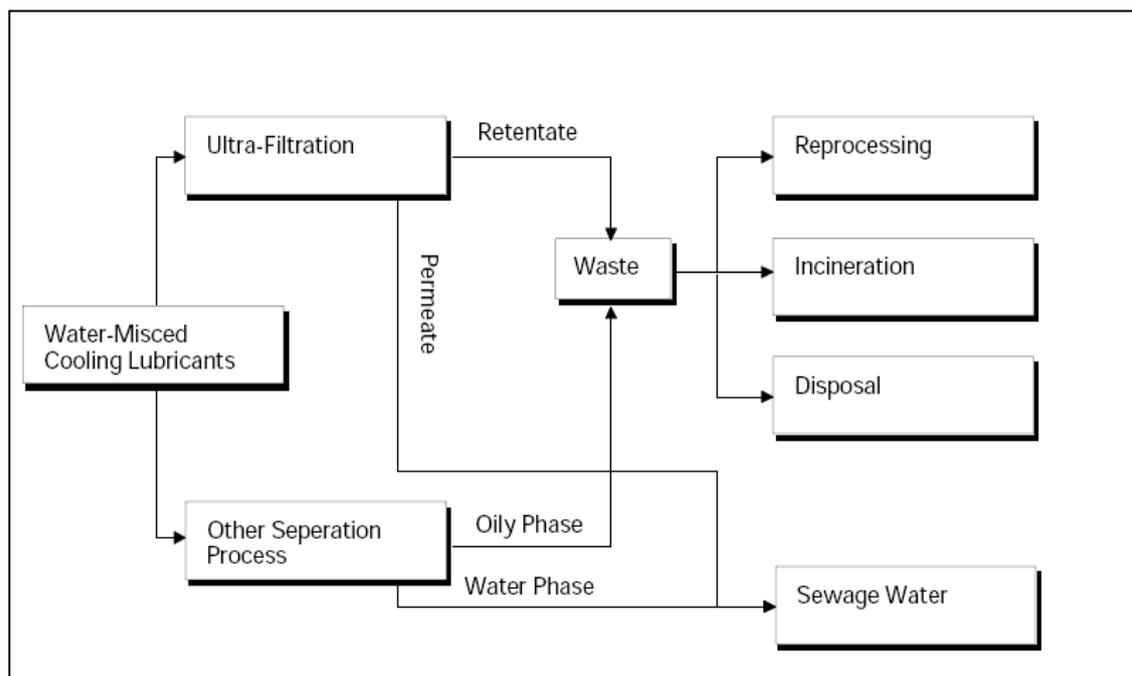


Figure 15: Treatment of Lubricants used for Metal Working [Baumann et al., 1999]



7.2.4. Further literature and links

- **Specific information about hazardous materials**

<http://www3.uwm.edu/Dept/shwec/publications/cabinet/LIEBL/Metal%20Fabrication%20manual.pdf>

<http://indoorairsite.com/Article%20Machine%20Shop%20Chemical%20Hazards.doc>

<http://www.p2pays.org/ref/04/03980>

- **Specific information about waste reduction options**

<http://www3.uwm.edu/Dept/shwec/publications/cabinet/LIEBL/Metal%20Fabrication%20manual.pdf>

<http://indoorairsite.com/Article%20Machine%20Shop%20Chemical%20Hazards.doc>

<http://wrrc.p2pays.org/indsectinfo.asp?INDSECT=45>

<http://www.dnrec.state.de.us/delmtlfb.htm>

<http://www.ecy.wa.gov/pubs/99412.pdf>

<http://www.p2pays.org/ref/03/02946.pdf>

<http://www.pca.state.mn.us/programs/pubs/p2fact.pdf>

http://www.smallbiz-enviroweb.org/html/pdf/BMP_MachineShop-7.pdf

<http://www.newmoa.org/prevention/topichub/bibliography.cfm?hub=23&subsec=7&nav=100&SortedBy=Title>

7.3. Cleaning and stripping



7.3.1. Process description

The fabrication of metal products often requires some form of cleaning or stripping. Cleaning (especially degreasing) may be a form of final treatment or also pre-treatment for further surface processing such as painting. Sand and hydro blasting are used to remove paint and corrosion, the metal being cleaned by mechanical impact.

Stripping is necessary to remove old paint, coatings or oxides. However, various harmful materials are involved in cleaning and stripping, such as halogenated and non-halogenated solvents, aqueous, semi-aqueous abrasive and cleaners, alcohols, aliphatic hydrocarbons and ketons. Depending on the process used, the following waste streams may accumulate.

7.3.2. Hazardous materials



The following subsection lists the most significant types of hazardous waste, which are generated in cleaning and stripping operations. Each kind of waste is characterized and recommendations for handling and disposal are given.

7.3.2.1. Halogenated solvent waste

Besides the solvent itself, the solvent waste contains metal particles and dust, organic materials such as oils or lubricants, and water. Typical halogenated solvents used for metal degreasing are per- and trichloroethylene as well as dichloromethane. These halogenated substances are very volatile and hence dangerous to handle, and also cause severe damage to the ozone layer. Consequently, using the most dangerous halogenated substances is already prohibited in many countries.

7.3.2.2. Halogen free solvent waste

Halogen-free solvent waste contains aliphatic and aromatic solvents such as alcohols, esters, ketones, acetates and glycols. Since these irritant, inflammable substances are mostly volatile, a considerable proportion of them is emitted into the air during and after use.

7.3.2.3. Blasting grit

Blasting grit contains a significant proportion of paint, dirt and rust particles. During typical use in an open system, about a third of the waste grit is diffusely lost to the air.

The most dangerous components are metals (lead, zinc, copper, chromium and nickel).

7.3.2.4. Waste of abrasive cleaning processes

Waste from abrasive cleaning processes often contains hazardous compounds removed during cleaning. Apart from very toxic heavy metals such as copper, cadmium and lead, paint can frequently be found in the grit, too, along with sand, steel grit, sodium bicarbonate and aluminium oxide.

7.3.2.5. Waste containing aliphatic hydrocarbons and Ketones

Apart from naphtha and mineral spirits, these waste streams contain solvents, toluene, xylene, hexane, methyl ethyl ketone and other hazardous compounds. Oil, grease and tar may also be present depending on the metals treated.



7.3.3. Waste reduction options

Waste can be reduced in cleaning and stripping as follows.

Avoidance of Cleaning

One way of reducing solvents and other waste fluids is to check whether cleaning is really necessary in the first place.

Minimizing vapour losses

Waste can be indirectly prevented by minimizing vapour losses from degreasing equipment. Placing lids on tanks and the addition of a freeboard chiller are just two possible examples.

Maintaining solvent quality

Stabilizers can be applied to lengthen the lifetime of halogenated solvents. Although the prevention potential is low, maintaining solvent quality could be a simple step towards reducing the amount of hazardous liquids in cleaning and stripping.

Alkaline degreasing

A common method to avoid liquid halogenated and halogen-free solvent waste from metal degreasing is cleaning and rinsing. The metal is transferred to a water-based alkaline cleaning system consisting of several immersion baths. The process can be optimized by ultrasonics, mixing or higher temperatures.

Recycling of solvents

Distillation processes such as vacuum distillation and thin-film evaporation can be used to recover solvents from waste. Such systems are available for both small companies as batch distillation units and large enterprises as continuous feed distillation.

In addition to proper recycling, other good housekeeping activities are necessary such as:

- Waste labelling
- Minimizing solids for optimum solvent recovery
- Separation of different solvents

Improved collection efficiency

In addition, improved collection efficiency can reduce waste in connection with the cleaning and stripping of metals.

Other methods used to prevent waste are improved rinsing and biological degreasing methods [European Commission, 1998].



7.3.4. Further literature and links

- **Specific information about hazardous materials**
<http://es.epa.gov/techinfo/facts/metalmfg.html>
- **Specific information about waste reduction options**
<http://es.epa.gov/techinfo/facts/metlprt.html>
<http://www.p2pays.org/ref/01/00021.htm>
<http://www.p2pays.org/ref/21/20279.pdf>
http://p2library.nfesc.navy.mil/P2_Opportunity_Handbook/1_4.html
<http://www.mntap.umn.edu/paint/56-PaintStrip.htm>
<http://www.p2pays.org/ref/01/00777/surface.htm>

7.4. Metal surface treatment and plating



7.4.1. Process description

There are four main types of processes. Chemical and electrochemical conversion processes produce a coating on the metal surface – either to provide protection against corrosion or to improve adhesive properties prior to painting. A metallic coating is mostly applied by

means of thermal galvanization, in which metal pieces are immersed in fluid zinc. Other conversion processes include phosphating, chromating, anodizing, passivation and metal colouring. Phosphating is used as a pre-treatment method. Chromating often uses chromate, which is very toxic and carcinogenic. Anodizing is an immersion process in which the bath contains a high concentration of metal salts or acids. In the case of passivation, nitric acid or sodium dichromate is used.

Galvanic processes mostly comprise electroplating: an electric current passes through dissolved metal salts and the workpieces. Heat treatment generates hazardous waste if carried out in salt-bath furnaces. Salt baths are used in liquid cyaniding, nitriding and carburizing. Usually some pre-treatment is necessary, which involves the above-mentioned cleaning and stripping, and sometimes pickling and etching. Electrolytic polishing, enamelling, electroless plating, immersion plating, cladding, case hardening and electropolishing are also used. The following figure shows the different steps of metal finishing and the main origins of waste streams [DPPEAb, 2006].

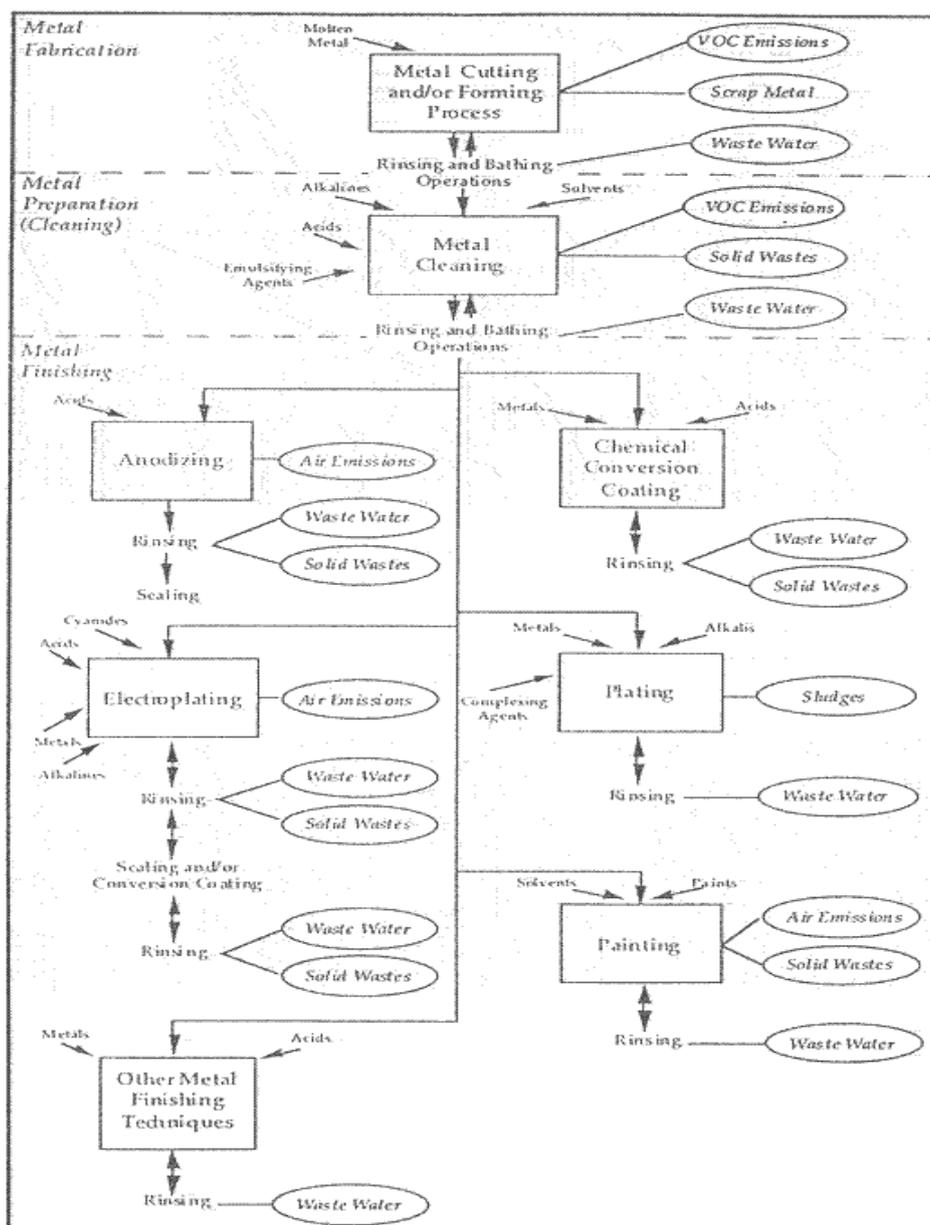


Figure 16: Overview metal finishing [WMRC, 2006]



7.4.2. Hazardous materials

Waste takes the form of spent process solutions such as salt baths or quenchant, filter sludge and wastewater treatment sludge. What makes this waste dangerous is the fraction of heavy metals, especially chromate and cyanide.

7.4.2.1. Spent bath solutions and filter sludge

Depending on the process used, the waste may contain heavy metals like chromium or cadmium as well as other metals like zinc. Moreover, many kinds of waste contain cyanides. Apart from these extremely toxic materials, organic compounds and other dangerous materials such as additives or phosphates may be part of the waste. Depending upon its composition, sludge in particular is regarded as acutely toxic because of its high concentration of metals, cyanide, fluoride or acids. The alkaline materials contained can also make the waste corrosive.

7.4.2.2. Spent salt baths

Spent salt baths are especially dangerous because they are corrosive. Furthermore, they may contain cyanide.

7.4.2.3. Wastewater treatment sludge

Whenever wastewater is cleaned, a concentrated hazardous sludge is always created. This sludge is usually heavily contaminated with substances such as heavy metals or acid depending on the metal treatment method used.

7.4.3. Waste reduction options



Reduction of rinse water consumption

The first step to reducing wastewater consumption could be to collect data on the bath volume in order to determine the minimized rinse water demand. Another possibility is to improve rinsing by air as well as mechanical, ultrasonic or hydraulic measures. The use of cascade baths can also improve the situation.

Change of bath composition

By altering hazardous compounds like chromate, wastewater streams can be reduced. Using less toxic components such as cyanide-free or low cyanide baths in zinc plating is also conceivable.

In the case of cyanide-free zinc plating, formerly complexing or chelating agents like sodium gluconate, triethanolamine or polymeric amines are used. Iron-zinc alloys could be created as a result of applying such substances. This could cause discoloration, yellow chromate films, or other problems.

Besides these inorganic agents, these days organic, chelate-free substances are often used. We distinguish between low-chemistry alkaline non-cyanide (low-metal bath) and high-chemistry alkaline non-cyanide (high-metal bath) technologies [Anonymous, 2006b].

Table 7: Comparison cyanide-free techniques

	Low Chemistry Bath	High Chemistry Bath
Efficiency	50 – 60 %	70 – 95 %
Conductivity	Poor	Good
Cost	Moderate	Higher

Alternative technologies

Besides the changing of bath composition, there exist alternative technologies to reduce hazardous wastes. Alternative methods to electro plating are e.g. hot dipping, metal powder coatings, vacuum plating, plasma-spraying or cladding.

Regeneration of baths

If spent bath cannot be prevented, the regeneration of baths by means of ion exchangers, the evaporation of plating baths for a higher concentration of chemicals, electro dialysis and electrolysis are all ways of reducing wastewater in metal surface treatment.

Prevention of spoil of salt baths

Another way of reducing waste is to increase the lifetime of salt baths. This can be achieved by:

- Pre-cleaning workpieces
- Closed baths if they contain cyanides
- Using cascade baths

Alternative process for nitriding and carburising

The proven techniques of ion-nitriding and ion-carburizing are two alternatives to conventional nitriding and carburizing. Induction heat treatment may also provide an alternative, but only after further development.

Optimising of quenching

Liquid salts adhering to metals can contaminate quenchant, reducing their effectiveness and requiring renewal. Reducing drag-in and drag-out are two ways of improving the situation.

Other good operating practices include controlling the temperature and using modified quenchant.

The internal treatment of quenchant is often too expensive for small companies [European Commission, 1998].



7.4.4. Further literature and links

- **Specific information about hazardous materials**

<http://www.p2pays.org/ref/03/02454/regover.htm>

- **Specific information about waste reduction options**

<http://www.p2pays.org/ref/03/02454/overview.htm>

http://www.epa.gov/nrmrl/std/mtb/metal_finishing.htm#nmmsfp

<http://es.epa.gov/techinfo/facts/california/metal-fs.html>

<http://es.epa.gov/techinfo/facts/jersey/njmetal.html>

<http://www.ahs.dep.state.pa.us/Clearinghouse/Documents/%7B216D8B77-01D4-4FB2-8057-49E272B745ED%7D/soqmt.pdf>

<http://www.p2pays.org/ref/15/14279.pdf>

<http://www.key-to-steel.com/Articles/Art126.htm>

7.5. Paint application



7.5.1. Process description

Paint can be applied through wet processes such as spraying, immersion, brushing or powder coating. Painting usually requires some cleaning process as already described [WMRC, 2006b]



7.5.2. Hazardous materials

7.5.2.1. Paint sludge

The danger harboured by paints and paint sludge depends on the solvents and pigments. Water-based paints are less hazardous. The problem with pigments is that they often contain heavy metals such as chromium, molybdenum, zinc, cadmium or lead.



7.5.3. Waste reduction options

Alternative paints

The use of alternative paints has a high potential to prevent sludge containing solvents. Particularly suitable alternatives include solid-free liquid coatings, waterborne coatings, low-reactivity solvent-based products, higher solids coatings and powder coating.

The following figure shows a good operating practice. In this case, the workpiece is prepared, dried and cooled during the production process. Afterwards the material is coated with powder, fired and cooled again. Unused powder can be recovered during a recycling step. Such systems allow not only powder use to be minimized but also the prevention of a waste stream containing powder. This technology is shown in Fig. 19 [Bilitewski, 1999].

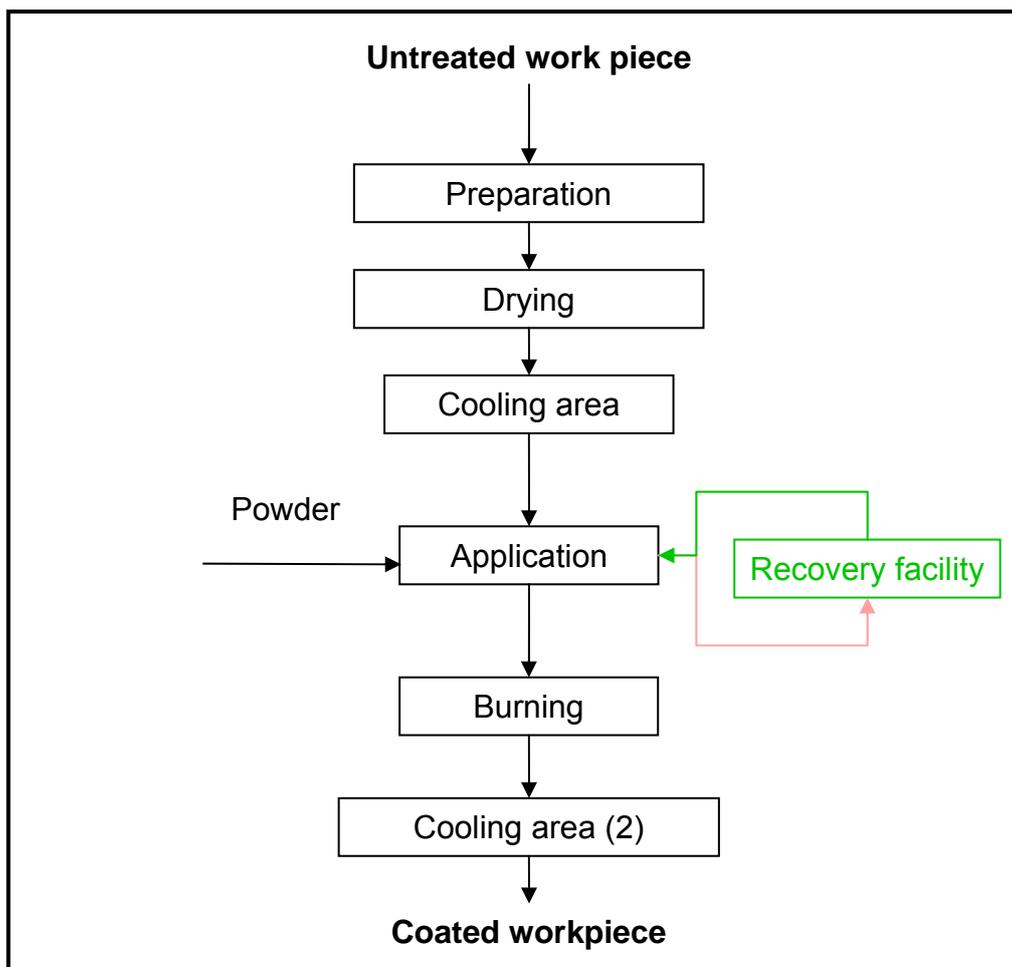


Figure 17: Internal treatment during paint application

Alternative application methods

Apart from alternative paints, there are also alternative methods of application. One conceivable option for instance is plunge-bath painting. The amount of waste paint can be reduced by improving painting parameters such as spray shape, spraying device design and spraying time. Other alternative methods include airless, electrostatic, and high-volume, low-pressure spray painting. Moreover, there are various steps which can be optimized by the operators:

- Checking all parts
- Avoiding excessive air pressure
- Setting an adequate overlap between spray pattern
- Setting an optimum distance between spray gun and workpiece
- Optimizing gun speed

Reduction, collecting and reuse of overspray

Other ways to reduce waste paint include improving painting processes (techniques with low overspray) and better operator training. Proven technologies with reduced overspray are conventional air-atomized, electrostatic air-atomized, electrostatic centrifugally atomized, and conventional pressure-atomized spraying.



