Guidelines

for

Hazardous waste

Part I

Recommendations for environmental politics and administration, Introduction to collection and disposal systems

under particular consideration of framework conditions in India and Vietnam

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Often used Abbreviations

ADB	Asian Development Bank
CCPB	Central Pollution Control board (India)
DOSTE	Department of Science, Technology and Environment (Vietnam)
DNA	Deoxyribonucleic-acid
EIA	Energy Information Administration (Vietnam)
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GTZ	Gesellschaft für Technische Zusammenarbeit
ISO	International Standards Organisation
LEP	Law on Environmental Protection (Vietnam)
MD	Mekong Delta
MOSTE	Ministry of Science, Technology and Environment (Vietnam)
NEA	National Environmental Agency (Vietnam)
NEAP	National Environmental Action Plan
NGO	Non-governmental organisations
NPESD	National Plan for Environment and Sustainable Development (Vietnam)
SPCP	State Pollution Control Board (India)
SME	Small and medium enterprises
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USD	US Dollar
VND	Vietnamese Dong

1. Introduction

1.1. Problems of hazardous waste

Fast economic growth is a general accepted aim in politics and society. Increasing welfare can not be reached without economic success. But economic and industrial growth has also its dark side. They are linked with environmental degradation and diminishing natural resources. Thus, economic activity can influence welfare also negatively. So, it is increasingly important to consider the negative impact of economic growth on the environment. One environmental issue is generation and treatment of hazardous waste.

Hazardous materials emerge as waste and as side product in many industries and some old worn out products contain hazardous substances. The dangers of these substances are often not fully recognised for many reasons. The absolute amount of hazardous waste is rather small compared to other waste. Furthermore, dangers of hazardous waste emerge often, only in the long run e.g. through spoiled groundwater or through bioaccumulation. So, hazardous substances can cause diseases like cancer or are sometimes mutagen. These negative effects emerge probably only years after exposure and so, it is difficult to find a link to the real reason for a health or environmental issue. So, problems of hazardous waste are often underestimated because dangers are difficult to perceive and costs to society emerge especially, in the long run.

Hazardous waste accounts for about 3-4% of total waste on average. The main characteristics of hazardous waste are the same as for industrial waste; its generation increases in line with Gross Domestic Product growth and the amount of hazardous waste produced varies enormously from one country to another according to their industrial structure. [OECD 2004, p 31 f]

Especially, in developed countries environmental impact of hazardous waste has been diminished through the last years for various reasons:

- Extensive regulation, especially, concerning landfills and incinerator emissions
- Management of certain material and waste flows as electronic waste or end-of-life vehicles
- Development of highly efficient technologies in control incinerator emissions, recycling, health and safety characteristics.

Nevertheless problems remain:

- In many cases disposal capacity remains insufficient
- Emission regulations and standards are often not complied with even in developed countries

- Poor waste management in the past created an inherited burden. To this belongs especially unsupervised landfills that led to long-term contamination of soil and groundwater
- Costs of managing waste are generally hard to evaluate. Consequently, waste prices do often not reflect the environmental externalities and fail to provide a coherent base for waste management.[1]

As this assessment shows, even in developed countries hazardous waste remains an issue despite the progress that was made during the last years. In fast developing countries, hazardous waste is an even larger problem:

- Many of the steps for a better management has to be done yet
- Knowledge has to increase
- The administrative and legal system can not keep pace with the fast economic growth
- Some of the dirty industries that used to be located within Europe or North America move now to other countries and with them environmental issues move
- Fast economic growth leads to other priorities than environment in investment choice

So, hazardous waste remains an issue that has to be tackled especially in fast growing economies.

1.2. Introduction to the project

This section will explain about the background and the goal of this special project SACODI.

1.2.1. Funding of the project

The whole project SACODI has been funded by all partners and the European Commission. The EC has financed thereby the larger part. The financing of EC was done within the framework of the ASIA-PRO-ECO-Programme.

The Asia Pro Eco Programme is one of a series of initiatives by the European Union designed to promote mutual benefit and understanding between the Member States and Asia. The Programme aims to improve environmental performance and technology partnership in economic sectors, and promote sustainable responsible investment.

The Asia Pro Eco Programme is a five-year European Union initiative, launched in 2002, based on the experience and the inputs provided by the Asia Eco Best Programme.