7.5.4. Further literature and links

- **Specific information about hazardous materials**

http://www.wmrc.uiuc.edu/main_sections/info_services/library_docs/manuals/coatings/backgr.htm#Sources%20of%20Wastes

- **Specific information about waste reduction options**

http://www.wmrc.uiuc.edu/main_sections/info_services/library_docs/manuals/coatings/planp2.htm

<http://outreach.missouri.edu/polsol/paint.htm>

<http://www.mntap.umn.edu/paint/85-Alternatives.pdf>

<http://es.epa.gov/techinfo/facts/vdwm/va-fs5.html>

http://cage.rti.org/altern_data.cfm?id=hvlp&cat=Process

7.6. Handling/ Disposal/ Prevention- general aspects

Properly handling, preventing and disposing of hazardous compounds is frequently very difficult. This section contains details on how to better protect both the environment and employees. Chiefly in order to avoid hazardous compounds, the following recommendations should be observed:

- Consider using reusable cleaning rags
- Purify polluted refrigerants to enable the maximum utilization of oils
- Minimize or if possible avoid altogether using the substances with a high level of chromate, lead or cadmium
- Stop using harmful solders
- Replace drinking water by process water whenever appropriate
- Clean up contaminated refrigerants
- Prevent the transportation of refrigerants into subsequent baths
- Decrease the amounts of refrigerants used
- Use vegetable oil if possible

- Stop using chlorinated liquids
- Substitute nitrite compounds
- Keep refrigerants free of foreign bodies and impurities
- Minimize the use of refrigerants
- Stop using harmful solvents
- Use varnishing methods with a high level of residue and waste prevention
- Improve staff training to ensure maximum utilization of the paints used
- Use substances with low levels of heavy metals and harmful solvents
- Use automatic dosing
- Mix residue with new material, especially for pre-treatment [AAU, 2006]

Besides these steps, also trainee courses in handling, prevention and emergency response are very important. Concerning the protection of human health and environment, the segregation, storage and transport of hazards is different to household waste. Therefore, the following points should be attended.

Designation of special storage areas

These areas should be placed under the control of one person. They should be clean, fitted with gas sensors and impermeable flooring, and separated from other parts of the factory. Other requirements include good ventilation and the presence of absorbent material. In addition, an emergency plan must be drawn up. The following diagram shows a typical factory storage area.

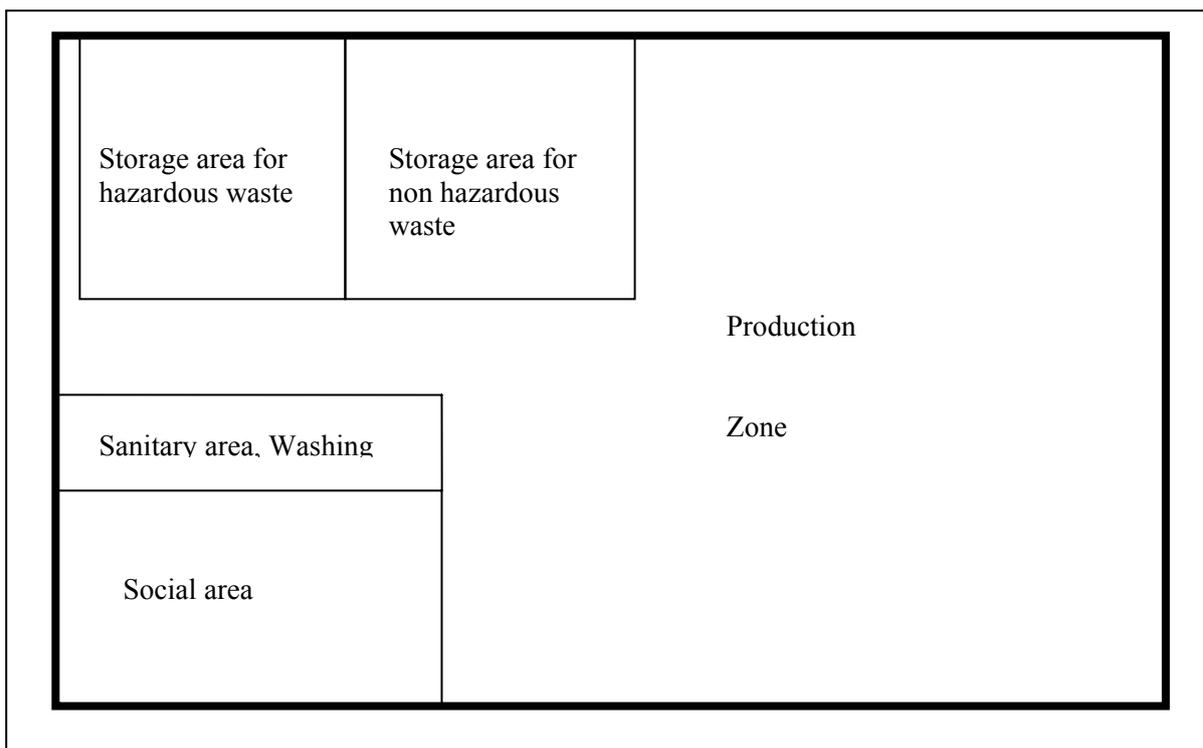


Figure 18: Floor plan

Finally, the following recommendations should be followed:

- Store waste and chemicals in suitable, labelled containers
- Check the chemical compatibility of different types of waste
- Use securely sealed containers for hazardous compounds
- Make sure that detailed information about the chemicals and substances used is available
- Only keep hazardous substances stored for a limited period of time [SDS, 2006]

Creation of labels, characteristics of the substances

During storage, transport and disposal, hazardous compounds must be properly labelled. The main objective of labelling is to identify and minimize risks.

In the case of hazardous materials such as raw chemicals, the label must always contain the following information:

- Specific chemical name
- Specific trade name
- Protective equipment
- Special hazard warnings

Apart from being marked “hazardous waste”, these labels must contain the following details:

- Chemical composition (if possible quoted in percentages)
- The waste generator (name, company, address, telephone number)
- Hazard category(ies)
- Date of accumulation

Labels such as “toxic” and “flammable” indicate the risk posed to health and the environment – but employees have to know how the substances are to be dealt with. In metalworking, spent cyanide solvents are frequently reused. They are classified as toxic because they are harmful if inhaled or ingested. When handling metalworking fluids, particular care must be taken to protect the skin.

Waste oils and solvents are flammable and often spontaneously combustible.

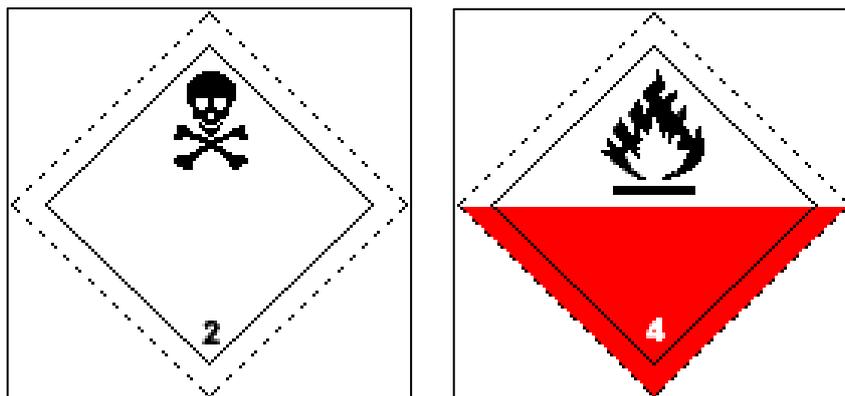


Figure 19: Labels [Wilson et al, 2002]

Ideally, the label should contain brief characteristics of the substance in both the local language and English (see the following illustration).

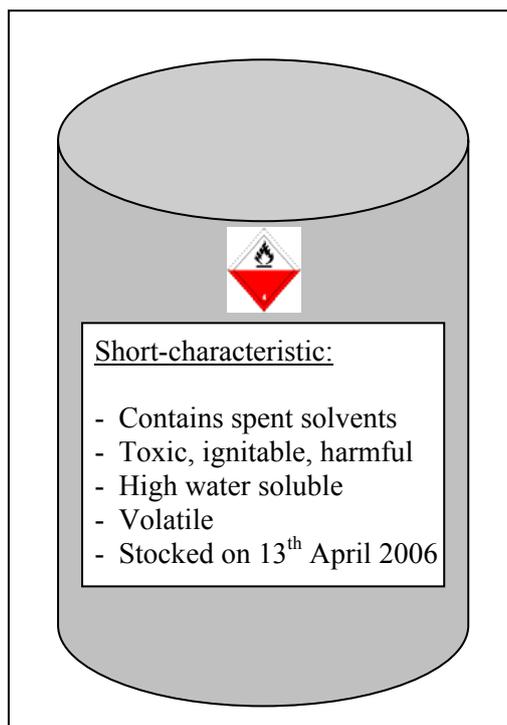


Figure 20: Marking, Labelling

International labels can be downloaded free under:

http://www.ecy.wa.gov/programs/hwtr/hw_labels/index.html.

Adapted container systems according to the substances

Regarding the storage and transport of hazardous waste, specially adapted container systems such as tanks, bunkers, silos, bags, boxes, drums or skips are necessary to prevent diffusion into the environment. The systems should be chosen depending on each substance's characteristics. Especially in the case of hazardous waste, compatibility between different chemicals as well as that of chemicals with the container material must be ensured.

Wear of personal protective equipment

Personal protective gear such as chemical-resistant safety boots and shoes, hard hats, inner chemical-resistant gloves, cooling units, coveralls, long cotton underwear, disposable gloves and boot covers is used to protect the respiratory system, skin, eyes, face, hands and feet. In addition, two-way radio systems are used for safety reasons [USEPA, 2006].

Attention needs to be paid to the characteristics of the substances concerned. Because of the extreme danger emanating from waste containing in particular chromium, cadmium, cyanides or fluorides, it must be handled with great care and must only be disposed of at special hazardous waste landfills.

When selecting the protective gear required, the following information about the chemicals and waste need to be considered:

- Chemical composition
- Degree of exposure
- Level of hazard
- Required level of performance of the protective gear

Generally speaking, information is available about chemical profiles and the chemical resistance of protective equipment. This information is summarized in the following table.

Table 8: Information about chemical resistance of protection equipment

Information	Remark
Excellent Resistance/ Many Data	Existence of many (quantitative) information that indicate an excellent chemical resistance
Good Resistance/ Limited Data	Existence of (quantitative) Information that indicate a good chemical resistance
Poor Resistance/ Many Data	Existence of many (quantitative) information that indicate a poor chemical resistance
Poor Resistance/ Limited Data	Existence of (quantitative) information that indicate a poor chemical resistance
Good Resistance/ Limited* Data	Existence of less (qualitative) information that indicate a good chemical resistance (mostly proved by the companies themselves)
Poor Resistance/ Limited* Data	Existence of less (qualitative) information that indicate a poor chemical resistance (mostly proved by the companies themselves)
Good Resistance/ Limited** Data	Existence of less (qualitative or quantitative) information that indicate a good chemical resistance (mostly without chemical specific tests)
Poor Resistance/ Limited** Data	Existence of less (qualitative or quantitative) information that indicate a poor chemical resistance (mostly without chemical specific tests)

Segregation of all of waste streams.

The segregation of waste streams is the first step toward preventing harmful substances, since data collection enables assessment for the subsequent replacement, abandonment, substitution or reduced usage of refrigerants, solvents and other harmful substances.

Transport of the harmful substances in special transport systems

If avoidance or in-house treatment are not possible, transportation to subsequent recycling or disposal will be necessary. Like the storage of hazardous substances, attention must be paid to health and environmental considerations.

The first step for the safe transport of harmful chemicals and hazardous waste is the proper training of drivers, loaders and handlers. Drivers must always:

- Have a certificate regarding the origin, destination and characteristics of transported substances
- Turn off the engine during loading
- Put the brakes on during loading
- Drive carefully and at moderate speed
- Take account of climatic aspects
- Not drink alcohol, take drugs or smoke
- Use proper personal safety equipment
- Have first-aid equipment to hand
- Be trained in what to do in the event of accidents and leaks

In addition, strict labelling, a suitable vehicle and containers made of appropriate material must be used. The following diagram gives details of suitable tank material [Wilson et al, 2002].

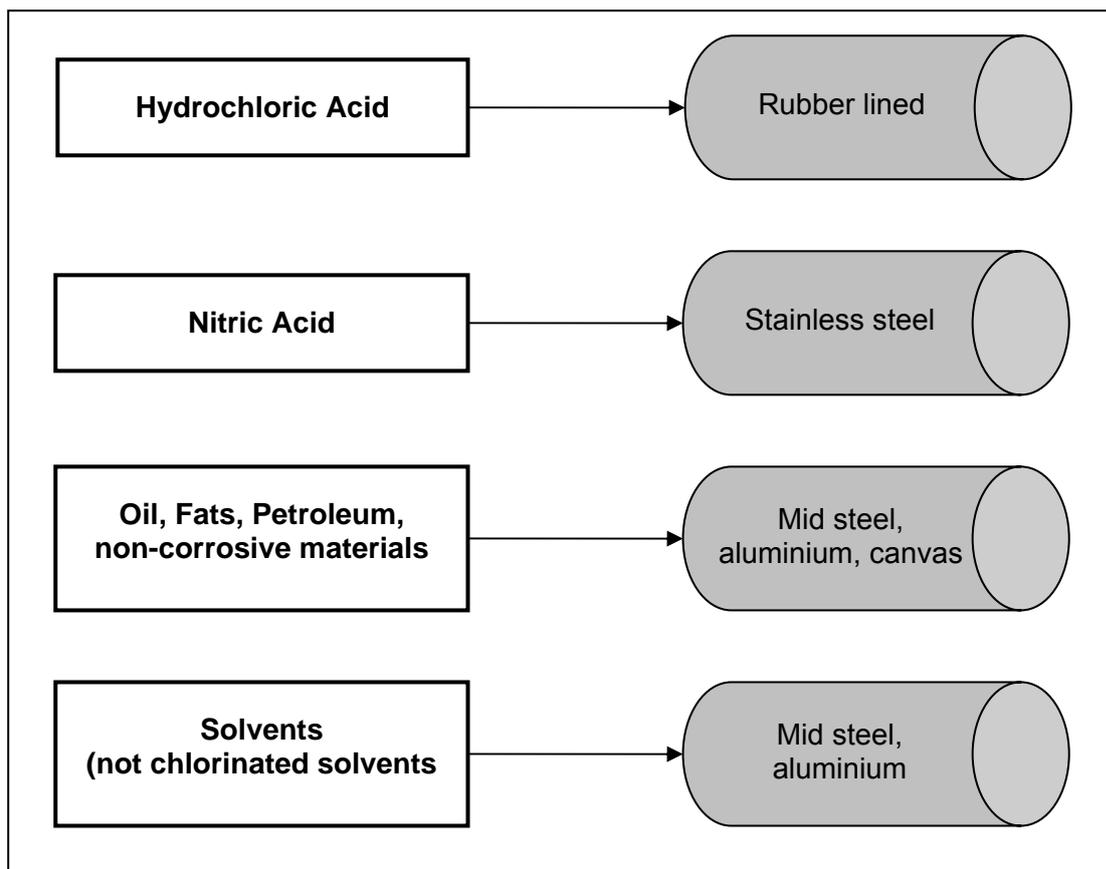


Figure 21: Tank material- examples



7.7. Summary

The four main processes in the metallurgical industry are machining operations, cleaning and stripping, metal surface treatment and plating and paint application. The most important details about the waste characteristic, risks and first steps to reduce the risks in the sector of treatment metallurgical work pieces are summarised in the following table.

Table 9: Overview- metallurgical industry (part 1)

	Waste characteristics	Probable risk	Steps to lessen risk
Machining operations (wastes from shipping)	<p>Metal working fluids, contain the following:</p> <ul style="list-style-type: none"> - Oil - Emulsifiers - Anti weld agents - Corrosion inhibitors - Extreme pressure additives - Buffers - Biocides 	<p>Hypersensitivity pneumonities</p> <ul style="list-style-type: none"> - Chronic bronchitis - Impaired lung function - Asthma 	<p>Waste reduction through:</p> <ul style="list-style-type: none"> - Working fluids management - Avoidance of work fluids - Selection of working fluids - recycling
Cleaning and stripping (wastes from metal degreasing, machinery maintenance, water and steam degreasing and mechanical surface treatment)	<ul style="list-style-type: none"> - Halogenated solvent waste - Halogen free solvent waste - Blasting grit - Waste of abrasive cleaning processes - Waste containing aliphatic hydrocarbons and ketones 	<ul style="list-style-type: none"> - Highly volatile, damaging to ozone layer - Volatile, irritating, flammable - Metals (including lead and copper) - Paint, heavy metals, sodium bicarbonate, aluminium oxide - Solvents, oil, grease and tar 	<ul style="list-style-type: none"> - Avoidance of cleaning - Minimising vapour loss - Maintaining solvent quality - Alkanic degreasing - Solvent recycling - Improvement of collection efficiency

Table 10: Overview- metallurgical industry (part 2)

	Waste characteristics	Probable risk	Steps to lessen risk
Metal surface treatment and plating (Liquid wastes from sludge from metal treatment and coating, Sludge and soils from tempering process)	<ul style="list-style-type: none"> - Spent bath solutions and filter sludge - Spent bath salts - Wastewater treatment sludge - Fractions of heavy metals (chromate and cyanide) 	<ul style="list-style-type: none"> - Heavy metals, cyanides, additives, phosphates Metals, fluorides, cyanide and acid in sludge - Corrosive, cyanide - Heavy metals, acids 	<ul style="list-style-type: none"> - Reduction of rinse water consumption - Change of bath composition - Alternative technologies - Bath regeneration - Prevention of spoil of salt baths - Alternative for nitriding and carburising - Optimising of quenching
Paint application (Wastes from manufacture, formulation supply and use of paint)	<ul style="list-style-type: none"> - Dependant on solvents and pigments - Pigments contain (chromium, molybdenum, cadmium, lead) 	<ul style="list-style-type: none"> - Exposure to heavy metals - Exposure to solvents - Exposure to pigments 	<ul style="list-style-type: none"> - Use of alternative paints to prevent sludge containing solvents - Alternative application - Reduction, catching and reuse of overspray

The basic issues associated with such wastes are:

- A small fraction of any metallurgical waste is hazardous.
- This can lead to the waste not being recognised.
- Many dangers are due to the emission of volatile substances for example: water pollution and soil and groundwater contamination.
- Imminent dangers to employees arise from volatile chemicals and aggressive liquids.
- Basic strategies for reduction should include recycling of metal scrap and residues, reduction of chemical use and the substitution of hazardous chemicals with less harmful options.



7.8. Case study

7.8.1. Vietnamese Mechanical Factory II

This Mechanical Factory is a medium-sized state enterprise. The factory has an area of 16,000 square metres. The factory makes mechanical products such as steel bridges for rural areas and steel frames for buildings. The production process includes welding, machining, painting and zinc-coating. Painting work is carried out outdoors, allowing dust to spread to the wider surroundings. Hazardous waste is generated by the coating and painting departments. The coating stage with a capacity of 1.5 tonnes per hour consists of chemical treatment. The wastewater is hazardous because it contains some toxic chemicals. To melt the zinc for coating, DO fuel is used at the rate of 24 litres per hour. Gas exhausted by burning fuel is treated by a filtering system.

7.8.2. Vietnamese Mechanical Company II

General information

This company, a private company, was founded in 1999. It is located in Tranoc Industrial Park, Can Tho City. The company has 130 employees and its site is 16,000 square metres in size. The company manufactures nails for export to the USA, Canada and Taiwan, and produces 6,000–7,000 tonnes annually. The production technology and equipment are Taiwanese. In response to customer demand, the company plans to obtain ISO 9000 certification in 2006.

Production process and waste generation

The nails are made in two stages: a mechanical and a plating process. The mechanical process comprises metal drawing, cutting and nail-pressing. In the plating process, the nails are coated with zinc, which first entails cleaning them of oil and rust. Plating involves several chemicals and so generates hazardous wastewater. The following diagram shows the structure of the plating process at Kim Xuan Company.

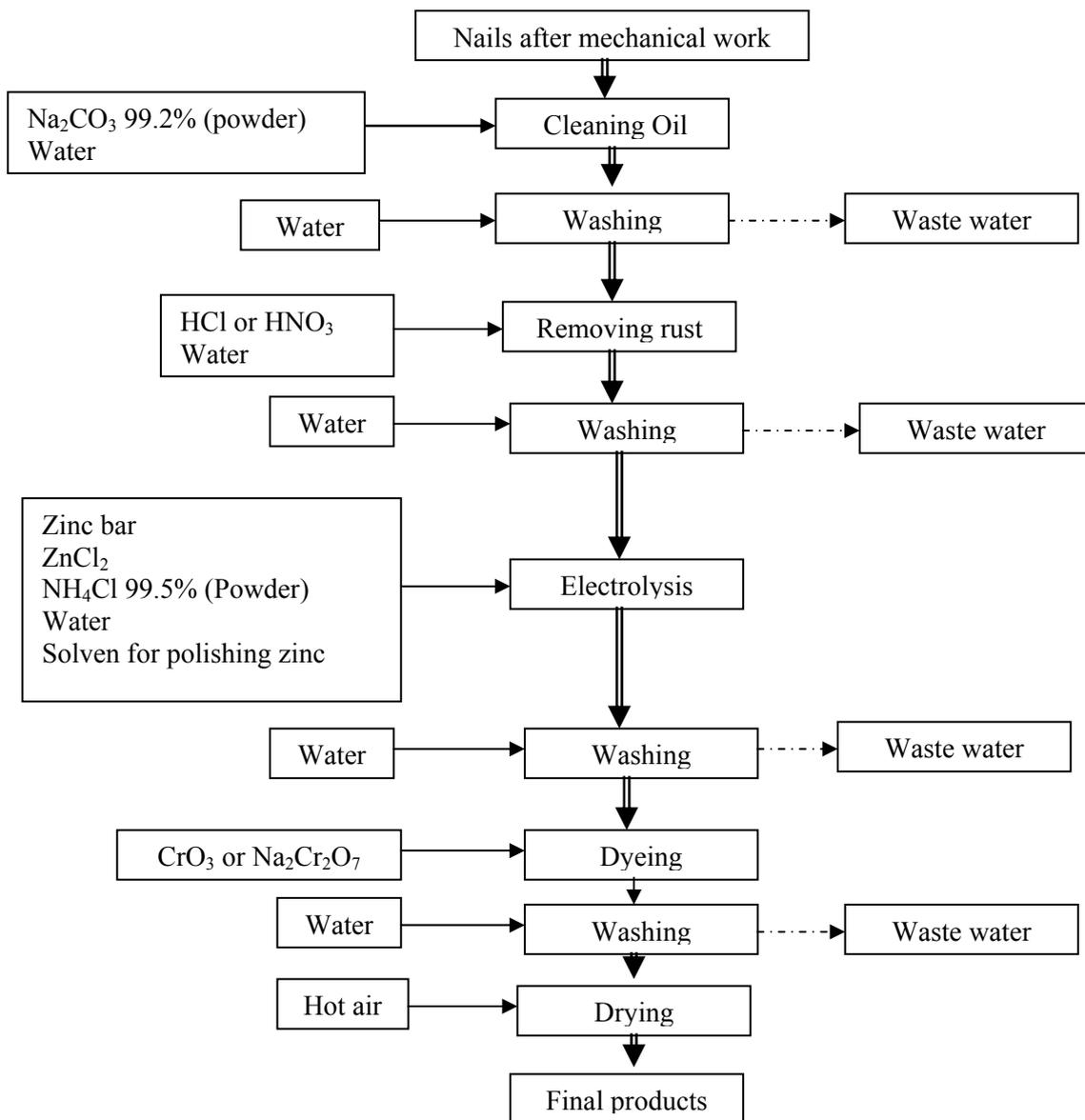


Figure 22: Layout of zinc plating process

Wastewater is generated during production at the rate of 51 cubic metres per day. It contains toxic substances such as hydrochloric acid (HCl), nitric (HNO₃), NaOH, Na₂CO₃, Fe, Zn, Cr and so on. Although the company currently applies a simple filtering system to treat wastewater, it is not efficient enough. The following table shows the value of some parameters of the wastewater at different stages of the plating process.

Table 11: The value of parameters of wastewater at Kim Xuan Company [(Source: Khanh, L.P. Thesis: Research for Treatments Process of Waste Water at Kim Xuan Company, 2005)

No.	Parameters	Unit	Stages			
			Oil cleaning	Rust removing	Electrolysis	Dyeing
1	pH		7.19 – 9.43	2.04 – 2.43	6.43 – 6.74	4.72 – 5.43
2	Zinc	mg/l	10.3 – 23.6	4.3 – 9.24	1897 – 10820	253 – 687
3	Chromium	mg/l	23.4 – 30.8	6.3 – 10.6	4.9 – 7.3	386 – 930
4	Iron	mg/l	20.3 – 40.6	30.6 – 50.7	14.1 – 30.5	10.2 – 20.3
5	COD	mg/l	960 – 2240	810 – 1980	2880 – 4920	2320 – 3160

In comparison to the Vietnamese Industrial Wastewater Standard (TCVN 5945-1995), these values are very high. With such wastewater being so dangerous for the environment and public health, attempts are now being made to minimize its hazardous impact.

8. Chemical and agrochemical industry

8.1. Economic characteristics

Table 12 shows the development of the production of insecticides and chemical fertilizers in Vietnam. Continuous economic growth has made the fertilizer-manufacturing sector especially important [Statistical Publishing House, 2005], which explains why it is addressed in this chapter.

Table 12: Development of fertilizer and pesticide- production in Vietnam [Statistical Publishing House, 2005]

Industrial sector	Unit	2000	2001	2002	2003	Prel.2004
Insecticide	Ton	20948	23921	33617	40949	44277
Chemical fertilizer	Thousand tons	1210	1270	1158	1294	1453

Figure 25 shows the relationship between the numbers of companies and employees in Vietnam. It is significant that most companies have fewer than 200 employees. There are 317 firms with 10–49 workers. Therefore, this chapter also contains simple steps for the improved protection of workers and the environment in small firms.

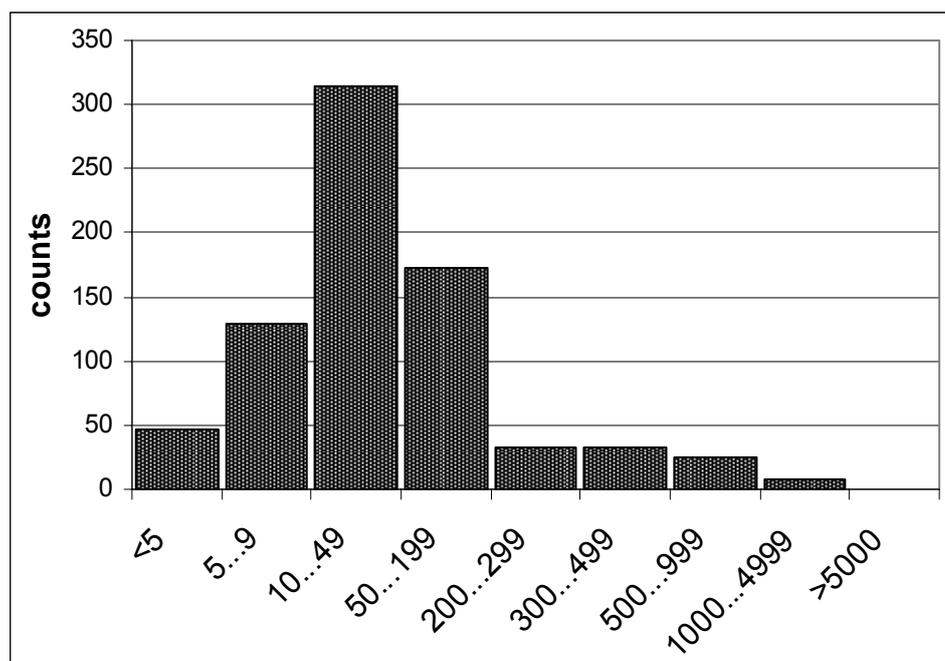


Figure 23: Counts of companies by size of employees

8.1.1. Processes and waste

The main area where waste can be reduced is the use of chemicals. This is especially true of the agrochemical industry. The best way to reduce environmental pollution is to train users of agrochemicals to use the required amount of chemicals and no more.

Since chemical industry employees are faced by a huge variety of processes, detailed information cannot be given here on specific types of waste and processes. This chapter deals with pesticide production and the fertilizer industry [Pesticide Action Network, 2006].

Table 13: Chemical products wastes

Process	Waste stream	Priority	Description
Fertilizer Industry	Depending upon process	++	Waste can emerge as a by-product, as unchanged main reactants, impurities or auxiliary chemicals
Manufacture of pesticides	Depending upon process	++	Applies the same like aspects of the fertilizer industry

Priority: ++ high significance, + medium significance, 0 low significance

8.2. Fertilizer industry



8.2.1. Process description

Since various production processes are employed in the fertilizer industry depending on the type of fertilizer required, it makes sense to explain the different types. The following groups of fertilizers can be used as straight or as complex fertilizers:

- Nitrogen fertilizers
- Phosphate fertilizers
- Potash fertilizers
- Multi-nutrient fertilizers

Before giving more details about the production processes, the following overview shows the resources used to make fertilizers and the intermediates arising [EFMA, 2001]

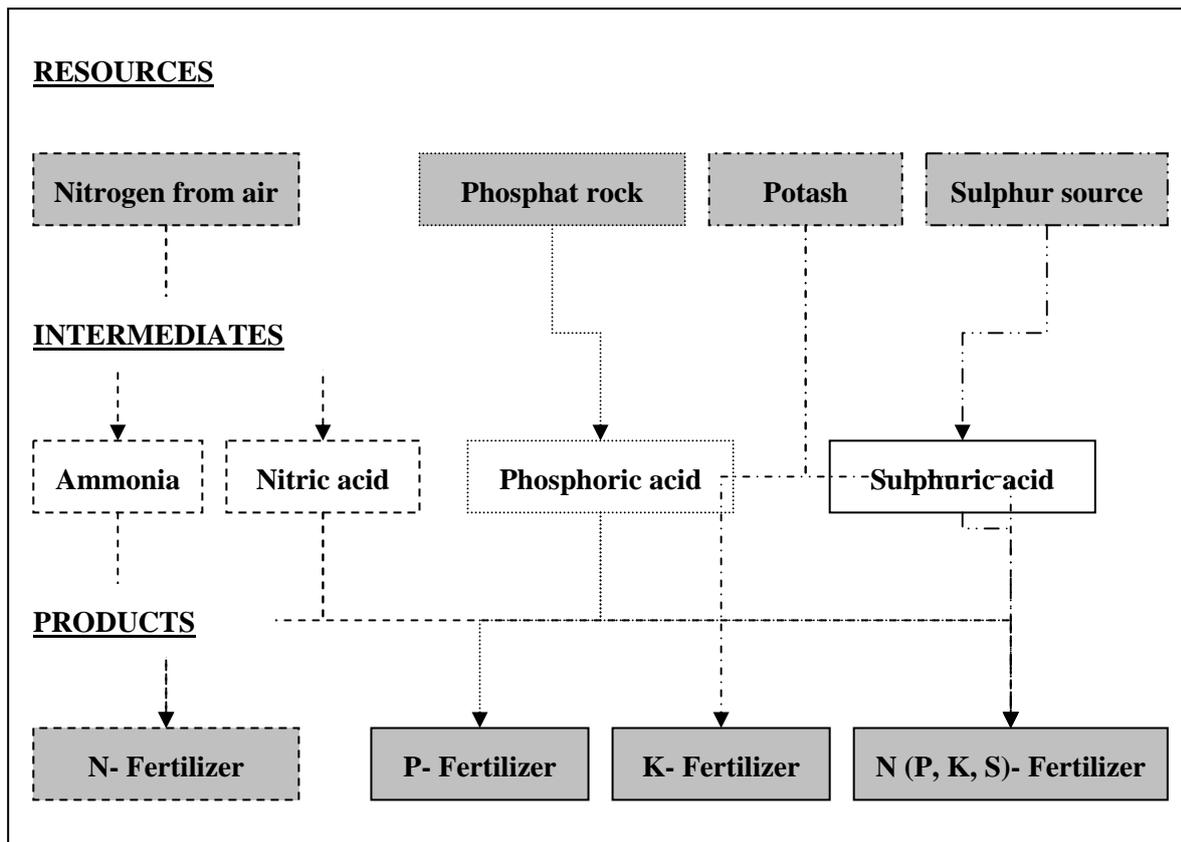
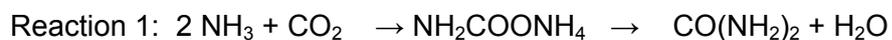


Figure 24: Fertilizer Production

Manufacture of N- Fertilizers

Urea

The production of urea takes place at a temperature of 180–190°C as well as at a pressure of 140–200 bar. The chemical reactions (cf Reaction 1) involve the formation of ammonium carbamate followed by dehydration to urea and water.



Four processes are used to synthesize ammonium carbamate: carbon dioxide stripping, ammonia stripping, the advanced cost and energy saving (ACES) process and the isobaric double recycle (IDR) process. Fig. 9 shows the production steps and possibilities for using the intermediates.

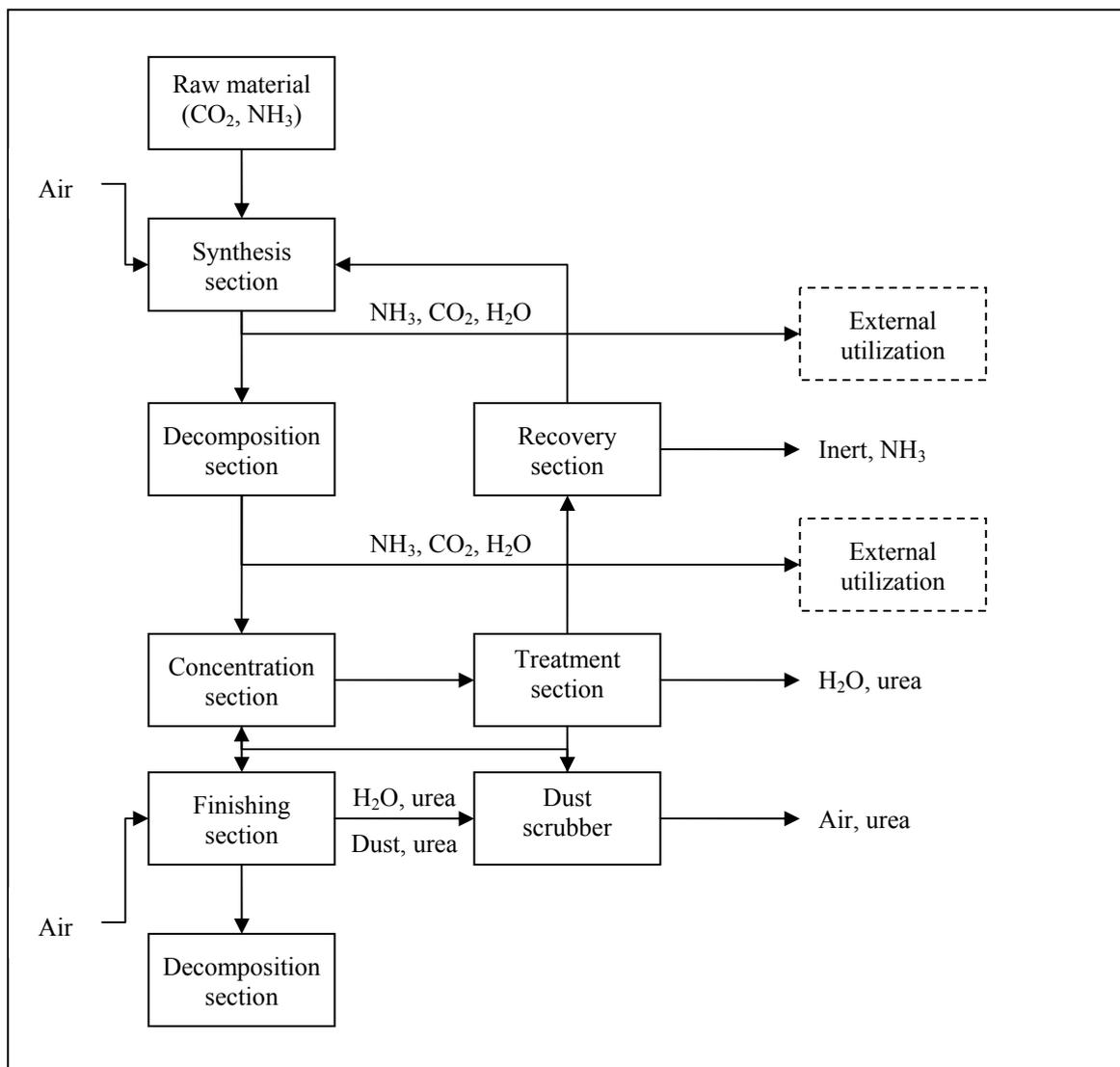


Figure 25: Processes and waste during Manufacture of N- Fertilizers

Urea-Ammonium Nitrate

This type of fertilizer is made by mixing concentrated urea with ammonium nitrate. Both continuous and batch processes are applied. Another method is to use unconverted NH₃ and CO₂ from the production of urea. The consumption of resources is shown in the following diagram.

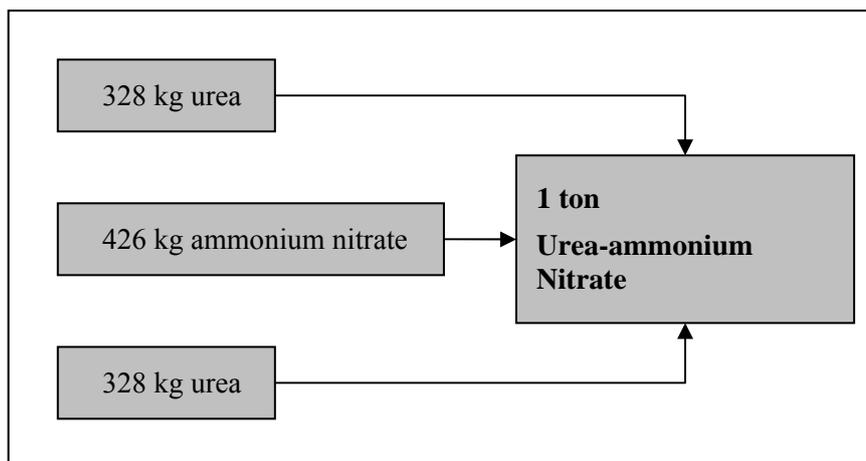


Figure 26: Necessary Raw- Materials for Manufacture of Urea Ammonia Fertilizer

Ammonium and Calcium-Ammonium Nitrate

Gaseous ammonia is used for the production of ammonium nitrate. Nitric acid is neutralized in an exothermic reaction. The formation of the substance is followed by concentration and often granulation.

If dolomite, calcium carbonate and ground limestone are added, a calcium ammonium nitrate-fertilizer can be produced.

Manufacture of N (P, K, S)- Fertilizers

Single and Triple Superphosphate

The main objective when producing superphosphate is to transform mineral phosphate into a water-soluble form. In the case of single superphosphate, this is done by using sulphuric acid. Calcium sulphate can also be formed.

If phosphoric acid is used both the sulphuric acid, double or triple superphosphate can be produced after mixing both the acids.

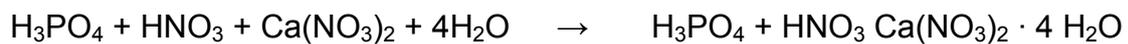
Multi-nutrient Fertilizers

One way of producing multi-nutrient fertilizers is the dry mixing of mono-fertilizers. Generally speaking, hardly any emissions are to be expected. Therefore, these guidelines deal with multi-nutrient fertilizers formed after chemical processes. Such processes are mostly classified as either the mixed acid route, the phosphoric acid route or the nitric acid route.

During production, in processes defined as the mixed acid route, sulphuric, nitric or phosphoric acid is mixed. Mineral phosphate can also be used. After adding ammonium

nitrate, neutralization is necessary. This can be done using gaseous ammonia. Often multi-nutrient-fertilizers are added. In a finishing process, the substances are dried, screened, cooled, granulated or coated. Mono-ammonium phosphate, di-ammonium phosphate and NPK are all fertilizers that are produced with the phosphoric acid route.

In addition, multi-nutrient fertilizers can be produced with the nitric acid route (cf Fig. 29). In this case, nitric acid is used to react with mineral phosphate. A secondary product is calcium nitrate, which can be used as fertilizer, too. The process consists of the following reactions.