With the EC’s contribution of € 31,5 million (total budget: € 82,3 million), the main objective of Asia Pro Eco is, to adopt policies, technologies and practices that promote cleaner, more resource efficient, sustainable solutions to environmental problems in Asia.

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[1] [OECD 2004, p.31 f]

The implementation concentrates on specific projects under the Call for Proposals mechanism accessible to public or non profit organisations in Asia and EU. The Programme provides support through grants. Activities such as, organisation of working conferences, diagnostic studies, policy advice, feasibility studies, technology partnership and demonstration activities in the field of environment can be considered for funding under the Programme.

1.2.2. The SACODI project

This guidelines represents the major result of the joint applied research project SACODI "Segregation, Collection and Disposal of hazardous waste". The project was conducted by an EU-ASIAN consortium, consisting of Technische Universität Dresden/Germany, Hochschule Bremen, University of applied Sciences/Germany, University of Cardiff/United Kingdom, Cantho University/ Vietnam and Environment Support Group Bangalore/India. The project started in August 2005 and ended in August 2006.

1.2.3. Objectives

Growing economic activities and wealth may aggravate waste problems. Ways should be developed to reduce the increasing amount of waste generated and improve handling of waste to reduce environmental and health impacts. The project intends to change the behaviour of those who generate hazardous waste in such a way that, they treat, transport and dispose it in an environmentally safe manner. So, the most important objective is to disseminate solutions for the minimisation of environmental and health problems which emanate from hazardous waste.

To reach this target more resource-efficient products, processes and services should be promoted. This includes waste minimising environmentally friendly technologies and optimised product design. For hazardous waste which is produced, technologies should be promoted which help to reuse and recycle the materials wherever possible. This aims to be a contribution to resource and energy saving. For any unavoidable generated hazardous waste, ways should be promoted for environmentally friendly and economically sustainable management, including safe handling, segregation and collection. These measures aim to relieve the burden of hazardous waste on business and communities and should help to ease any further treatment. Proper hazardous waste treatment and disposal technologies which suit to the country specific technological, institutional and economical framework should be promoted.

The project intends to focus on hazardous waste from small scale industries. Especially, many units in the small scale handle hazardous wastes without any pollution control. The project may help to increase awareness and responsibility in authorities and with workers concerned and managers and thereby reduce problems originating from this waste. Thereby, it is expected that institutional and technical capacity will be built up and demand for modern environmental solutions will be increased.

1.2.4. Target groups

For local decision makers, the system will consist of guidelines which help to choose between different technologies to process and deposit dangerous and hazardous waste and hereby, to find an environmentally sustainable solution which is also, economical and socially suitable. (Part I)

For trade and factories a handbook was written which helps to understand the issue of dangerous and hazardous waste and the urgent need for proper handling, collection and disposal (Part II). The handbook will contain information how to reduce waste and thereby, save material, reduce costs and reduce the negative environmental impact. The handbook talks especially, to managers and workers in small and medium enterprises because, there is the lack of knowledge particularly, big and ways to control their actions are small. The handbook will concentrate on some most relevant industries.

The guidelines and the handbook will be general so that, they can be transferred to other regions in India and Vietnam and to other less developed Asian countries.

1.3. How to use this guidelines

These guidelines address local authorities and decision makers. So, they contain administrative, financial, economic as well as technical and environmental aspects. So, there is a description of economic and environmental aspects in general and hints for decision making in the field of hazardous waste in particular. Furthermore, practical and technical aspects of hazardous waste collection, treatment and disposal are discussed. This is complemented by country specific information from India and Vietnam.

Chapter 2 introduces the issues of hazardous waste. Hazardous materials are defined and properties of most relevant substances are described. This includes especially, health and environmental impacts. The last section will give a framework to data collection about hazardous waste.

Chapter 3 describes the situation in India. A comprehensive review of the legal and policy framework introduces the general picture. This will be complemented by some case studies depicting special situations: an illegal, but from the authorities tolerated dumpsite, issues of a coal fired power plant and an example for electronic-waste handling.

Chapter 4 depicts the situation in Vietnam. A general picture of the economic and waste situation is drawn. This is followed by an analysis of the political system. The chapter closes with an introduction to the situation in Mekong Delta and Cantho city.

Chapter 5 explains main issues of policy making. It starts with a general approach to environmental policy and goes then more into detail on special issues of hazardous waste policy. Issues like education, efficient waste handling, waste reduction, incentives and long term strategies are explained.