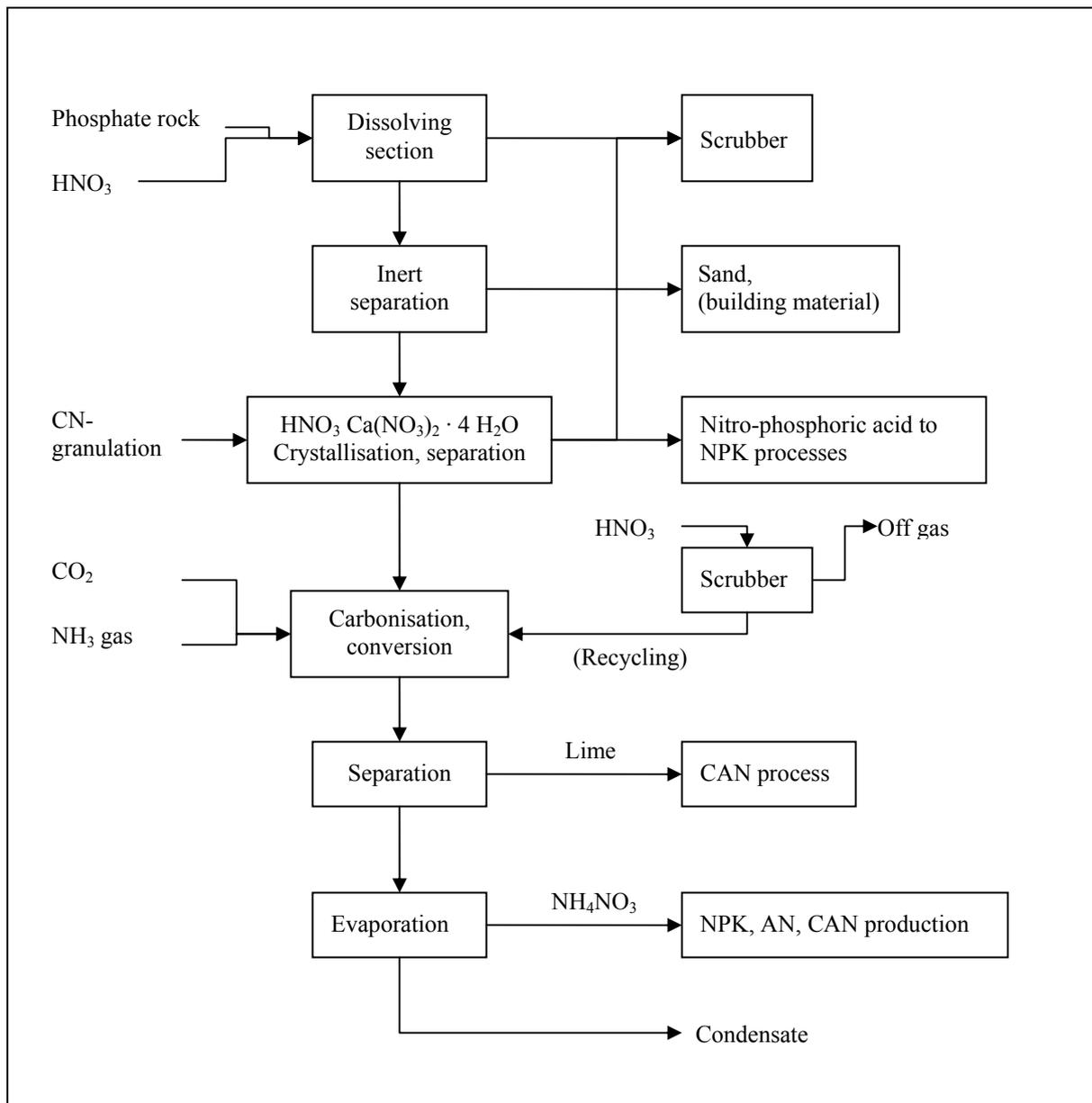


Figure 27: Multi- nutrient fertilizer- production with Nitric Acid Route



8.2.2. Hazardous materials

During the production of fertilizers, only a small amount of hazardous substances accrues. However, problems can occur with the fertilizers themselves if there are for example leak-ages. Therefore, this section mentions just the hazardous components in wastes and their characteristics. Depending on the production process, the following waste may be formed:

- Asbestos
- Waste or spent batteries
- Heavy metals
- Spilt chemicals

- Waste oils
- Additional components like herbicides

Characteristic of ammonia, urea, nitric acid, ammonium and calcium nitrate and other compound fertilizers

Leaks of synthesis gas in the gas compression area or the hydrocarbon feed system could cause fire or an explosion. Moreover, ammonia is toxic.

Like ammonia, urea is a toxic hazard too. If urea forms a gas mixture, explosions may occur. Urea and nitric acid cause corrosion to the production systems. Furthermore, nitric acid is an explosion hazard if nitrite or nitrate salts are formed. Ammonium nitrate and calcium nitrate are oxidizing agents.



8.2.3. Waste reduction options

8.2.3.1. Options in Production of nitrogen fertilizers

In urea production processes, it is important to try to recycle and recover carbamate gases and liquids. A good practice is to work in a vacuum at the top of the prilling tower. Furthermore, air emissions can be minimized by improving the operation of the baghouses and scrubbers.

In nitric acid plants, the efficiency of the absorption of nitrous gases needs to be increased in order to minimize NO_x emissions. This can be done by setting higher pressures and reducing the temperature of the weak acid liquid in the absorber.

8.2.3.2. Options in Production of phosphor fertilizers

Fluorine compounds can be minimized by using scrubbers. In order to reduce the amount of scrubber effluent, using a recycling process is conceivable. However, if this is not possible, the effluent should be treated separately and the fluorine, phosphorus and heavy metals removed.

8.2.3.3. Options in Production of mixed fertilizers products

The formation of gases such as NO_x should be prevented by adding urea directly during the digestion stage. Scrubbers enable emissions of ammonia (with phosphoric acid) and fluorine (with water) to be reduced [SAFPC, 2006].



8.3. Manufacture of Pesticides

8.3.1. Process description

The manufacturing of pesticides consists of two main parts. The first part involves the development of basic pesticide active ingredients such as petroleum coal, natural gas, feedstocks, biological sources and inorganic acids. In the second phase, fillers, inert ingredients (include volatile organic and petroleum-based solvents, oils and others), propellants and binders are added. The formulators, often also referred to as 'PFPRs' (pesticide formulating, packaging and repackaging), operate as distributors. Depending on the ingredients, a distinction is drawn between the following types of pesticides:

- Disinfectants
- Repellents
- Rodenticides
- Fungicides
- Insecticides
- Herbicides [AIG Environmental, 2006]

An overview about the processes gives figure 30.

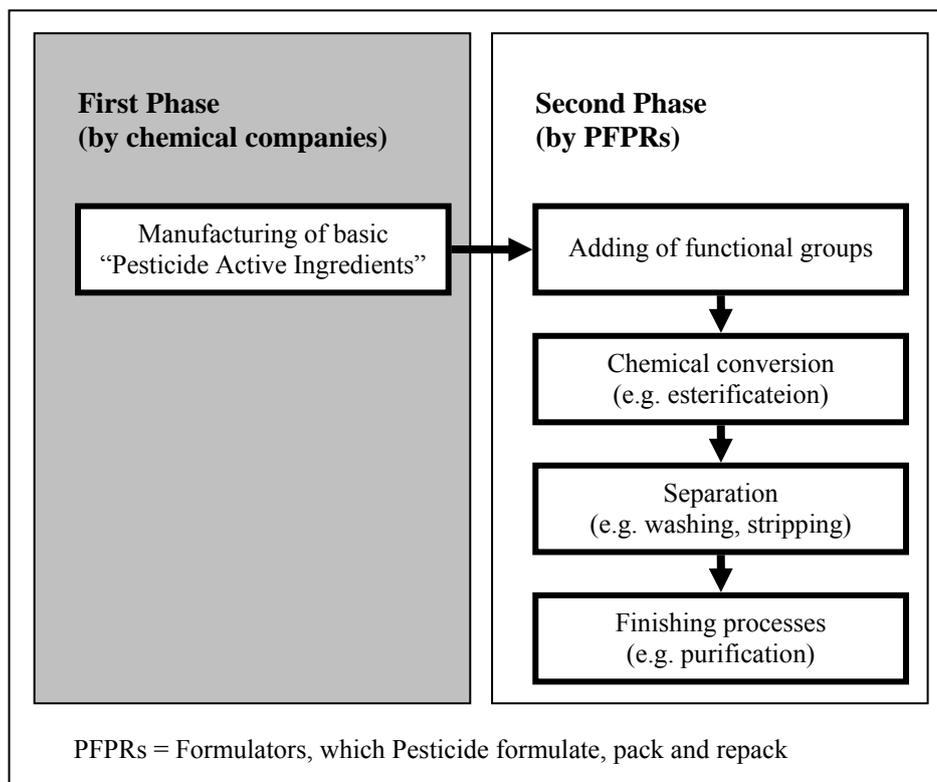


Figure 28: Manufacturing of pesticides- process overview

8.3.2. Hazardous materials

The hazardous materials found in pesticides include organophosphate, carbamates, chlorinated hydrocarbons, organic and inorganic compounds, alachor, paraquat, nitrofen, thiram, benomyl, borax, captan, ferbam, methyl bromide, sulfuryl fluoride, azaconazole, lindane, azaconazole, diazinon, parathion, aldin and dieldrin as well as heavy metals such as antimony, arsenic, beryllium, cadmium, chromium and copper. Details about the health risks are contained in the appendix as well as Part 1 of the guidelines for the SACODI Project.



8.3.3. Waste reduction options

Waste reduction options in manufacturing pesticides include on the one hand measures to reduce air emissions and on the other activities to prevent effluents and solid wastes. There are also several other ways, which are dealt with in the section “Handling, disposal and prevention: general aspects”.

To prevent air emissions, flue gas needs to be scrubbed. Treatment by baghouses or carbon adsorption is practicable, too. If the amount of toxic organic compounds is high, gas treatment can include a combustion step with a temperature exceeding 1100°C being maintained for at least half a second.

Filtration processes (ultrafiltration and reverse osmosis) are ways of separating tiny solid particles from the gas or liquid stream. After filtration, the resulting effluents still require further treatment. Options include biological treatment, oxidation processes such as peroxide solutions, or ultraviolet for the elimination of toxic components, flocculation, settling and carbon adsorption. Toxic solids should be incinerated. Separation methods and measures to treat the effluents are described in Part 1 of the SACODI Project guidelines [PPA Handbook, 1998]

Another way to prevent hazardous waste resulting from pesticide production is to always consider and try out using alternative fertilizers and pesticides based on biological substances [CPI LLC, 2006].



8.3.4. Further literature and links

- **Specific information about hazardous materials**

<http://www.who.int/heli/risks/toxics/chemicalsdirectory/en/index1.html>

- **Specific information about waste reduction options**

<http://www.cleanerproduction.com/Directory/sectors/subsectors/Fertilizer.html>

[http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/\\$File/76_phosp.pdf](http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/76_phosp.pdf)

[http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/\\$File/69_nitro.pdf](http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/69_nitro.pdf)

[http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/\\$File/67_ferti.pdf](http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/67_ferti.pdf)

[http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/\\$File/71_pestf.pdf](http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/71_pestf.pdf)

[http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/\\$File/72_pestm.pdf](http://wbIn0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/72_pestm.pdf)

<http://es.epa.gov/techinfo/facts/fact1.html>

8.4. Handling/ Disposal/ Prevention- general aspects

There are many ways of preventing risks and danger during the handling and disposal of pesticides and fertilizers. The most important ones are listed below:

- Data collection of all the quantities of substances used
- Recycling waste products and reusing them as raw materials (if possible)
- Installing automatic dosing systems to prevent spillages
- Working in closed systems to prevent evaporation
- Substitution of halogenated and aromatic solvents
- Pre-treatment of baths
- Installing dust collectors as the basis of dust treatment
- Minimizing the storage of hazardous substances

Another very important measure to prevent any risk is the secure storage and labelling of the substances. More information is contained in chapter 7.6.



8.5. Summary

The main approach to waste reduction is to reduce the amount of chemicals used in the process. Those using chemicals also need to be trained appropriately.

Fertiliser industry:

The following fertilisers can be used as straight or complex fertilisers:

- nitrogen fertilisers,
- phosphate fertilisers,
- potash fertilisers,
- Multi nutrient fertilisers.

Manufacture of N (nitrogen) fertilisers:

Urea – this occurs at temperatures between 180° and 190°C as well as being under between 140 and 200 bars of pressure. Ammonium carbamate is formed and is followed by dehydration and to water and urea.

For the synthesis of Ammonium carbamate, the following processes are applied: carbon dioxide stripping, ammonia stripping, the advanced cost and energy saving process (ACES) and the isobaric double recycle process (IDR).

Urea ammonium nitrate:

This is formed by mixing concentrated urea with ammonium nitrate. There are continuous and batch processes applied. Another possibility is the use of unconverted NH_3 and CO_2 from the production of urea.

Ammonium and calcium-ammonium nitrate:

Gaseous ammonia is used to produce ammonium nitrate and nitric acid is neutralised. If dolomite, calcium carbonate and ground limestone is added, a calcium ammonium nitrate fertiliser is created.

Manufacture of N (K, P, and S) – Fertilisers:***Single and triple Superphosphate:***

The main objective is the transfer of mineral phosphate to a water-soluble form. For single Superphosphate, this is achieved with sulphuric acid, if phosphoric acid is formed, double or triple-Superphosphate can be produced.

Multi nutrient fertilisers:

This is possible by the dry mixing of mono- fertilisers. During production, processes that belong to mixed acid route sulphuric, nitric or phosphoric acids are mixed. Neutralisation is achieved by the addition of gaseous ammonia. In the finishing process the substances are dried, screened, cooled granulated or coated.

Fertilisers that are produced with the phosphoric acid route are mono-ammonium phosphate, di-ammonium phosphate and NPK fertilisers.

Multi nutrient fertilisers can be produced with the nitric acid route, a secondary product is calcium nitrate, which can also be used as a fertiliser.

Hazardous materials:

The following wastes can be formed:

- asbestos,
- waste or spent batteries,
- heavy metals,
- spilt chemicals,
- waste oils,
- Components like herbicides.

Characteristics of compound fertilisers:

There is a risk of fire and explosion and ammonia is toxic. Urea is a toxic hazard and if it forms a gas mix, explosions can occur. Both urea and nitric acid can corrode operating systems. Nitric acid is an explosion risk if nitrate or nitrate salts are formed. Ammonium nitrate and calcium nitrate are oxidising agents.

Waste reduction options:

Production of nitrogen fertilisers:

- Recycling and recovering of carbamate gases is important. A vacuum at the top of the prilling tower and improved operations in the baghouses and scrubbers can reduce this and air emissions.
- In nitric acid plants, higher pressures and reduction of the temperature in the weak acid liquid in the absorber can increase the absorption of nitrous acid gases.

Production of phosphor fertilisers:

Scrubbers can reduce the production of fluorine compounds. A recycling process can reduce the amount of scrubbing effluent. If this is not an option, the effluent can be treated separately and the heavy metals removed.

Production of mixed fertiliser products:

The forming of gases like NO_2 can be prevented by the addition of urea in the digestion stage. By scrubbers, it is possible to reduce emissions of ammonia.

Manufacture of pesticides:

There are two phases:

- 1) development of basic pesticide active ingredients
- 2) fillers, inert ingredients, propellants and binders are added.

A distinction is drawn between the following types of pesticides:

- disinfectants,
- repellents,
- rodenticides,
- fungicides,
- insecticides,
- herbicides.

Hazardous materials:

This involves the reduction of air emissions, prevention of effluents and solid wastes.

Air emissions – flue gas is to scrub, treatment by baghouses and carbon absorption is possible. If the levels of toxins are high, a combustion step can be used.

Effluents and solid wastes – filtration processes and ultrafiltration through osmosis is often used methods. After filtration, oxidation, biological treatments, flocculation and carbon absorption can be used.

Solid toxic wastes should be incinerated.

**8.6. Case study****8.6.1. A Vietnamese Pesticide Company****General information**

This company is a medium-sized enterprise with the total area of 41,000 square metres (factory area – 1,050 m²; warehouse – 6,500 m²; offices – 500 m²; local road area – 7,200 m²; green spaces – 25,350 m²). The company employs 166 people (36 females and 130 males), of whom two have a postgraduate degree, 40 have a BSc, 22 people have a diploma, and the rest are manual workers.

Production process

Can Tho Pesticide Company is state-owned. Its main products are used in crop protection and include pesticides, insecticides and fungicides. Its annual production capacity is about 8,050 tonnes, comprising powder (3,500 t/a), granular (650 t/a) and liquid products (3,900 t/a). Materials are imported and formulated to synthesize the products in the following processes.

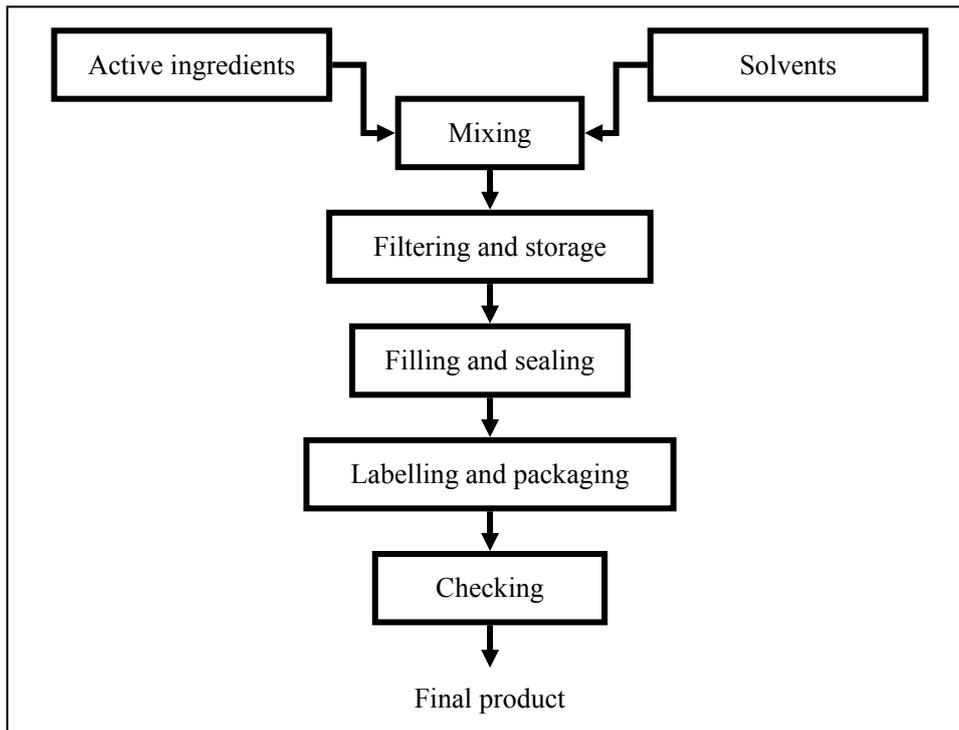


Figure 29: Process layout for liquid products

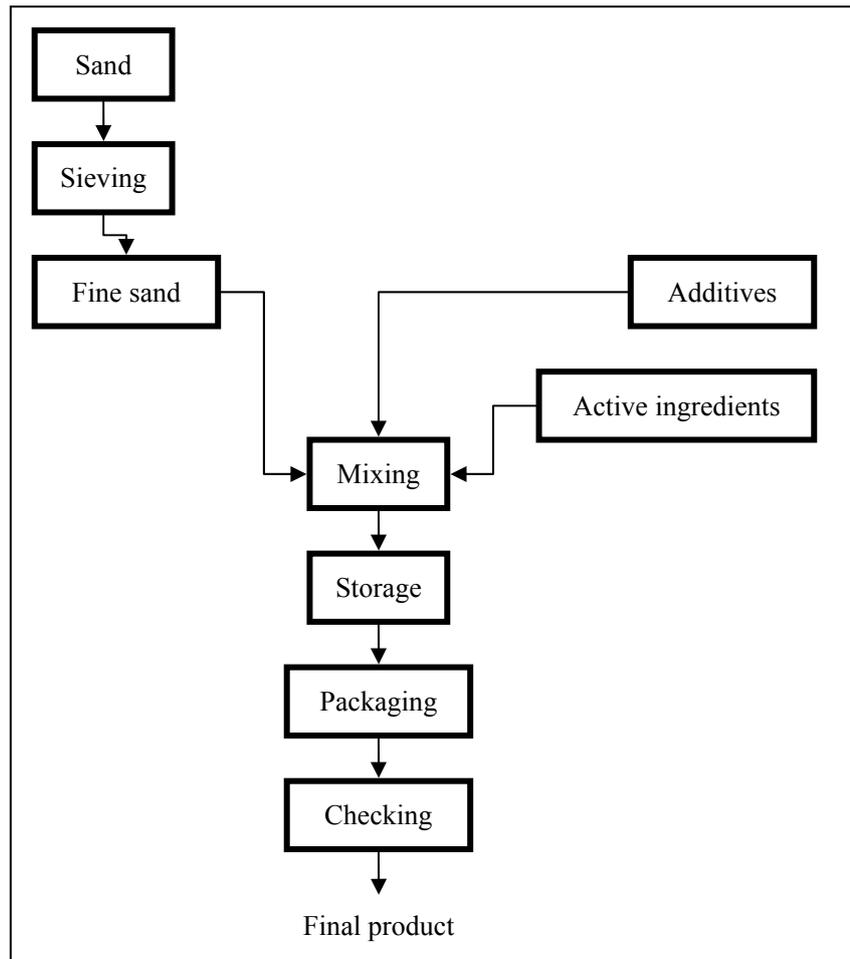


Figure 30: Process layout for powder products

- Amount of materials needed:

- o Active ingredients: 24.62 t/a
- o Additives: 8,025.28 t/a

- Supplied water: groundwater, total quantity of 17,476 cubic metres per annum

- Waste generation: the waste produced by the company contains toxic chemical ingredients and is therefore dangerous.

o Air waste:

Vehicles and materials in storage and in production cause air pollution. The company applies two methods to treat polluted air:

- 1) Natural: the company plants trees with an area of 25,350 m² in order to reduce toxicity in the air surrounding the company.
- 2) Mechanical: the company has installed four systems to treat the polluted air with a total capacity of 80,000 m³ per hour.

- Liquid waste:

Wastewater from the production lines and from washing containers is very dangerous because it contains toxic elements such as organic chlorides, carbonate pyrethroid, solvents and other additives. To treat wastewater, the company has built a treatment system with a capacity of 250 m³ per day. After treatment, the wastewater is stored in a biological pond for a year before being discharged into the river.

- Solid waste:

Solid waste is segregated into hazardous and non-hazardous before treatment.

Hazardous waste generated in production takes the form of for example packaging materials, defective products, etc. Hazardous waste is treated by incineration. The company has two combustion incinerators with a capacity of 50 kg per hour. DO fuel is used to burn hazardous waste at a maximum temperature of 1,200°C. Exhaust gas from the incinerator is treated by NaOH solution.

Non-hazardous waste is created during the daily activities of employees. It is collected for reuse, recycled or incinerated.

Working safety and security

The workers are provided with protective gear such as masks, gloves, working clothes, etc. To familiarise employees with aspects of industrial safety, the company holds a training course on industrial health and safety every year. The company has a first-aid centre for use in an emergency. It also services its equipment every two months. No cases of occupational disease or accidents have occurred for several years.

To prevent risks from fire and explosion, the company has a special team employed for the purpose. It also has a fire-extinguishing system in place.

For safety reasons, the company has to submit an environmental monitoring and control report to the local authority every year.

8.6.2. Vietnamese Pesticide Company II

Production process and waste

This company produces three types of products: fertilizers, detergents and powdered lime. Its total production capacity is about 115,000 t/a (fertilizer –100,000 t/a; detergent – 10,000

t/a; powdered lime – 5,000 t/a. The following tables show the types and quantity of input materials needed for each product.

Table 14: Materials for fertilizer product

No	Name of material	Quantity (tons/year)
1	DAP	32000
2	SA	25000
3	Kali	16000
4	Urea	16000
5	Kaolin	1
6	Super	3200
	Total	92201

Table 15: Materials for detergent product

No	Name of material	Quantity (tons/year)
1	LAS	1100
2	SODA	300
3	STPP	50
4	Na ₂ SO ₄	3500
5	Na ₂ SiO ₃	3200
6	TINOPAL	700
7	Na ₂ CO ₃	700
	Total	9550

Table 16: Materials for Powdered lime product

No	Name of material	Quantity (tons/year)
1	Lime stone (CaCO ₃)	7000

To run the production lines, it needs about 2,135,330 kWh of electricity and 1,670,000 litres of Fuel Oil per year.

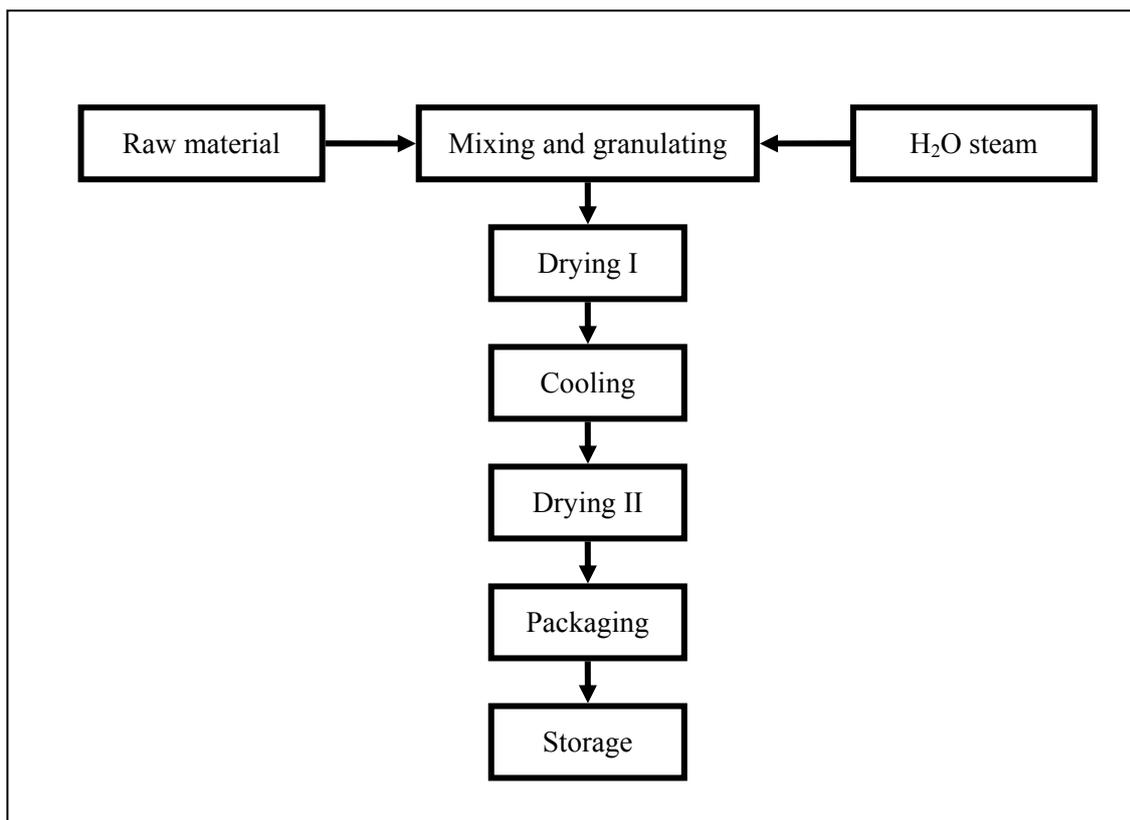


Figure 31: Process layout of fertilizer production

The company's waste is considered hazardous because it contains toxic elements as shown in the tables of materials. The most dangerous waste is dust. The sources of waste generation and the treatment methods used are outlined below.

- Air waste:

The bulk of the dust is generated by the grinder in the powdered lime production line, the dryer and cooler in the fertilizer production lines, and the sprayer in the detergent production line.

The company presently uses cyclones and a water-spraying system to filter air and collect dust, CO₂, NH₃, and N₂.

- Liquid waste:

Because the company uses a water-spraying system to treat dust, this causes water pollution. The total amount of wastewater is estimated at about 100 m³ per hour. Wastewater is treated by a filtering system. Sediment from wastewater treatment is collected and reused.

- Solid waste:

Solid waste includes the residues of the inputs.

Environment control and security:

To minimize waste pollution, the company services its equipment frequently. It also uses its waste treatment systems to full capacity and cleans the factory often.

Planting trees is one way of alleviating the company's environmental impact. There is 600 square metres of parkland around the factory. To improve the working environment, the company plans the following future activities:

- Installing more waste treatment systems
- Intensifying the factory cleaning and drainage system
- Reusing and recycling waste
- Pumping water by way of cooling during the summer
- Preventing oil leakage and evaporation
- Changing the fuel from FO to DO in order to reduce the level of sulphur in flue gas
- Raising the height of the chimneys
- Absorbing NO₂ and SO₂ by using alkali
- Constructing a wastewater treatment system

9. Manufacture of paper and board

9.1. Economic characteristics

Like the other industries dealt with, the manufacture of paper and cardboard is increasing rapidly. Between just 2000 and 2004, the production of paper and board rose by as much as 70%.

Table 17: Development of Manufacture of Paper and Board [Statistical Publishing House, 2005]

	2000	2001	2002	2003	Prel. 2004
Manufacture of paper and paper products	3930.3	4561.6	4876.5	5654.5	6696.9



9.2. Processes and waste

Paper production, especially fibre preparation, generates a huge amount of waste. Although much of it is not regarded as hazardous, it is still an environmental danger because of the sheer amount of waste involved. However, this chapter mainly focuses hazardous components of this waste. The main processes involved are:

- Pulping
- De-inking
- Bleaching
- Paper production

Pulping

There are many different types of pulping processes, the most important of which are explained here. The raw material for most processes is cellulose fibre based on wood, recycled paper and wood-less compounds. Each tree contains approximately 50 per cent cellulose. The main task of the pulping process is to separate the cellulose and remove impurities. Pulping processes can be divided into several groups.

a) Chemical pulping- wood fibre

Sulphate pulping is the most common type of chemical pulping, although sulphite pulping is also used.

In the former case, a long fibre is produced. The content of lignin is low. The process entails a sulphurous smell. Mainly softwood is used as wood source. During the process, the wood is boiled in sodium liquor containing sodium hydroxide in order to separate the lignin and cellulose fibre. The chemicals used are sodium sulphate and calcium carbonate.

In contrast to the sulphate pulping process, sulphite pulping uses different chemicals like sulphuric acid and hydrogen sulphite to boil the wood. In addition, a reactive metal base is employed to produce an acid sulphite pulp. The equipment used is similar to that described above. The result of this type of pulping is a lighter fibre, requiring less bleaching.

Both processes entail high water consumption.

b) Mechanical pulping- wood fibre

The most common form of mechanical pulping is groundwood pulping involving grinding debarked logs or hips. One disadvantage of these pulping systems is the relatively low quality because lignin is not eliminated. By contrast, energy consumption is much lower.

To raise pulp quality, processes have been developed to pre-soften the wood chips known as thermomechanical pulping (TMP) and chemo-thermomechanical pulping (CTMP). In both cases, 'thermomechanical' means treating the wood chips with steam before grinding. In addition, during CTMP, sulphur-based chemicals are added.

c) Mechanical pulping- waste fibre

There are three different types of waste paper used for the production of waste fibre. These are:

- Waste paper from paper production
- Waste paper from the printing and publishing industry
- Waste paper collected from households

Before mechanical pulping, the baling wire needs to be removed. In addition, small foreign bodies and short fibres have to be eliminated. Afterwards, caustic soda, aluminium sulphate and dispersion agents are sometimes added before re-pulping begins.

d) Chemo- mechanical pulping- waste fibre

De-inking is carried out to ensure paper with higher fibre quality. In addition to the mechanical pulping of waste paper, detergents, dispersants and foaming agents are used to separate ink and fibre.

e) Mechanical/ chemical pulping- non-wood fibre

Non-fibre woods include annual crops (jute, hemp, etc), wild plants (grasses, etc) and farming residuals (rice straw, etc). The advantage of these plants is that they contain less lignin than wood while their cellulose content is nearly equal. The disadvantage of using non-wood plants is the length of the fibres and the higher amount of silica and hemi-cellulose. Therefore, pre-cutting is often carried out before pulping. Some plant-based fibres are thinner than wood-based fibres.

Concerning mechanical pulping, the same methods are used as in the mechanical pulping of wood. Chemical pulping is a little different, however: in contrast to conventional chemical pulping processes, organic solvents such as alcohol and potassium hydroxide are used. The BVIS system has been developed in France especially for the pulping of non-wood pulping.

Deinking

The physicochemical removal of ink from waste paper is called de-inking. This process is the most important step in waste paper treatment. It is used to remove contraries and ink and to increase the whiteness of the paper. Hydrogen peroxide can be used to attain better whiteness. About 70% of the colouring can be eliminated. To enable this, some chemicals have to be used, mainly sodium hydroxide, hydrogen peroxide, sodium silicate, tensides and complexing agents.

The process can be divided into three steps:

- Dissolving the waste paper in water, the aim being to expand the fibres with moisture and defibration. Additionally, the chemicals can act on the suspension.
- Removal of contraries and impurities
- Separation of ink

There are two different processes in common use:

a) Flotation

The waste paper is dissolved in a basic solution. Air is injected by agitation. The ink-pigments float to the surface, are discarded and dried until they have a disposable concentration. The water is recycled. Fibre loss is about 7–10%.

b) Elutriation

The ink is washed out of the fibres. By using tensides, the ink is dissolved in the washing water. The loss is about 10–20%. This process should be used for easily removable inks.

The ink-sludge is contaminated with different chemicals (through the ink used), foils and staples, and can be used to generate energy through combustion. One interesting aspect is that the fibres lost in the ink-sludge are mostly short or pulverised. In this way, the quality of the waste paper also increases because the long fibres are still as good as new fibres [Umweltlexikon-online, 2006].

Bleaching

a) Hydrogen peroxide brightening

Hydrogen peroxide bleaching is used on mechanical pulp with a high content of lignin to lighten the pulp. One disadvantage of this process is that lignin remains in the pulp because no lignin-removing agents are used. In addition, the use of hypochlorites and sodium bisulphate is not environmentally sound, and the process is also very energy-intensive. This kind of pulp should be used for paper with a duller appearance.

b) Chlorine bleaching

In contrast to hydrogen peroxide brightening, during chlorine bleaching lignin is removed. To achieve this, chlorine gas is used and various process steps follow. Therefore, besides chlorine, hazardous chlorine dioxide and hyperchlorite are required, leading to the formation of organochlorines such as dioxins and furans.

c) TCF bleaching

Total chlorine free (TCF) is a bleaching method using no chlorine whatsoever. Delignification occurs with peroxide brightening following several stages of treatment. Enzymes can be used to enhance the bleaching process. Additionally, a chelating agent like EDTA ought to prevent the decomposition of hydrogen peroxide following a possible reaction with metal ions in the pulp. Ozone is often used in the final step.

d) ECF bleaching

Elemental chlorine bleaching (ECF) is a process using oxygen in the first stage and chlorine dioxide in later steps. In addition, chlorine dioxide, caustic soda, oxygen and hydrogen are utilized.

Because of the several stages of treatment during TCF and ECF bleaching, fibre is lost [FOE, 2006].

Paper production**a) Layering/ bonding**

The next stage in manufacturing paper is layering and bonding. Here the pulp is introduced as very thin slurry and screened to drain off the water. Additionally, principles like gravity, vacuum action, pressure or heat are applied. Following the removal of water, the fibres bond to a web of paper.

b) Forming

During forming, the paper is pressed and dried as a long thin length. It is often followed by coating.

c) Coating

Coating improves the paper's writing or printing characteristics. This is necessary because raw paper soaks up water.

To attain the desired quality in the printing surface, polymers (e.g. starch) are applied in 'sizing'. In addition, latex, binding agents, kaolin or calcium carbonate are used for greater smoothness during other coating processes.

d) Finishing

In contrast to the processes described above, finishing is a dry process. Finishing includes trimming, cutting and continuous preparation for sale or subsequent usage.

Fig. 34 summarizes the processes necessary in the manufacturing of paper. It also reports the probable sources or hazardous and non-hazardous waste.

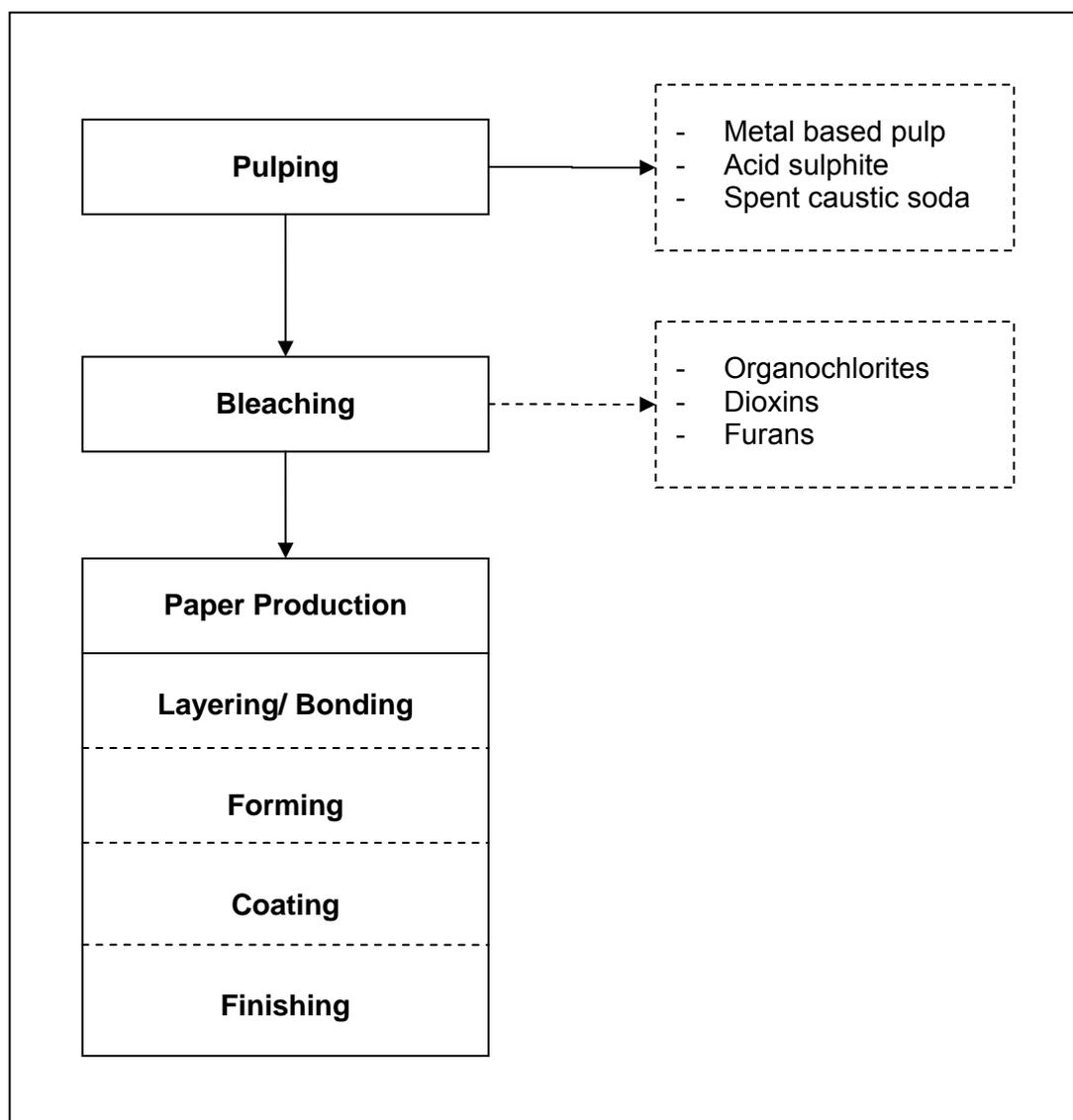


Figure 32: Manufacture of paper and probable waste streams

Waste streams

The lion's share of waste and wastewater cannot be classified as hazardous. Often, the wastewater is polluted by organic substances that can be eliminated with relatively simple wastewater treatment. For example, biological treatment of the activated sludge forming is possible, the waste being purified with microorganisms and air. More information concerning biological and non-biological wastewater treatment can be found in the guidelines for the decision-makers in the SACODI Project.

Generally speaking, hazardous compounds are concentrated in small amounts in the following:

- Spent halogenated solvents used
- Corrosive waste generated from the use of strong acids and bases
- Paint waste containing solvents and heavy metals
- Ink waste, including solvents, metals and ignitable materials



9.3. Hazardous materials

This section contains further details about the hazardous compounds in the different waste streams depending on the processes used.

During chemical pulping, acid waste like sodium sulphate, acid sulphite and bisulphite, and alkaline waste such as spent sodium hydroxide are formed. Toxic wastewater, wastewater treatment sludge as well as acid and alkaline waste are generated from processes of bleaching. Waste from the manufacture of paper (papermaking, sizing and starching, drying, cleaning and degreasing) can consist of wastewater, wastewater treatment sludge, toxic waste, including added chemicals, spent solvents, ignitable waste and toxic rinse water [EPA, 2006]. The waste streams may contain chemicals such as carbon tetrachloride, methylene chloride, tetrachloroethylene, 1,1,1 trichloroethylene, trichloroethylene, chloroform, benzene, ethylene dichloride, chlorobenzene, methyl ethyl ketone, dioxins, furans and other halogenated compounds. More information can be found in Part 1 of the guidelines for decision-makers of the SACODI Project



9.4. Waste reduction options

When manufacturing paper and cardboard, there are several ways to prevent hazardous and non-hazardous waste. A number of them are dealt with below.

Optimizing of de-inking process

Because the de-inking sludge can contain a high amount of good fibres, the sludge should be treated with for example a pressure screen. In this process, fibres with an adequate length are separated and can be reused. Moreover, this reduces the volume of sludge. Another possibility is separation by flotation. The sludge is aerated, the contact between air bubbles and ink causing the ink to rise to the surface, where it can be removed. Another type of filtration is enhanced cellulose filtration, which is called TURBOSCREEN.

The TURBOSCREEN decanter is an advanced solid/liquid separation process for dehydrating sludge with a high amount of solids. It combines a screen centrifuge with the decanter technique. The drum and the conveying screw rotate at slightly differing speeds. At first, densification takes place in the solid bowl centrifuge. Then the pre-thickened sludge is dehydrated in the screen drum. This has a wider diameter than the solid bowl and so there is a thinner layer of material on the screen, reducing the residual moisture.

Another future way of optimizing the de-inking process could be enzymatic waste paper treatment. The aims are twofold: to improve dehydration characteristics and enzyme-supported de-inking. The ecological and economical potential of such processes has been demonstrated in several studies using cellulases, hemicellulases, pectinases, ligninases, amylases and lipases. The commercialization of these processes is expected in the near future.