Chapter 6 gives mainly technical information about collection and transport of hazardous waste. As an extension to this chapter with special hints to careful handling and safety at work, the handbook (part II) is recommended.

Chapter 7 explains in detail technical options for treatment and disposal of hazardous waste. Physical, chemical, thermal, biological treatment and standards for dump sites are explained. This is followed by an assessment and exemplary application to some industries.

1.4. References and Links

OECD 2004, Addressing the Economics of Waste. OECD Publications, ISBN 92-64-10618-9

For more information on the Asia pro Eco programme see:

http://europa.eu.int/comm/europeaid/projects/asia-pro-eco/index_en.htm

More co-operation programmes of the European Commission: Europe aid co-operation office

http://ec.europa.eu/comm/europeaid/index_en.htm

More information about development policies of the European Commission:
Directorate-General Development: http://ec.europa.eu/comm/development/index_en.htm

Education and culture programmes of the European Commission:
Directorate-General Education and culture: http://ec.europa.eu/dgs/education_culture/index_en.html

See also: The European Union in the world: http://ec.europa.eu/comm/world/

Further information on SACODI and all results and publications (downloads) can be obtained from the project website: www.sacodi.tu-dresden.de .

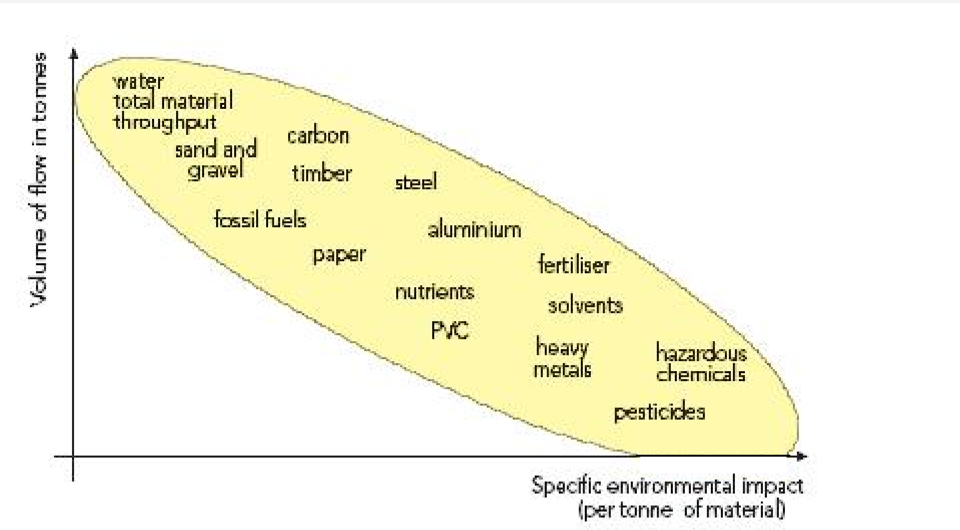
2. Introduction to hazardous waste

2.1. What is hazardous waste?

Waste is something the owner no longer wants and, which has no current or, perceived market value. There are two main channels of hazardous waste generation. The first source are hazardous components of old worn out products (e.g. batteries or electronic waste). The second source is hazardous waste generated as a by-product, as an unwanted side-product or process residues (e.g. sewage sludge or paint leftovers). Hazardous materials and waste have chemical, physical or biological characteristics which require precautionary measures for handling, treatment and disposal to avoid dangers and risks to human health and the environment. Due to its quantity, concentration or physical, chemical or contagious characteristic, hazardous waste can be of a considerable danger to the human health or to the environment if, unprofessionally treated, stored, transported, dumped or faulty used.

Material Flow and specific environmental impact[2]

The relative environmental impact of waste is related to both the quantity and the degree of hazard associated with it. There are therefore two aspects to waste generation: quantitative, i.e. how much is generated, and qualitative, i.e. the degree of hazard. This is shown here for a selection of materials. Waste with a high specific environmental impact per tonne is normally found in minor volumes and is therefore more difficult to separate and collect. Until now waste management has mainly concentrated on waste streams in the middle of the area marked.



[2] Source: [EEA 1999] and [Steurer 1996]

There exist formal definitions and lists for hazardous waste depending upon the national legal system and upon technical requirements. But there is no general valid definition for the term "hazardous waste". Even, the Basel Convention – a programme of the United Nations Environment Programme (UNEP) for minimization of the production and import of hazardous waste, refers to different definitions of the member states. But, a generally accepted classification is given by special chemical properties, for instance, chemical activity, combustibility and explosive, toxic and corrosive properties as well as danger for human beings and environment (see also section 6.1.3). The following section 2.2 will characterise some of the most relevant classes of hazardous materials.