Use of non-metal containing inks

Since the development of de-inking, an important factor in selecting inks has been their de-inkability, with resin-based and oil-based inks being used. This requires a reduced amount of chemicals for the separation of fibres and ink. Additionally, water-based inks have been tested successfully, especially for newspapers [European Commission, 1998].

Recycling of coating colours

Coating colours can be recycled by means of membrane or other filtration technologies. The OptiFilter CR is an ultrafiltration system in which filter cassettes are equipped with membranes on both sides. Many cassettes are combined by stacking them vertically together. To reduce the fouling effect and enhance the filtrate capacity, rotors are positioned between the cassettes. The effect is achieved through the turbulence caused by the rotors. Within the OptiCycle process, the OptiFilter CR is equipped with soft polymer membranes to separate chemicals, water and suspended solids. The coating colours in the wastewater of the coating process can be concentrated to 30–35%. This concentrate can be recycled to fresh coating colour, and because the concentrate only consists of coating colour components, there are no problems regarding the quality of the coating process.

The OptiFilter CR can also be used for white water treatment [Metso Paper Inc, 2006].

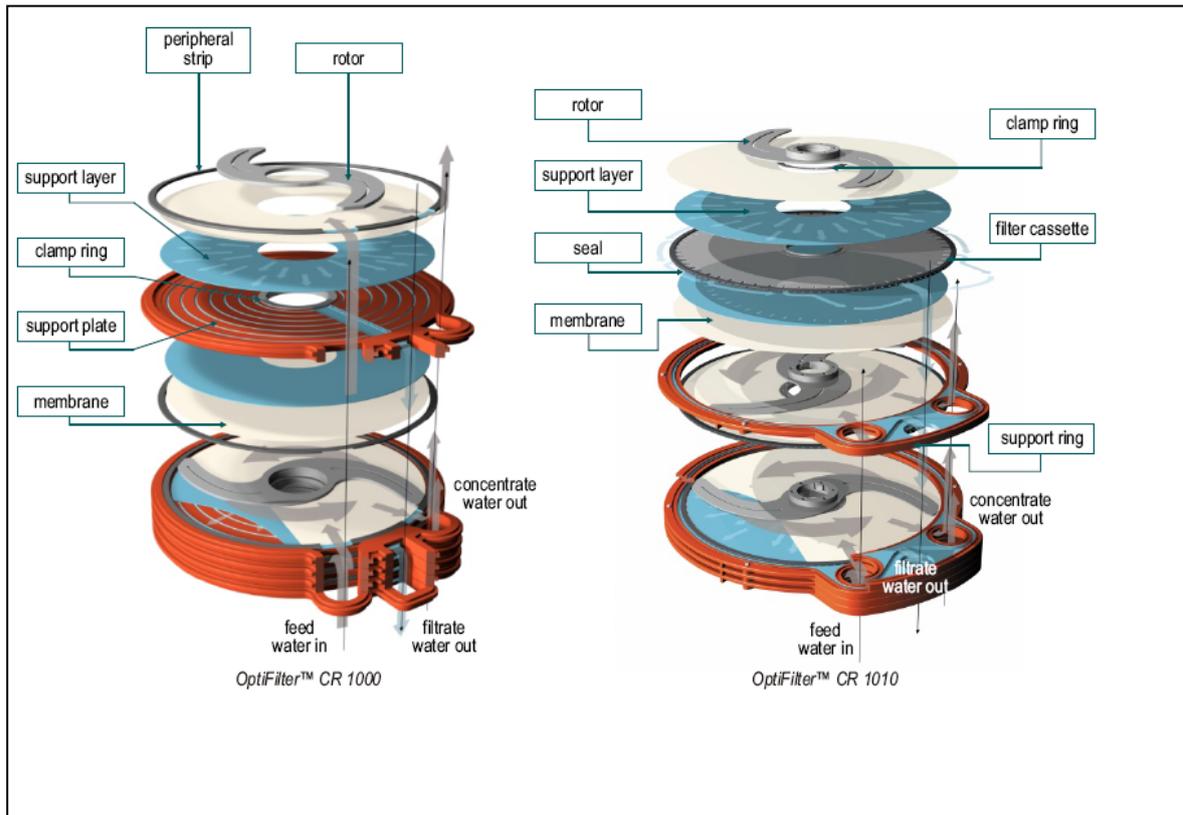


Figure 33: Model of an OptiFilter

However, because these techniques are very expensive in invest cost they are not suitable for companies in small scale [European Commission, 1998].



9.5. Further literature and links

- **Specific information about hazardous materials**

<http://es.epa.gov/techinfo/facts/pulppapr.html>

<http://www.p2pays.org/ref/11/10446.htm>

http://www.energysolutionscenter.org/gasirpaper/Learn%20About/Paper_Manufacture.htm#PaperManf

- **Specific information about waste reduction options**

<http://www.epa.state.oh.us/opp/p2regint/csp2sep1.html>

<http://es.epa.gov/techinfo/facts/epa/printing.html>

<http://www.p2pays.org/ref/13/12193.pdf>

9.6. Handling/ Disposal/ Prevention- general aspects

The first step to preventing both waste and hazardous waste can be data collection on all substances, chemicals and waste in the company. This enables the composition of waste to be identified and ways of reducing the amounts to be found. The next step could comprise searching for and pinpointing alternative, non-hazardous chemicals, if technically and financially feasible. Additionally, employee training is necessary.

Concerning storage and segregation, hazardous waste is always to be kept separate from household and other non-hazardous waste so that the former can be treated or disposed of using an environmentally sound method (see Part 1 of the guidelines for decision-makers). If feasible, water should be conserved. Once leaking pipes, pumps, valves and seals have been identified, they must be repaired or replaced. Halogenated solvents and toxic compounds are to be substituted (cf 5.4) and if necessary alternative techniques should be used.

The output of the fibre yield can be increased by for example optimizing digesters. Another way of preventing harmful chemicals is to use wastepaper, naturally in connection with an optimized de-inking process; this minimizes fibre costs. Especially during the pulping process, air emissions need to be trapped and treated. Additionally, chemicals should be recovered and reused in a closed-loop system. Other waste prevention measures include:

- Adapting water use and wastewater system to the local climate as well as technical and economically requirements
- Using chlorine-free bleaching methods
- Preventing the formation of dioxins and furans in connection with chlorine bleaching [CHMR, 1996]



9.7. Summary

Processes and waste:

Paper production generates huge amounts of waste. Although the majority of it is not hazardous, it can still cause environmental damage due to its sheer volume.

Pulping:

There are various types of pulping. The main task of pulping is to separate cellulose and remove impurities.

Chemical pulping, wood fibre: A long fibre is produced, the wood is boiled in a mixture containing sodium hydroxide, and as a result sulphite pulp is produced. Other chemicals used include sulphuric acid and hydrogen sulphite.

Mechanical pulping, waste fibre: Waste paper from paper production, the publishing industry and used paper from households are used. Caustic soda, aluminium sulphate and dispersion agents are used in this process.

Chemo-mechanical pulping, waste fibre: For higher-quality fibre paper, de-inking is carried out. Detergents, dispersants and foaming agents are used for the separation of ink and fibre.

Mechanical/chemical pulping, non-wood fibre: Non-wood fibres are annual crops, plants and residuals from agricultural production. Although the same methods are used as in the mechanical pulping of woods, by contrast, organic solvents such as alcohol and potassium hydroxide are employed.

Bleaching:

Hydrogen peroxide brightening is used for mechanical pulp with a high level of lignin. The change results in a lighter structure in the pulp. The lignin is left in the pulp and energy consumption is high.

Chlorine bleaching: In contrast to hydrogen peroxide bleaching, chlorine gas is used to remove lignin. As well as chlorine, hazardous chlorine dioxide and hyperchlorite are necessary and organochlorines are a possible by-product.

TCF (total chlorine free) bleaching: Delignification takes place with peroxide brightening with the help of enzymes. A chelating agent such as ETDA prevents the decomposition of hydrogen peroxide.

ECF (elemental chlorine) bleaching: This process uses oxygen in the first stage and chlorine dioxide in the latter stages. Caustic soda, oxygen and hydrogen are also used.

Paper production:

Layering/bonding: This is the next stage in the paper production process. Water is removed from the pulp and the fibres are bonded to a web of paper.

Forming: Here the paper is pressed and dried into a long length; this is often combined with the coating process.

Coating: This process leads to improved writing or printing quality. It is necessary because raw paper soaks up water. Polymers such as starch are added in the 'sizing' process, and latex, binding agents, kaolin or calcium carbonate is added to increase smoothness.

Finishing: This is a dry process which also includes trimming, cutting and continuous preparation for sale.

Waste streams:

The largest volumes of wastewater are not hazardous and can be treated in a simple wastewater treatment process. Hazardous components are found in the following:

- Spent halogenated solvents
- Corrosive waste from acids and bases
- Paint waste containing solvents and heavy metals
- Ink waste with solvents, heavy metals and ignitable materials

Hazardous materials:

Chemical pumping process: Sodium sulphate, acid sulphate and bisulphate and alkaline waste such as spent sodium hydroxide.

Bleaching: Toxic wastewater, wastewater treatment sludge, acid and alkaline waste is generated.

Paper manufacture: Wastewater, wastewater treatment sludge, toxic waste including added chemicals, spent solvents, ignitable waste and toxic rinse water.

The waste streams may contain any of the following: carbon tetrachloride, methylene chloride, tetrachloroethylene, 1,1,1 trichloroethylene, trichloroethylene, chloroform, benzene, ethylene dichloride, chlorobenzene, methyl ethyl ketone, dioxins, furans and other halogenated compounds.

Hazardous waste reduction options:

1) Optimization of de-inking process: Fibres which are long enough can be reused by a pressure screening process. Separation takes place by flotation, in which air is added to the sludge and the ink rises to the water surface and can be removed. Enhanced cellulose filtration known as TURBOSCREEN can be used.

2) Use of non-metal containing inks: Resin-based and oil-based inks can be used. The separation of the fibres and ink requires lower amounts of chemicals. Water-based inks for newspapers have been tested successfully.

3) Recycling of coating colours: This can be done by membrane technologies. However, these technologies are expensive and not viable for small companies.

Handling/disposal/prevention – general aspects:

The first step should be data collection on all substances, chemicals and waste in the company. The next step should be to search for and identify alternative, non-hazardous chemicals. Employees also require property training.

Regarding storage, hazardous waste should always be kept separate from household and non-hazardous waste. It should then be easier to treat or dispose of the hazardous compounds with an environmentally sound method.

All equipment should be free of leaks or other damage.

Fibre costs can be lowered by the using waste paper in the de-inking process. Other chemicals can be recovered in a looped system.

Other techniques for waste prevention are as follows:

- Adapting water use and the wastewater system to the local climate as well as technical and economic requirements
- Using chlorine-free bleaching methods
- Preventing the formation of dioxins and furans in connection with chlorine bleaching



9.8. Case study

9.8.1. Indian Paper Mill

9.8.1.1. Introduction

This company set up in the early 50's soon after India's independence in an effort to bring economic progress to the Dandeli region in the industrially backward Uttara Kannada district of Karnataka State. This chlorine based paper mill was set up in the heart of the Bamboo forests in Dandeli, a core area of Central Western Ghats region of Karnataka. Bamboo came almost free of cost to the company and so did water from the Kali River. In fact to access water in plenty, the plant was located at Dandeli on the banks of Kali. Even power comes at a subsidized rate to the Company from the Karnataka Power Transmission Corporation Limited and all these factors have helped the company grow manifold, with its turnover and profits climbing constantly over the past five decades.

Since inception, the company has been operating without a standard effluent treatment plant and waste water is being directly discharged into Kali River. Very recently owing to enormous pressure from environmental groups the company has set up an effluent treatment plant. But this plant can only handle a little over half the effluent released in production. With a nine-fold capacity increase in production since inception, the total production in 2002 -03 has reached 151,477 MTPA, making it amongst the largest paper mills in the country. With its outdated production technology and inefficient effluent treatment plant, the toxicity of the river has reached very high levels making it extremely risky for downstream communities to consume the water or even use it for agriculture.

That Kali River is amongst the four most heavily polluted in Karnataka State, and that because of pollution from WCPM, is a fact admitted in a submission made to the Parliament of India by the Union Ministry of Environment and Forests on 28 February 2006. An alarming revelation from independent studies conducted by People Science Institute, Dehradun is that high levels of mercury are present in the river water downstream of the effluent discharge point, making it a critical threat to life and livelihood. Thereby, it is fit case for study under the SACODI project.



Figure 34: Women working in paddy fields are directly exposed to the polluted water from Kali used for irrigation

9.8.1.2. Impacts of pollution from WCPM

The villages downstream are inhabited mainly by the nomadic cattle rearing tribal communities and settled agricultural families. Also present are fishing communities. The polluted

waters of the Kali can no longer support agriculture, while cattle grazing on the grass near the banks of the Kali are either very sick or dying. Fish stocks have depleted and mutations are a common occurrence now. Human lives too are in danger with a high rate of neonatal deaths, gastrointestinal disorders in children, gynecological problems in women, skin diseases that are rampant and a variety of other diseases that haunt the communities. Even ground water is contaminated due to discharge from the paper mill.

9.8.1.3. The Process

The West Coast paper Mill's manufacturing process is based on the conventional Kraft sulphate technology, where wood is used as the principal raw material.

Pulping

In a chemical pulping process, heat and chemicals are added to wood chips in a pressure cooker called the digester. In the Kraft process, an aqueous solution of sodium hydroxide and sodium sulphide, known as white liquor, selectively dissolve the lignin and make it soluble in the cooking liquid. After 2 to 4 hours, the mixture of pulp, spent pulping chemicals and wood waste is discharged from the digester. The pulp is washed to separate it from the black liquor - the pulping chemicals and wood waste. Kraft pulping is a low yield process - only 45% of the wood used becomes pulp. The pulp, called brown stock at this point in the process, is ready to be bleached. Softwood pulp from a conventional cooking process contains about 4.5% lignin. This lignin will be removed and the pulp will be brightened during the bleaching process.

Efficient pulp washing is very important because it ensures the maximum recovery of the pulping chemicals and it minimizes the amount of organic waste carried over with the pulp into the bleaching process. Poorly washed pulps require higher bleaching chemical doses, thus increasing the cost and the amount of organic waste discharged in the bleach plant effluent.

Bleaching

- Performed in stages
- Early stages remove remaining lignin; final stages brighten the pulp
- Pulp is usually washed between stages to remove any soluble organic material
- Classes of bleaching chemicals:
 - Strong oxidizing agents,
 - Alkali,

- Metal removal agent

Strong Oxidizing Agents

Oxidizing chemicals can either degrade the lignin or remove colour from the pulp depending on operating conditions. The following agents are used: Elemental Chlorine, Chlorine Dioxide, Sodium Hypochlorite, Ozone, Oxygen, and Hydrogen Peroxide

Elemental chlorine (Cl_2) is an effective delignifying agent. As it breaks lignin bonds, it adds chlorine atoms to the lignin degradation products, thus producing significant amounts of chlorinated organic material.

Ozone (O_3) is also an effective delignifying agent. It also brightens the pulp as well. Ozone has not been used in the past because mills have not been able to improve its selectivity - ozone attacks the cellulose fibre as well as the lignin. Recent technological developments, however, have solved this problem and have allowed mills to take advantage of this cost-effective bleaching agent.

Chlorine dioxide (ClO_2) is a highly selective chemical that can both delignify and brighten pulp. It oxidizes lignin, but does not add chlorine atoms onto lignin fragments; however, small amounts of elemental chlorine and other chlorine compounds formed during the chlorine dioxide bleaching process react with degraded lignin to form chlorinated organic compounds.

Oxygen (O_2) is an inexpensive, highly effective delignifying agent that is usually used at the beginning of the bleaching process. It has intermediate selectivity.

Sodium hypochlorite (NaOCl) is an inexpensive delignifying agent formed by mixing elemental chlorine with alkali at the mill. Mills are phasing out the use of hypochlorite because it generates large quantities of chloroform when it is used to bleach pulp.

Hydrogen peroxide (H_2O_2) is mainly used to brighten pulps in the final bleaching stages. Peroxide is often used at the end of a conventional bleaching sequence to prevent the pulp from losing brightness over time. Researchers have found operating conditions under which peroxide will delignify pulp, and are working on technologies that will consume less.

Alkali Extraction

Caustic soda (sodium hydroxide) solubilizes degraded lignin products. Oxygen, hydrogen peroxide or both are often added to the caustic solution to enhance the removal of organic waste.

Chlorine, chlorine dioxide and ozone work best when they are run in acidic conditions at pHs that range from 1.5 to 4. Once the bleaching reactions are finished, the pulp is washed to remove the degraded lignin or other organic waste that has been dissolved in the wastewater. Much of the organic waste, however, consists of organic acids and alco-

hols. These compounds are not soluble in acidic water so they remain with the pulp during washing.

In the alkali extraction stage, these organic acids and alcohols react with the caustic (sodium hydroxide) to form organic sodium compounds and water. These organic substances do dissolve in water. In fact, most of the colour and organic waste in mill effluent comes from this first extraction stage. There is much less organic waste in the second extraction phase, if one is used, because very little lignin is removed in the later stages of the bleaching process.

Chlorine Chemistry

Elemental chlorine and chlorine dioxide react differently with lignin. Elemental chlorine breaks up the lignin molecule by adding chlorine to the lignin.

Chlorine dioxide transfers an oxygen to the lignin to break up the rings. Hypochlorous acid is also formed. It can react directly with the aromatic rings on the lignin or be converted to elemental chlorine.

Thus, the only way to be sure that chlorinated organic compounds including dioxins are not formed in the bleaching process is to eliminate all chlorine-based bleaching chemicals.

Metals Removal

Transition metals present in wood react with ozone and hydrogen peroxide; thus, they are removed before these chemicals are applied to the pulp.

A ... Acid wash

Q... Chelating agent

Environmental Impacts of Bleaching With Chlorine

As soon as pulp is exposed to chlorine or chlorine dioxide during the bleaching process, the concentration of chloride ions in the waste water makes it too corrosive to be recirculated to the recovery system where the organic waste is stripped from the water and burned for energy in the recovery boiler. The organic waste Chlorine dioxide (ClO_2) is a highly selective chemical that can both delignify and brighten pulp. It oxidizes lignin, but does not add chlorine atoms onto lignin fragments; however, small amounts of elemental chlorine and other chlorine compounds formed during the chlorine dioxide bleaching process react with degraded lignin to form chlorinated organic compounds

It is in the bleaching process that the most problematic contaminant for pulp and paper mills is produced: dioxins. Dioxins (and also furans) are a class of chemicals of the highest toxicity to all life. They are extremely persistent and cannot be broken down by bacteria. Dioxins bio-accumulate, that is to say its concentration in the tissues of animals increases

as you move higher up the food chain. Dioxins are a byproduct of the use of elemental chlorine and, to a lesser extent, other chlorinated substances. In bleaching, the processed and refined pulp is chemically altered to increase brightness.

As soon as pulp is exposed to chlorine or chlorine dioxide during the bleaching process, the concentration of chloride ions in the wastewater makes it too corrosive to be recirculated to the recovery system where the organic waste is stripped from the water and burned for energy in the recovery boiler. The organic waste in the effluent must be discharged to the effluent treatment system and ultimately rivers and lakes.

Thus, the only way to be sure that chlorinated organic compounds including dioxins are not formed in the bleaching process is to eliminate all chlorine-based bleaching chemicals.

AOX and the Bleaching process

AOX means Adsorbable Organic Halides. The AOX test measures organic (carbon-based) compounds that have halides attached and that adsorb, or stick, to an activated carbon filter. Halides are highly reactive elements in the halogen family: fluorine, chlorine, bromine, and iodine. These elements bond easily with organic substances, allowing quick entry into the environment and the food chain. Because chlorine is by far the most common halide present in a pulp mill, the AOX test essentially measures chlorinated organic compounds, also called organochlorines.

We should care about AOX in our environment because many organochlorines have been shown to have toxic effects. Only a small number of AOX compounds have been tested. Organochlorines are a significant component of effluent from pulp mills that still use chlorine compounds for bleaching.

Many organochlorines have been linked to health problems, such as cancer, birth defects, endometriosis, low sperm counts, and impaired foetal development. Organochlorines have also been shown to cause genetic damage and low survival rates of salmon and other fish. Organochlorines can last a long time in the environment (they are persistent) and build up in oils and animal, including human, tissues (they bio-accumulate).

Issues of Concern about WCPM

A wide range of evidence has been collected through a variety of sources, including the Central Pollution Control Board, the Karnataka State Pollution Control Board, independent reports and survey of literature to appreciate the environmental impacts of the WCPM.

Broadly the main issue of concern arises from the fact that the company had been operating with an inefficient and inadequate effluent treatment plant since its inception. Severe pressure from the environmental groups, including ESG, in recent years pushed the regulatory agencies such as Pollution Control Boards to pressurize the company to redesign its

effluent treatment plant. However, investigations by ESG undertaken over the past year reveal that the modifications undertaken by the company during 2004 of their effluent treatment plant has the following drawbacks:

Inadequate capacity of Effluent Treatment Plant

In the modified design of the ETP prepared by M/s KLEAN consultants, the raw waste flow is taken as

Pulp mill effluent	=	30,000 m ³ /d
Paper machine effluent	=	36,000 m ³ /d
Domestic sewage	=	3,000 m ³ /d
Total	=	69,000 m ³ /d

The Central Pollution Control Board per its investigations has found the volumetric flow of the effluent claimed to be treated as 110,868.5 m³/d (24 Jan 2003, current meter measurement by the CPCB). The new effluent treatment plant is designed only for 69,000 m³/d of raw sewage.



Figure 35: Halmaddi Nala (Canal) which is used to dispose the partially treated effluent into the river Kali

The Central pollution Control board had analyzed the single-point discharge output of the existing ETP and their report too confirmed the high levels of pollution in the river. Their analysis shows that the total suspended solids, the pH value, BOD, and COD values were

over the maximum permissible values allowed by the Karnataka State Pollution Control Board. The detailed values are shown in the below.

Table 18: Analytics results of discharge output

Parameter	Parameter value at different times			KSPCB standard
	12 noon – 8 pm	8 pm – 4 am	4 am – 1 pm	
Suspended solids	80	431	217	100
pH	11.2	10.8	10.2	5.5 – 9
BOD	55	160	120	30
COD	185	621	495	250

Source: Central Pollution Control Board assessment conducted during January 2003. A subsequent survey was undertaken by CPCB in August 2004 but the results of this survey has not been revealed despite many efforts.

Over production

According to the data accessed by ESG during the SACODI project and earlier WCPM has been producing in excess of consented capacity from 1998 onwards. WCPM had initially made an application for expansion from 119,750 MTPA to 163,750 MTPA, whereas the consent given was only for 85,500 MTPA¹⁸. It is indicated in the same letter that the industry has made an amendment to the application for expansion of production from 85,500 MTPA to 119,750 MTPA as phase I and from 119,750 MTPA to 163,750 MTPA in phase II of the expansion of the plant. This letter clearly shows that WCPM is producing and will continue to produce in excess of what it is allowed to produce.

Table 19: Actual Production by WCPM in comparison with Consented Production

	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003
Total Paper and Paper-board produced BDMT	110,245	107,770	112,997	113,075	151,477
Consented quantity by KSPCB (MTPA)	85,500	85,500	85,500	85,500	85,500

¹⁸ Letter dated 6 April 2002, from Member Secretary, KSPCB to Executive director, WCPM.

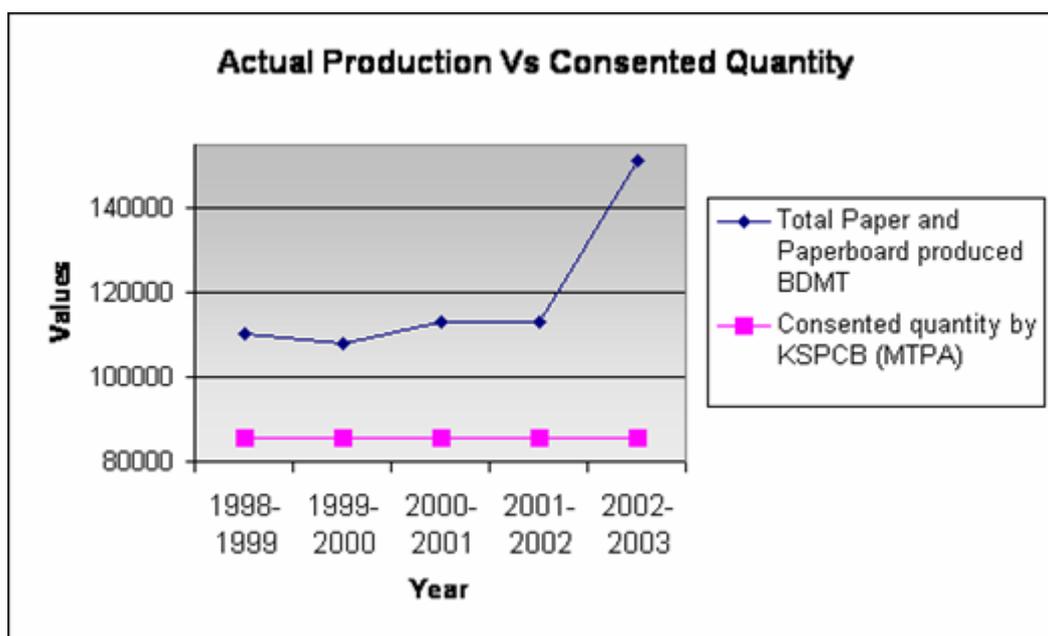


Figure 36: CHART: WCPM: Actual Production Vs Consented Quantity

According to the annual report of WCPM (2001-02), the production is reported at 120,293 MT¹⁹, while the consented quantity for production from KSPCB is clearly for 85,500 MTPA²⁰. In addition, it is to be noted that in any of the subsequent correspondence with WCPM, available with us, there is no mention of the production exceeding consented quantity having been discussed. This raises serious worries of the extent of pollution because the newly developed ETP is for a much lower capacity than production levels mandate.

Presence of Mercury in Kali River:

A detailed analysis of the Kali River water conducted by Peoples Science Institute, Dehradun, revealed that mercury was present and accumulating at alarming levels. PSI study shows 5 µg/l of mercury in the effluent aggregating to a daily influx of mercury into the river to be 345 g/day. Inflow of high amounts of mercury into the Kali River may lead to severe environmental hazards if appropriate steps are not taken immediately.

In addition, this study revealed the suspended solids present in the treated effluent is very high and reveals that the settling is not taking place efficiently in the ETP. The pH of the treated effluent is higher than the permissible limit and that adequate lime treatment is not given to the wastewater.

¹⁹ Page 14 of the annual report 2001-02.

²⁰ See footnote 1, also para 3 of letter dated 24 August 2002, in letter to the Executive Director WCPM from the MS, KSPCB.

The BOD of the treated effluent is very high than the standard stipulated by the Central and the State Pollution Control board. This shows that the secondary biological treatment given to the sewage is insufficient and inefficient. The COD of the treated effluent is also not in conformance with prescribed limits.

Table 20: Water quality analysis in different sites in Kali river, Uttar Kannada undertaken by People Science Institute, Dehra Dun

Sampling Location	Parameters							
	Temp. °C	pH	TSS mg/L	TDS mg/L	EC (µmho/cm)	DO mg/L	COD mg/L	Mn mg/L
Standard values set by CPCB		6.5 to 8.5	100	500		> 5	< 250	0.1
Up stream of Supa Dam (Ganesh Gudi)	29.5	5.7	115	83	108	6.2	39	NT
Down stream of Supa Dam	29	7.4	96	37	59	5.6	25	NT
Upstream of Paper mill (Near Jungle Resort)	26.0	8.0	146	42	62	6.0	43	NT
West Coast Paper mill (Effluent before confluence in Kali river)	29.8	12.1	1810	3300	4785	N.D.	1740	ND
After confluence of Paper, mill effluent near Dandeli Appa Temple.	27.0	8.9	490	420	567	Nil	295	ND
Up stream of Kadara Dam	27.5	8.3	225	77	114	5.8	93	NT
Down stream of Kadara Dam	25.0	7.7	180	72	99	4.6	31	NT
Natural stream coming from mining areas near Barchi Bridge	24.5	8.5	74	147	194	N.D.	25	NT

N.D: Not done N.T: Not traceable

Table 21: Solid Waste Generated From WCPM

	Annual Environment Audit Statement (KSPCB)					CPCB
	Year					
	2002 - 2003	2001- 2002	2000- 2001	2000- 1999	1999- 1998	
	<i>All figures in tons / annum</i>					
Saw Dust	2,958	3,146	3,321	3,815	2,996	3,800
Lime Sludge	36,309	39,058	35,112	35,197	35,972	36,000
Hypochlorite Sludge	2,000	1,590	1,736	1,615	1,566	1,600
Dust from Chemical Recovery Boiler	13,855	9,266	4,277	4,827	4,752	4,800
Ash from FBC Boiler	30,956	31,720	39,826	42,290	51,568	42,920
Sludge from ETP plant(paper mill)	7,564	5,643	5,426	5,598	3,803	5,600
Sludge from ETP plant(Pulp mill)	887	1,082	1,327	1,380	1,402	1,400
Dust from Rotary Lime Kiln	2,390	2,488	2,726	2,786	2,796	2,800

Summary and Conclusion

The effects of untreated effluents being discharged into the Kali River has had severe and deleterious effect on the health and livelihood of communities living downstream for several decades now. Cases of cattle deaths, gastroenteritis outbreaks and gynaecological problems are commonly encountered along the banks of this highly polluted river. Considering that there is no other major industry causing this pollution, and the fact that studies by regulatory agencies have confirmed that WCPM is the major polluter, a fact admitted in the Indian Parliament too, the consequences of such high levels of pollution are to be critically understood. Yet, there is no comprehensive programme of enquiry towards remedying the situation.

The presence of mercury in very high levels clearly is a matter of critical concern, especially given its accumulation in the dams and in ecosystems and humans. It is an established fact that WCPM produces far more than its environmental protection systems allow, and thus it is a fit case for effective environmental regulation. Such illegal releases of huge quantities of wastes, including hazardous wastes, such as mercury, call for immediate and effective regulative action against the industry.

10. Production/ Application of Fibrocement

10.1. Economic characteristics

Because of delaying banning the production and use of fibro cement and asbestos respectively, in this chapter should be given information about the production process of fibro cement. Besides this, this chapter deals with the protection both of employees in manufacturing plants and users of work pieces containing fibro cement. The following figure shows the consumption of asbestos in India from 1920 until 2000 [Statistical Publishing House, 2005].

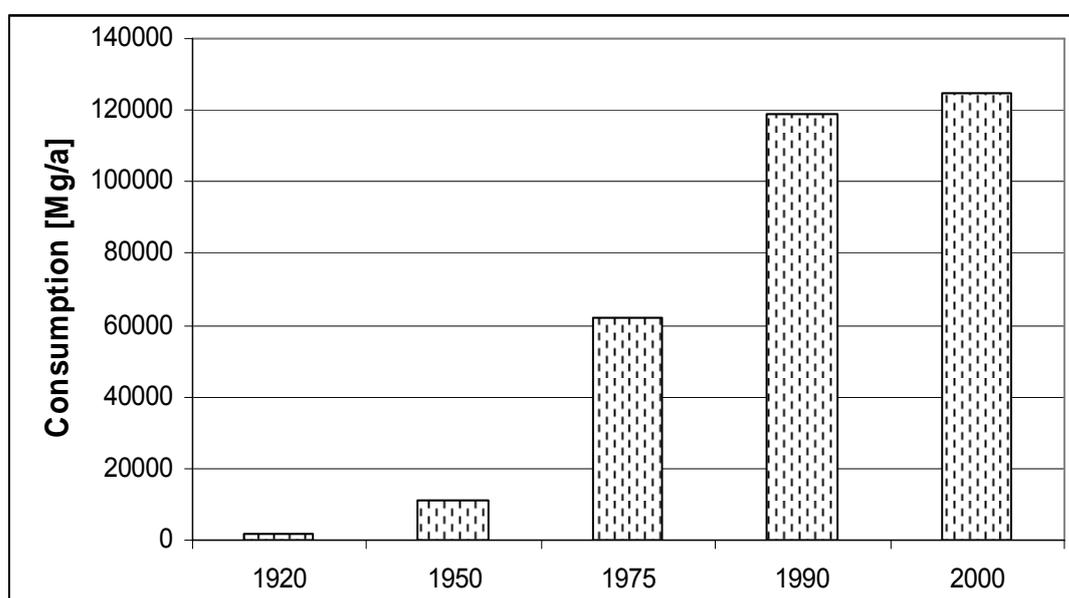


Figure 37: Asbestos consumption in India



10.2. Process description

Because the production of fibrocement is permitted in Vietnam, in this section the manufacturing process is briefly explained. The reason for adding asbestos is to improve the product's elasticity.

The manufacture of fibrocement starts with the grinding of the asbestos. The prepared asbestos is mixed with water, and then cement is added. In the following finishing step, the material is cut. Fig. 40 contains an overview of the general production process.

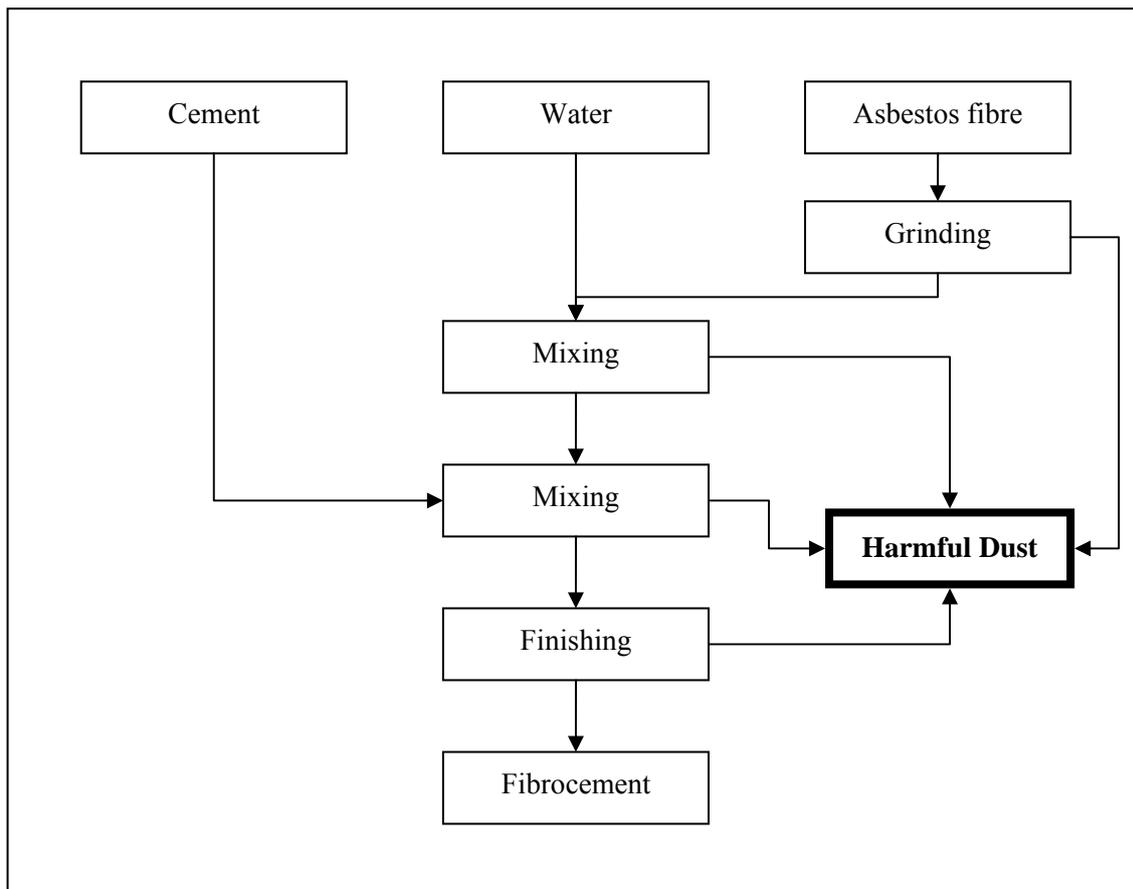


Figure 38: Processes in Production of fibrocement



10.3. Hazardous materials

The term 'asbestos' actually covers a group of substances. It includes the minerals chrysotile, amosite, crocidolite, tremolite, anthophyllite and actinolite. Therefore, when speaking about asbestos, all six of these substances are referred to, although only chrysotile, crocidolite and amosite are used in industry. Chrysotile belongs to the serpentine group and contains curled fibres. Amosite and crocidolite are considered amphiboles and have needle-like fibres.

Apart from this difference, all six types share common characteristics. As well as consisting of magnesia silicate, these characteristics are their crystal structure with diameters of 3–20 micrometers, their high flexibility, resistance to acid and fire, and their low electrical conductivity. Crocidolite is the most dangerous type of asbestos [Decision Guidance Document].

Asbestos is classified as hazardous because it can cause asbestosis (a chronic lung disease) as well as mesothelioma (a tumour of the epithelium lining the lungs, abdomen or heart) [Queensland Government, 2006].

More information about the structure and chemical characteristics is contained in Part 1 of the guidelines for decision-makers of the SACODI Project.



10.4. Waste reduction options

In the case of asbestos, waste reduction means preventing products containing asbestos and the substitution of asbestos fibres in the production of fibrocement. The following alternatives have become established in recent years:

- Manufactured inorganic fibres
- Naturally occurring crystalline fibres and other minerals
- Natural organic fibre
- Manufactured organic fibre

Manufactured inorganic fibres (MIF)

The idea behind manufacturing inorganic non-hazardous fibres was to generate fibres with a larger diameter to prevent them from reaching the lungs. For many years, glass fibre seemed to provide a suitable alternative. However, research has revealed glass fibre to be breathable and hence able to cause lung cancer, too. Consequently, glass and stone wool products should be avoided, and if used (e.g. for thermal insulation, roofs, walls, or car bodies) be handled like hazardous material such as asbestos.

Naturally occurring crystalline fibres and other minerals

Natural occurring crystalline substances such as wollastonite and perlite can also be used as alternative substances. Similar to manufactured inorganic fibres, they too are breathable, causing inflammation in the lungs and respiratory tract. Handling natural occurring crystalline is governed by the same rules as manufactured inorganic fibres.

Natural organic fibre

Natural organic fibres are for example based on cotton or cellulose. They are more harmless than asbestos. Because they also cause lung disease, they should be handled carefully.

Manufactured organic fibre

Kevlar, polyvinylalcohol (PVA) and polystyrene are manufactured organic fibres used as alternatives to asbestos. Analysis has shown that Kevlar, a para-aramid fibre, is less likely to cause lung cancer and hence safer than asbestos. The size of the fibres can be relatively easily checked. The same goes for polyvinylalcohol, which is characterized by highly stable fibres.

Polystyrene has the risk of toxic emissions if heated [Gopal, K., 2004].



10.5. Further literature and links

- **Specific information about hazardous materials**

<http://www.epa.gov/asbestos/>

http://www.hc-sc.gc.ca/iyh-vsv/alt_formats/cmcd-dcmc/pdf/asbestos_e.pdf

http://www.ruig-gian.org/ressources/comeliau-health_Vietnam-Tu-Huong-Diep-Lan.pdf#search=%22fibro%20cement%20vietnam%20manufacture%22

- **Specific information about waste reduction options**

<http://www.toxiclink.org/art-view.php?id=12>

<http://www.nedlac.org.za/research/fridge/asbestos/app-10.pdf>

<http://www.nedlac.org.za/research/fridge/asbestos/app-5.pdf>

http://www.asbestos-institute.ca/presskit/press_3.html

[http://www.asbestos-institute.ca/newsletters/nl-95-2/nl-95-2\(part1\).html](http://www.asbestos-institute.ca/newsletters/nl-95-2/nl-95-2(part1).html)

<http://www.nohsc.gov.au/PDF/Standards/AsbestosGuide.pdf>

<http://hesa.etui-rehs.org/uk/dossiers/files/chrysotile-niosh.pdf>

10.6. Handling/ Disposal/ Prevention- general aspects

The main principle of preventing asbestos risks is to substitute it in the following items:

- Cement for pipes, guttering, drains
- Cement sheeting for roofs and walls
- Floor tiles
- Pipe lagging
- All forms of thermal insulation
- Ceiling and wall decorative products
- Packing products
- Gaskets and seals
- Vehicle clutch plates

- Vehicle brake linings and pads
- Cavity wall insulation
- Ironing board hot pads
- Insulation in cookers
- Parts of night storage heaters
- Fire blankets

Like the handling of hazardous substances in the metal casting industry, metal surface treatment, and the production of chemicals, paper and cardboard, employees handling asbestos need proper training. It is important for them to know about the risks not only of breathable fibres like asbestos but also of alternative materials, too.

The demolition and removal of hazardous components in buildings should be performed manually to prevent mobilization. Of course, it is imperative that appropriate protective gear such as masks, hats, gloves and overalls is worn. Overalls are necessary because contact between these substances and the skin can cause diseases. Masks must be worn until all contact with asbestos is finished and all other clothing coming into contact with asbestos has been removed. After the working with asbestos, workers must have a shower immediately [LCHS, 2004].

During demolition and removal, a vacuum cleaner is to be used to directly collect fibres. Following the collection of asbestos, the bags are to be kept separately from household waste. The bags must be sealed, leak-tight and non-reusable. In some cases, wet systems are to be used to prevent the mobilization of fibres. The storage system containing asbestos should be labelled with information about the risks (the presence of lung carcinogens), the origins of the material, and the member of staff in charge.

If fibres are moved on transport systems, they must be packed in such a way as to prevent tipping, spilling or breaking.

When fibrocement components are produced, it is essential that all fibre emissions are trapped and not allowed to enter the environment. Workers should wear protective clothes, including gloves, overalls, masks and hats.

Given all these risks, it must be ensured that there is no danger of fibres being released and inhaled.



10.7. Summary

Process description:

The manufacture of fibrocement starts with the grinding of the asbestos. It is then mixed with water and then cement. During the finishing stages, the material is cut.

Hazardous materials:

Asbestos contains the following substances:

- chrysotile,
- amosite,
- crocidolite,
- tremolite,
- anthophyllite,
- actinolite.

They all consist of a magnesia silicate; they have a crystal structure with diameters of between 3 and 20 micrometers. Crocidolite is the most dangerous type of asbestos.