Radioactive waste

Radioactive waste has some very special characteristics. There are no real treatment opportunities. Other hazardous wastes can be treated somehow which means some chemical reaction like oxidation or biological treatment. A proper treatment may reduce the danger. Chemical or biological reactions will not change radioactivity. Radioactivity will only decrease with the time, depending upon material specific half-life. Therefore, the only solution for radioactive waste is to collect it properly and store it in a safe place. Because, all precautionary measures are very special and different from other kinds of hazardous waste, radioactive waste disposal is beyond the scope of this document.

As mentioned above, any classification of hazardous waste is quite difficult. For practical purposes, it is often useful to distinguish between organic and inorganic chemicals.

Organic chemicals

Source of organic chemicals is mainly crude oil, natural gas and to a lesser extent coal. Out of these raw materials, there are several conversion and downstream processes. First step of chemical processing is done in huge batch plants like refineries. With every further processing step the plants are more specialised and therefore will be smaller and on the other hand the variety of produced substances (and kinds of waste) increases. It is estimated that about 30,000 chemicals are manufactured at amounts greater than 1 tonne per annum. This shows that waste handling and treatment gets more and more difficult as more downstream the activity is. Because of the huge variety of organic chemicals there is an enormous lack of knowledge about many of theses materials and the emanating waste.[3]

[3] The European Initiative REACH has the goal to reduce this knowledge gap. All chemicals that are produced at amounts of more than 1 t per year has to be registered. New information about environmental and health effects of this chemicals will be collected.

Inorganic chemicals

The amount of inorganic chemicals produced is much greater than the amount of organic chemicals produced. But, the variety of inorganic chemicals is much smaller. Problems arise especially from sulphur compounds, different acids, and bases and heavy metals.

Biomedical waste

As the handling of biomedical waste is beyond the scope of this guidelines, they will be mentioned only here with a few words. Biomedical waste is generated mainly by hospitals, doctors and, also in laboratories. It conveys dangers especially through bacteria and viruses, and, hence, it has to be handled with extreme care. Biomedical waste can cause huge damage to human lives. Therefore biomedical waste needs:

- A very strict regulation: The regulation has to cover all, even small generators of biomedical waste
- A close control of regulation
- A proper treatment of **all** biomedical waste , e.g. through thermal treatment, no landfills!

Figure: 2-1 Thermal Treatment of biomedical waste in Vietnam

2.2. Classes of substances

There is a huge number of chemicals that can be assigned as hazardous waste. To obtain a more comprehensive picture of the most important classes of substances and its significance, and spreading within the industrial sector, follows a short description of most important substance classes.

2.2.1. Petroleum

Petroleum, is a natural substance. It can make complex chemical bonds with hydrocarbons, nitrogen, sulphur, and oxygen. This happens by chemical and biochemical reactions that take a longer period of time. Depending on geological duration and main existing flora and fauna, different chemical compounds emerge. Petroleum can be found and used in a gaseous, liquid (e.g. crude oil) or solid (e.g. asphalt) phase. It is used in many ways: for petrol, kerosene and diesel. Furthermore, it can be used in car industry, fuel oil, for generating electricity, as solvent, for plastics and some intermediate products in industry. Dangers emanating from petroleum are due to an improper storage, disposing and dumping of waste oil. Furthermore, contaminations come into existence, owing to the use of subterranean tanks for storing fuel oil, patrol stations, military bases, refineries, and, also, owing to damaged pipelines.

The following shows the classification of petroleum:

- Paraffins
- Olefins
- Naphthenes
- Aromatic compounds

Alkanes are rated among paraffins, an example for olefines are alkenes, cycloalkanes are naphthenes and aromatic compounds are monocyclic and polycyclic aromatic hydrocarbons. Table: 2-1 shows some often used products of petroleum and their characteristics.

Table: 2-1 Characteristics of some petroleum products[4]

Use	Temperature range of distillation	Length of hydrocarbon chain	Main substances of content
Petrol	40-205 °C	C_5-C_{10}	Alkanes, Iso-alkanes, Cyclo-alkanes, Arenes, BTEX[5]
Kerosene	175-325 °C	C_{12}-C_{16}	Alkanes, Iso-alkanes, Cyclo-alkanes, PAH[6]
Diesel	200-400 °C	C_{14}-C_{25}	Alkanes, Iso-alkanes, Cyclo-alkanes, PAH
Fuel oil	140-400 °C	C_{10}-C_{25}	Alkanes, Iso-alkanes, Cyclo-alkanes, BTEX, PAH

Some compounds of this class of substances are toxic and carcinogenic. The Polycyclic Aromatic Hydrocarbons (PAH) differ from each other, concerning, their degradability and toxicity. With increasing number of rings in the molecular structure, the degradability decreases and the carcinogenic impact increases.

[4] [Watts 1997 p. 80]

[5] Abbreviation used for hydro carbons: Benzene, Toluene, Ethylbenzene and Xylene.

[6] Polycyclic aromatic hydrocarbons

2.2.2. Pesticides

Pesticide is an international collective term for chemical, physical or biological agents, that are used for crop protection against pests. They protect plants, parts of plants and, products of plants (e.g. crops, seed) against microbes, vermin or fungus. Destructive organisms are dispatched or controlled by pesticides. There are different types of pesticides:

- Bactericides for the control of bacteria
- Herbicides for the control of weeds
- Fungicides for the control of fungi
- Insecticides for the control of insects
- Miticides for the control of mites
- Nematicides for the control of nematodes
- Rodenticides for the control of rodents
- Virucides for the control of viruses

All these substances should have a high impact on the target organisms whereas, their effect on human beings, animals and useful plants has to be as low as possible.

Pesticides are very important. There are estimations, that we may loose about one third of the world crop each year without the use of pesticides. Furthermore, pesticides are enormously important for fighting against epidemics like malaria. Although, the benefit of pesticides is without controversy, yet, there arise undesirable damages on the environment by the use and the disposal of these toxic chemicals. In addition, soil and groundwater may be contaminated. Main sources of damages are locations of mixing and loading and agricultural regions [Watts 1997].

Because of the general biological effect of pesticides, that damage organisms, there is, also, a harmful side effect on other organisms besides the target organisms. The danger comes from the agent or, from its degradation products. So, pesticides can exhibit a high toxicity against agricultural crops, wild animals, humans and pets. There can be an accumulation of negative effects on an organism even if there is a constant uptake of little doses. Furthermore, a lot of pesticides have a high persistency within the soil because of the content of chlorinated hydrocarbons. This causes a diffusion of the pollutants within the ecosystem. Pesticides are accumulating within the food chain thereby creating a new source of danger. To keep the danger as low as possible, an expert handling with these substances, is necessary. Correct handling during production, transport, storage and application are very important [Lohns 1999].

Insecticides

Insecticides are used for protection against insects. The best known insecticide is dichlorodiphenyltrichloroethane (DDT). It belongs to the chlorinated organic insecticides. Although, its use is banned in many countries, it is produced and exported. It was used in gardens and on fields in agriculture. It was banned in the USA in 1985, nevertheless 330 tons were exported to foreign countries. DDT accumulates within the fat tissue, brain, liver and within the kidneys. Particularly in developing countries DDT (Figure: 2-2) is, still, used against malaria. Here is the estimated benefit higher than the expected damage [Lohns 1999].

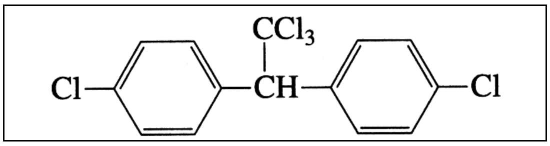


Figure: 2-2 DDT

As a biodegradable alternative for DDT, Methoxochlor was generated (Figure: 2-3). The reason for the better biodegradability is the Methoxy group at the benzene cycle.

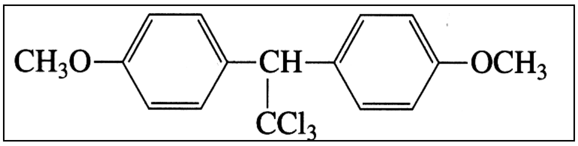


Figure: 2-3 Methoxychlor

Lindane (Figure: 2-4) is used for sterilisation of soil, for keeping locusts under control and, for abatement of insects, that cause damage to cotton plants. Its characteristics are a wide impact and a good initial effect. Small amounts swallowed can be deadly for humans. Because it is very easily introduced into the water, it is also very dangerous to fishes and to bees [Lohns 1999].