Asbestos is classed as a hazardous substance because it can cause asbestosis (a chronic lung disease) and mesothelioma (tumour of the lung).

Waste reduction options:

This refers to the prevention of products containing asbestos and the substitution of asbestos fibres in the production of fibrocement. The following alternatives have been developed:

- 1) Manufactured inorganic fibres – the purpose of these non-hazardous fibres was to develop a fibre with a diameter too large to enter the lungs. Long time glass fibre was thought to be an alternative researches determined that it could be inhaled. Glass and stone wool products are used instead and to handle materials like asbestos.
- 2) Naturally occurring crystalline fibres and other materials – examples are wollastolite and perlite can be used, they are breathable and can damage the lung. The handling is the same for manufactured inorganic fibres.
- 3) Naturally organic fibre – these are based on cotton or cellulose, they can however be harmful to the lungs and should be treated with care.
- 4) Manufactured organic fibre – Kevlar, polyvinylalcohol (PVA) and polystyrene are manufactured organic fibres that are used as an alternative to asbestos. Kevlar and PVA are less likely to cause lung cancer than asbestos, polystyrene gives off toxic fumes if heated.

Handling/disposal/prevention- general aspects:

The handling and treatment of asbestos should be taught. It is always appropriate to wear a protective mask, hats, gloves and overalls. A shower should be taken after exposure to asbestos.

During destruction, a vacuum cleaner should be reduced to minimise fibre spread. The bags from the vacuum cleaner should be disposed of separately to household waste. The bags should be sealed and non-returnable.

The storage of asbestos should cover all information concerning risks of exposure, the origin of the waste and the responsible person.

Transport should ensure there is no spillage.

With regard to fibrocement, all fibre emissions are to be collected and workers should wear protective clothing.

**10.8. Case study****10.8.1. Construction Material Production Company****General information**

This company is a state-owned construction-material production company. It was founded in 1996. The company is located on an area of 1,500 square metres and has 75 employees. The company specializes in producing fibrocement corrugated roof sheeting. Its fibrocement products are sold on the domestic market and exported to Cambodia.

Fibrocement is made from asbestos fibre and cement. Asbestos dust is extremely dangerous, causing cancer of the chest and lungs. Therefore, many developed countries have stopped producing fibrocement. In Vietnam, however, the government allows fibrocement to be produced under Prime Minister's Directive 133/2004/QĐ-TTg, which stipulates that companies making fibrocement have to ensure environmental regulations are observed. There are currently about 33 enterprises producing fibrocement roof sheeting in Vietnam (17 government enterprises, 8 private enterprises, and 8 joint-stock enterprises). The total annual production of fibrocement is about 6.4 million square metres. The environment in most of the enterprises is contaminated, affecting workers' health (source: Vietnam Environment Protection Agency -VEPA dated 17/2/2005).

Production process and waste generation

The production capacity of the company is about 1.76 million square metres per year (equivalent to 26,400 t/a). The two main types of materials used to make fibrocement are asbestos fibre (15%) and cement (85%; see Table 22). Cement is bought from the Can Tho Ha Tien 2 Cement Company, while asbestos is imported from Russia or China.

Table 22: The quantity of materials used per year

No.	Type of materials	Quantity (tons/year)
1	Poolang PCB 30 Cement (tons/year)	22,997
2	Asbestos, (tons/year)	3,403
	Where A 6-45	1,548
	A 5-65	1,548
	A 3-60	307
3	Ground water (cu. m/year)	63,000

The company uses obsolete technology to produce fibrocement. The equipment is an open system, meaning it generates dust. In particular, the fibre grinder is an open, batch operation machine with no dust control system.

Wastewater also needs to be monitored. Although wastewater is filtered before disposal in the river, it still contains a lot of small suspended asbestos fibre. In fact the main point of filtering wastewater is not to treat it but to recover the materials contained.

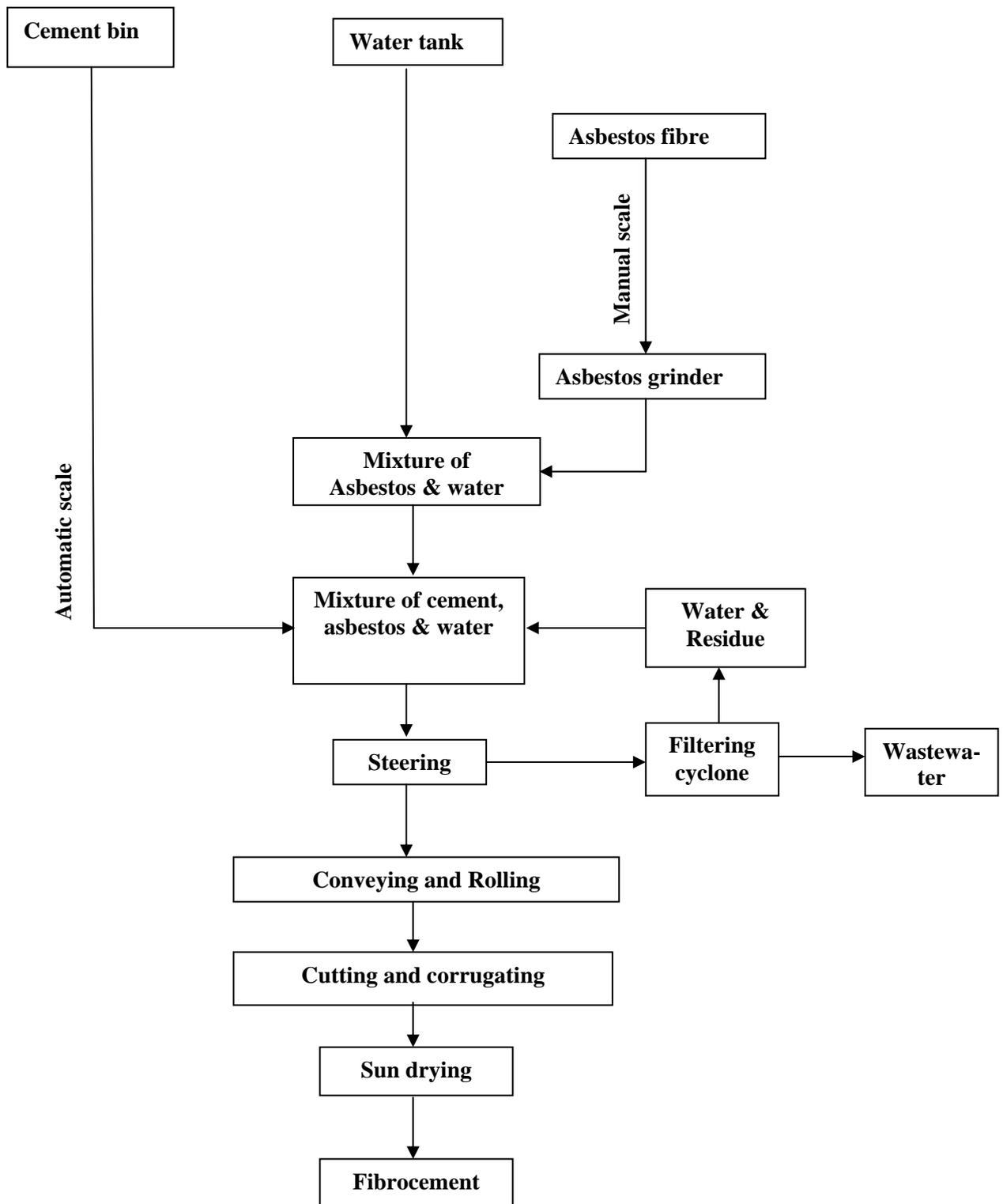


Figure 39: Production process of fibrocement at a Vietnamese Company

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Annex 1

PESTICIDE	SIGNS AND SYMPTOMS
Acrolein	Conjunctivitis (irritation of mucous membranes, tearing) Skin irritation, rash, blistering, or erosion (without sensitization) Pulmonary edema Tearing Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Acrylonitrile	Seizures/convulsions (tonic-clonic), sometimes leading to coma Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Aminopyridine	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Salivation Sweating (diaphoresis) Thirst
ANTU	Dyspnea Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Arsenicals (inorganic)	Anemia Abdominal pain Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Bloody diarrhea Keratoses, brown discoloration Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Leukopenia, thrombocytopenia Metallic taste in mouth Paralysis, paresis (muscle weakness) Paresthesia of extremities Runny nose Stomatitis Thirst
Arsine	Anemia Chills Hemoglobinuria Hemolysis Hyperkalemia Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia)
Borate	Abdominal pain Beefy red palms, soles Diarrhea Hypotension, shock Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Nervous system depression (stupor, coma, respiratory failure, often without seizures/convulsions) Tremor
Cadmium compounds	Abdominal pain Conjunctivitis (irritation of mucous membranes, tearing) Cyanosis Diarrhea Dyspnea Pulmonary consolidation Pulmonary edema Salivation Skin irritation, rash, blistering, or erosion (without sensitization) Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Carbamate insecticides	Abdominal pain Anorexia Bradycardia (sometimes to asystole) Diarrhea Diplopia Dyspnea Incoordination (including ataxia) Miosis Muscle twitching Nervous system depression (stupor, coma, respiratory failure, often without seizures/convulsions) Paralysis, paresis (muscle weakness) Runny nose Salivation Sweating (diaphoresis) Tearing Tremor

PESTICIDE	SIGNS AND SYMPTOMS
Carbon disulfide	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Breath odor of rotten cabbage Incoordination (including ataxia) Paresthesia of extremities Seizures/convulsions (tonic-clonic), sometimes leading to coma
Carbon tetrachloride	Jaundice Liver enlargement Liver enzymes elevated (LDH, ALT, AST, alkaline phosphatase)
Cationic detergents	Skin irritation, rash, blistering, or erosion (without sensitization) Pulmonary edema
Chlordimeform	Anorexia Hot sensations Kidney (dysuria, hematuria, pyuria) Skin irritation, rash, blistering, or erosion (without sensitization) Sweet taste in mouth
Chlorhexidine	Contact dermatitis Urticaria
Chloroform	Jaundice Liver enlargement Liver enzymes elevated (LDH, ALT, AST, alkaline phosphatase)
Chloropicrin	Conjunctivitis (irritation of mucous membranes, tearing) Dyspnea Tearing Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Cholecalciferol	Anorexia Hypercalcemia Polyuria Thirst
Copper compounds	Abdominal pain Conjunctivitis (irritation of mucous membranes, tearing) Hypotension, shock Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Liver enlargement Skin irritation, rash, blistering, or erosion (without sensitization) Stomatitis
Coumarins	Bloody diarrhea Ecchymoses Hypoprothrombinemia
Creosote	Contact dermatitis Hypothermia Methemoglobinemia Pallor Pulmonary edema Seizures/convulsions (tonic-clonic), sometimes leading to coma Smoky urine
Crimidine	Cyanosis Seizures/convulsions (tonic-clonic), sometimes leading to coma
Cyanamide	Dyspnea Hypotension, shock Skin flushing Tachycardia
Cyanide	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Bradycardia (sometimes to asystole) Breath odor of bitter almonds Dilated pupils Salivation Seizures/convulsions (tonic-clonic), sometimes leading to coma Unreactive pupils
DEET	Contact dermatitis Seizures/convulsions (tonic-clonic), sometimes leading to coma Urticaria

PESTICIDE	SIGNS AND SYMPTOMS
Dibromochloropropane	Low sperm count Skin irritation, rash, blistering, or erosion (without sensitization)
Diquat	Abdominal pain Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Bloody diarrhea Conjunctivitis (irritation of mucous membranes, tearing) Ileus Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia Nervous system depression (stupor, coma, respiratory failure, often without seizures/convulsions) Skin irritation, rash, blistering, or erosion (without sensitization) Stomatitis
Endothall	Bloody diarrhea Conjunctivitis (irritation of mucous membranes, tearing) Hypotension, shock Seizures/convulsions (tonic-clonic), sometimes leading to coma Skin irritation, rash, blistering, or erosion (without sensitization)
Ethylene dibromide	Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia Skin irritation, rash, blistering, or erosion (without sensitization) Pulmonary edema Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Ethylene oxide	Cardiac arrhythmias Conjunctivitis (irritation of mucous membranes, tearing) Dermal sensitization Pulmonary edema Skin irritation, rash, blistering, or erosion (without sensitization)
Fluoride	Abdominal pain Bloody diarrhea Dilated pupils Hypocalcemia Seizures/convulsions (tonic-clonic), sometimes leading to coma Tetany, carpopedal spasms
Formaldehyde	Conjunctivitis (irritation of mucous membranes, tearing) Skin irritation, rash, blistering, or erosion (without sensitization) Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Fumigants (halocarbon)	Cardiac arrhythmias Incoordination (including ataxia)
Hexachlorobenzene	Anorexia Porphyrinuria (wine-red urine)
Hexachlorophene	Contact dermatitis Seizures/convulsions (tonic-clonic), sometimes leading to coma Skin irritation, rash, blistering, or erosion (without sensitization)
Indandiones	Bloody diarrhea Ecchymoses Hypoprothrombinemia
Mercury (organic)	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Constricted eye fields Hearing loss Metallic taste in mouth Paresthesia of extremities Tremor
Metaldehyde	Abdominal pain Seizures/convulsions (tonic-clonic), sometimes leading to coma Tremor

PESTICIDE	SIGNS AND SYMPTOMS
Metam sodium	Conjunctivitis (irritation of mucous membranes, tearing) Skin irritation, rash, blistering, or erosion (without sensitization)
Methyl bromide	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Dyspnea Conjunctivitis (irritation of mucous membranes, tearing) Pulmonary consolidation Pulmonary edema Skin irritation, rash, blistering, or erosion (without sensitization)
Naphthalene	Anemia Conjunctivitis (irritation of mucous membranes, tearing) Hemoglobinuria Hemolysis Hyperkalemia Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Sweating (diaphoresis) Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Nicotine	Abdominal pain Anorexia Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Cardiac arrhythmias Diarrhea Cyanosis Diplopia Dyspnea Hypertension (early in poisoning) Incoordination (including ataxia) Muscle twitching Paralysis, paresis (muscle weakness) Salivation Seizures/convulsions (tonic-clonic), sometimes leading to coma Sweating (diaphoresis) Tremor
Nitrophenols	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Fever Hot sensations Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Skin flushing Sweating (diaphoresis) Tachycardia Thirst Yellow stain on skin Yellow sclera
Organochlorines	Cyanosis Pallor Paresthesia (chiefly facial, transitory) Seizures/convulsions (tonic-clonic), sometimes leading to coma
Organophosphates	Abdominal pain Acetylcholinesterase depression (RBC and/or plasma) Anorexia Bradycardia (sometimes to asystole) Diarrhea Diplopia Dyspnea Incoordination (including ataxia) Miosis Muscle twitching Nervous system depression (stupor, coma, respiratory failure, often without seizures/convulsions) Paralysis, paresis (muscle weakness) Paresthesia (chiefly facial, transitory) Runny nose Salivation Sweating (diaphoresis) Tearing Tremor
Organotin compounds	Abdominal pain Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Conjunctivitis (irritation of mucous membranes, tearing) Skin irritation, rash, blistering, or erosion (without sensitization)
Paraquat	Abdominal pain Bloody diarrhea Conjunctivitis (irritation of mucous membranes, tearing) Contact dermatitis Cyanosis Dyspnea Jaundice Keratitis Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Myalgia Pulmonary consolidation Skin irritation, rash, blistering, or erosion (without sensitization) Stomatitis Upper respiratory tract irritation: rhinitis, scratchy throat, cough

PESTICIDE	SIGNS AND SYMPTOMS
Pentachlorophenol	Anorexia Contact dermatitis Dyspnea Fever Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Sweating (diaphoresis) Tachycardia Thirst Urticaria
Phosphorus	Abdominal pain Breath odor of garlic Hypotension, shock Jaundice Pulmonary edema Skin irritation, rash, blistering, or erosion (without sensitization) Tetany, carpopedal spasms Thirst
Phosphides	Abdominal pain Breath odor of garlic Hypotension, shock Jaundice Paresthesia (chiefly facial, transitory) Pulmonary edema Tetany, carpopedal spasms Thirst
Phosphine	Breath odor of garlic Chills Hypotension, shock Jaundice Liver enlargement Liver enzymes elevated (LDH, ALT, AST, alkaline phosphatase) Pulmonary edema Seizures/convulsions (tonic-clonic), sometimes leading to coma Thirst
Povidone-iodine	Cardiac arrhythmias Seizures/convulsions (tonic-clonic), sometimes leading to coma
Propargite	Dermal sensitization Skin irritation, rash, blistering, or erosion (without sensitization)
Pyriminil	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Breath odor of peanuts Cardiac arrhythmias Constipation Glucosuria Hyperglycemia (elevated serum glucose) Ketoacidosis Ketonuria Paresthesia of extremities Urinary retention
Pyrethrins	Contact dermatitis Runny nose
Pyrethroids	Diarrhea Pulmonary edema
Sabadilla	Cardiac arrhythmias Sneezing
Sodium chlorate	Anemia Cardiac arrhythmias Cyanosis Hemoglobinuria Hemolysis Hyperkalemia Hypotension, shock Jaundice Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Liver enlargement Methemoglobinemia Seizures/convulsions (tonic-clonic), sometimes leading to coma Skin irritation, rash, blistering, or erosion (without sensitization)
Sodium fluoride	Cardiac arrhythmias Hypotension, shock Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Pallor Nervous system depression (stupor, coma, respiratory failure, often without seizures/convulsions) Salivation Salty, soapy taste in mouth Thirst

PESTICIDE	SIGNS AND SYMPTOMS
Sodium fluoroacetate	Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Cardiac arrhythmias Cyanosis Paresthesia of extremities Seizures/convulsions (tonic-clonic), sometimes leading to coma
Strychnine	Cyanosis Seizures/convulsions (tonic-clonic), sometimes leading to coma
Sulfur	Breath odor of rotten eggs Diarrhea Skin irritation, rash, blistering, or erosion (without sensitization)
Sulfur dioxide	Conjunctivitis (irritation of mucous membranes, tearing) Dyspnea Pulmonary edema Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Sulfuryl fluoride	Dyspnea Kidney (proteinuria, hematuria, sometimes leading to oliguria, acute renal failure with azotemia) Muscle twitching Upper respiratory tract irritation: rhinitis, scratchy throat, cough
Thallium	Abdominal pain Behavioral-mood disturbances (confusion, excitement, mania, disorientation, emotional lability) Bloody diarrhea Cardiac arrhythmias (ventricular) Hypertension (early in poisoning) Hypotension, shock Ileus Incoordination (including ataxia) Loss of hair Paresthesia of extremities Ptosis Seizures/Convulsions (tonic-clonic), sometimes leading to coma Tremor
Thiram	Alcohol intolerance Contact dermatitis Diarrhea Skin irritation, rash, blistering, or erosion (without sensitization)
Veratrum alkaloid (see sabadilla)	

GLOSSARY OF MEDICAL TERMS:²¹

Anorexia: diminished appetite.

Bradycardia: Slow heart rate (generally less than 60 beats per minute).

Carpopedal spasms: spasm of the hands and/or feet.

Conjunctivitis: inflammation of the conjunctiva (the mucous membrane covering the surface of the eye)

Cyanosis: a dark blueish or purplish coloration of the skin and mucous membranes.

Diaphoresis: sweating, perspiration.

Dyspnea: shortness of breath.

Ecchymoses: Bruises of the skin larger than 3mm in diameter.

Glucosuria: Presence of glucose in the urine.

Hemoglobinuria: Presence of hemoglobin in the urine.

Hemolysis: destruction of red blood cells.

Hypercalcemia: increased calcium in the blood.

Hyperkalemia: increased potassium in the blood.

Hypertension: increased blood pressure.

Hypoprothrombinemia: low levels of prothrombin in the blood.

Hypothermia: decreased body temperature (significantly below 98.6° F.

Ileus: Obstruction of the bowel.

Keratosis: a hard, thick circumscribed skin lesion (characterized by overgrowth of the horny layer).

Ketoacidosis: an increase in the pH of the blood caused by the enhanced production of ketones.

Ketouria: Presence of ketones in the urine.

Leukopenia: Decreased number of white blood cells in the blood.

Methemoglobinemia: the presence of methemoglobin in the blood.

Miosis: pinpoint pupils.

Myalgia: muscular pain.

Paresis: muscle weakness.

Paresthesia: an abnormal sensation such as of burning, pricking, tingling or tickling.

Polyuria: increased production of urine resulting in increased frequency of urination.

Porphyria: increased porphyrins in the urine manifesting as wine-red urine.

Ptosis: a sinking down of the eyelid.

Pulmonary consolidation: an infiltrate in the lung observed on a chest x-ray.

Rhinitis: inflammation of the nasal mucous membranes.

Stomatitis: inflammation of the mucous membranes of the mouth.

Tachycardia: Rapid heart rate (generally greater than 100 beats per minute).

Tetany: a clinical neurological syndrome characterized by muscle twitches, cramps, carpopedal spasm, and when

severe, laryngospasm and seizures.

Thrombocytopenia: decreased number of platelets in the blood.

²¹ Adapted from:

Morgan DP. Recognition and management of pesticide poisonings. 4th ed. Washington: US Environmental Protection Agency; 1989.

Reigart JR, Roberts JR. Recognition and management of pesticide poisonings. 5th ed. Washington: US

Environmental Protection Agency; 1999.