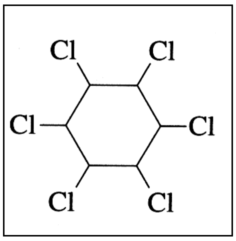


Figure: 2-4 Lindane

Parathion, malathion und diazinon are popular organic phosphorus ester. They are less persistent than organic chlorinated insecticides. Because of its relatively good degradability, the potential danger is lower. However, there is a higher acute toxicity instead of a chronic toxicity. An average adult dies when there is contact of, only, three drops of parathion on his skin [Watts 1997].

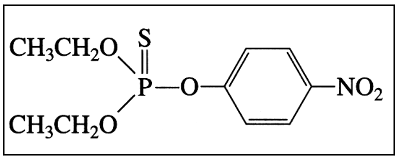


Figure: 2-5 Parathion

Parathion (Figure: 2-5) is very effective against a large number of insects and, it is extremely toxic for humans, therefore, it should be handled only by well informed experts.

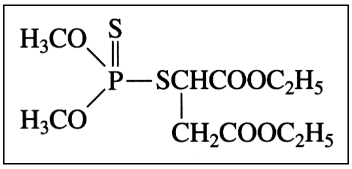


Figure: 2-6 Malathion

In contrast, malathion (Figure: 2-6) has a low toxic effect on humans and, it is often used in private households, fruit orchards and so forth.

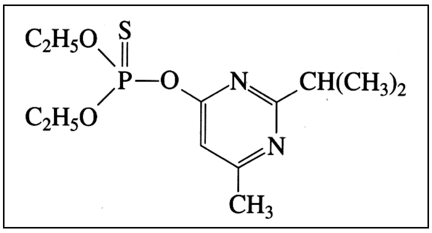


Figure: 2-7 Diazinon

Diazinon (Figure: 2-7) is used for keeping away insects living in the soil, insects on fruits, vegetables and crops.

Carbaryl and aldicarb pertain to the carbamates – esters of carbamit acid. Carbaryl (Figure: 2-8) is used to protect more than 100 different kinds of fruits.

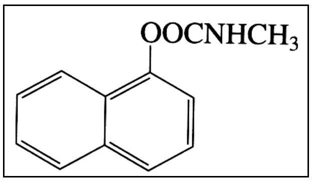


Figure: 2-8 Carbaryl

On the other hand, aldicarb (Figure: 2-9) is used for treating soil and seed – mainly for citrus fruits and ornamental plants. It belongs to the systemic insecticides. After putting on the soil the roots of plants assimilate the substance. The insecticides, from the soil, are absorbed by the roots of the plants so as to get diffused into the whole plant and it protects the plant against insects, from within. Humans, who get into contact with aldicarb, get sickness, dizziness, sweating and get partial irritation on skin and muscosa [Lohns 1999].

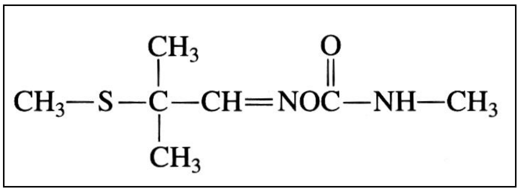


Figure: 2-9 Aldicarb

Herbicides

Herbicides are used to wipe out unwanted plants. It can be distinguished between non selective herbicides (total herbicides) that destroy the total natural cover on the treated area and the selective herbicides that, only destroy special species of plants. Therefore, selective herbicides are used for cultivated plants [Lohns 1999].

There is a classification regarding the biological effect:

- Photosynthesis inhibitor, that stop the Hill-reaction during the hydrocarbon creating process. Examples of this group of herbicides are, uraciles, urea (Figure: 2-10) and triacines. Atracine (Figure: 2-11) and cyanicine (Figure: 2-12) are the most established ones.

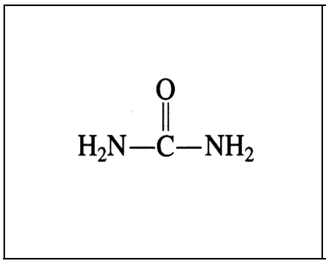


Figure: 2-10 Urea

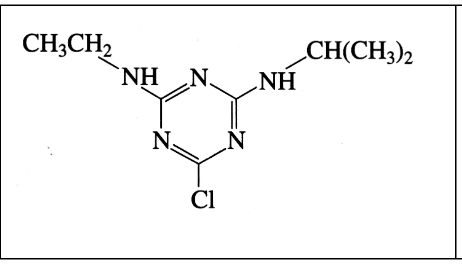


Figure: 2-11 Atrazine

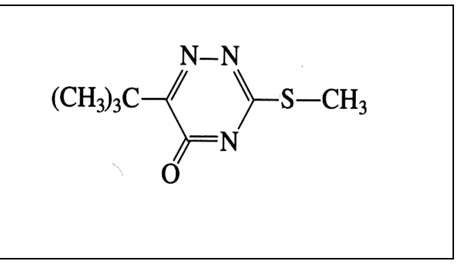


Figure: 2-12 Cyanizine

- Respiration inhibitor, that disturb the transfer during the decomposition process of hydrocarbons. Examples are dinitrophenoles, benzonitriles and analines.
- Growth agents (auxinanaloga, e.g. halogenated phenoxycarbon acid).
- Mitosis inhibitor, that influence the cell division process. Examples are carbamates and chloro acylamides.
- Germination inhibitor, that disturb the germination of the seed by modifying the RNA synthesis and synthesis of proteins or by inhibiting the mitosis.

Fungicides

Fungicides are agents for inhibition or for total prevention of growth of fungus. The aim is, to inflict a selective damage on fungus, while, the plant is protected. Heavy metal salts were used in the past. Today, organic fungicides and antibiotics dominate. The best-known fungicide, probably, is pentachlorophenol (PCP). It protects railway sleepers made of wood, wooden fences, telephone poles and other wooden constructions. Furthermore, it was used for wood preservation, treatment of textiles, leather, paper and cellulose. In some countries, it is banned because of dioxin contaminations caused by the production process [Watts 1997].

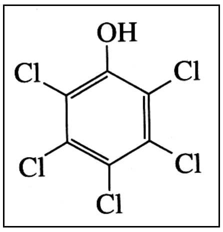


Figure: 2-13 Pentachlorphenol

It is due to an enormous amount of production of pentachlorophenol (Figure: 2-13) over a long period of time, that huge contaminations have emerged. These contaminations were, not only local but, even global. The reasons for their ubiquitous incidence are owing to their chemical properties like water solubility, lipophilicity, volatility and a low rate of biodegradability [Lohns 1999]. PCP is carcinogenic, mutagenic, reproduction damaging, highly toxic, irritating and environmentally hazardous.

2.2.3. Industrial intermediate products

Some aliphatic and aromatic compounds are used for synthesis of pesticides, plastics, artificial fibres (nylon, polyester, acryl), dyes and other products. The best-known intermediate products are benzene, chlorobenzenes (Figure: 2-14) and chlorophenols. Different amounts of these chemicals can be found within liquid industrial waste and sludge. As there are a lot of industrial intermediate substances and, as not all of them can be described here, only chlorophenols and chlorobenzenes which belong to the CHC group will be described here. Both of them are used for synthesis of pharmaceuticals, plastics and in many more products.

Chlorobenzenes are mainly used for producing disinfectant and, also, were used for synthesis of DDT in the past (see 2.2.2 Pesticides). Dichlorbenzene for instance, is used in mothballs [Watts 1997]

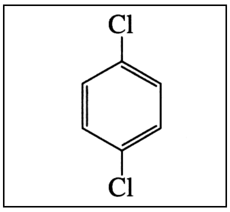


Figure: 2-14 Chlorobenzene

Chlorphenols (such as Trichlorophenol in Figure: 2-15) are used as wood preservative, for slime reduction in paper production and as disinfectant, because of its bacterial and fungicidal impact. Monochlorbenzene for example is used in dye and antidegradant production.

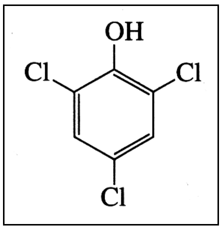


Figure: 2-15 Trichlorophenol

A lot of these substances are highly bactericidal. Because of its hydrophobic characteristic CHC can be accumulated in the fat tissue.

2.2.4. Polychlorinated biphenyls

As polychlorinated biphenyls (PCB) are heat-resistant, they are mainly used in hydraulic and transformer oil. In addition to transformers, PCBs can be found also in a lot of other electric appliances like motors, refrigerators and freezers as cooling liquid. Furthermore, they are used as impregnating agent for wood and paper, diluter and, also, isolation agent. The basic structure of polychlorinated biphenyls is the aromatic hydrocarbon biphenyl (Figure: 2-16). [Watts 1997]

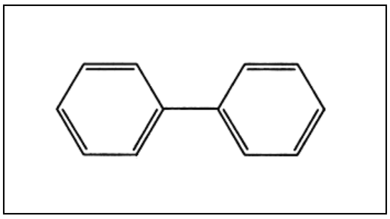


Figure: 2-16 Biphenyl

With an increasing grade of chlorination increases the danger because of a higher concentration of chlorine. Examples: 2,4’ Dichlorobiphenyl (Figure: 2-17) and 3,3’,5,5’ Tetrachlorobiphenyl (Figure: 2-18).

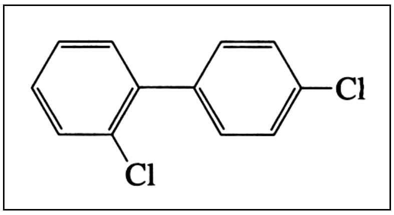


Figure: 2-17 2,4’- Dichlorobiphenyl

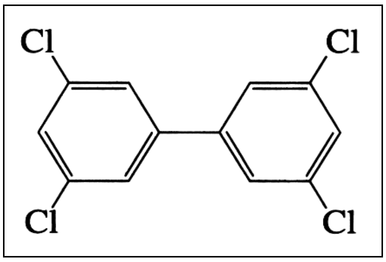


Figure: 2-18 Tetrachlorbiphenyl

Within the human organism, PCBs can cause damage to liver, spleen and kidneys (Yuscho disease). When PCBs take part in a combustion process, huge amounts of dioxins and furans can be created [Lohns 1999].

2.2.5. Polychlorinated Dibenzodioxins und Dibenzofurans

In contrast to other organic compounds, polychlorinated Dibenzodioxins and Dibenzofurans (PCDD/PCDF) are not produced for industrial or private use. The only exception is the production for analytics. They are generated mainly during the production, chlorination or combustion of organic compounds as an unwanted side product. For instance, PCDD/PCDF were found in chlorine bleached paper and other industrial products [Watts 1997].

Necessary conditions for creating PCDD/PCDF are:

- existence of hydrocarbons and halogens (in particular, the so called “dioxin pre substances” like halogenated aromatic hydrocarbons)
- existence of oxygen
- temperature between 250 and 800°C
- sufficient time for reaction

Heavy metal containing dust, can catalyse the reaction of PCDD (Figure: 2-19) and PCDF (Figure: 2-20) creation [Lohns 1999]. Other ways of generation PCDD and PCDF are in the de-novo-synthesis -a low temperature reaction- and a gradual creation from the elements C, H, O, Cl and Br during an incomplete combustion process. An effective disintegration of PCDD/PCDF can be reached by activated carbon filters.

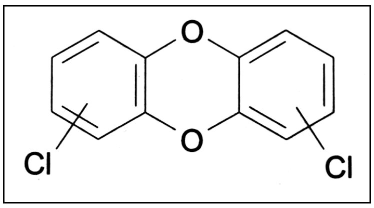


Figure: 2-19 Polychlorinated Dibenzodioxin

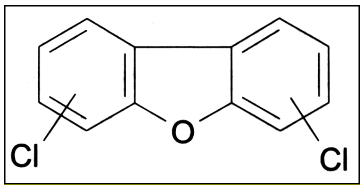


Figure: 2-20 Polychlorinated Dibenzofurane

Tetrachlorodibenzodioxin (TCDD) is one of the most toxic substances. For example, the acute toxicity of TCDD is three times higher than the toxicity of strychnine. Acute symptoms of poisoning are nausea, vomiting and irritations of the upper respiratory tracts. After-effects are massive damage of liver, kidneys, pancreas, respiratory tract and heart [Lohns 1999]. After a few weeks of contamination a person can get chlorine acne that partly can last for years. Besides, there is a proved carcinogenic effect on animals but, it is not clear if it is carcinogenic for humans too.

2.2.6. Metals and inorganic non-metals

By ecological aspect heavy metals are very important.

Through a redox reaction, heavy metals in insoluble compounds can become soluble. As they are ionised when they are dissolved, they are highly mobile and can be assimilated and even partly accumulated by plants. A biological decomposition is very difficult.

The main fields of their use are tanneries, wood impregnating facilities and cyanisation facilities to kill wood damaging organisms. Heavy metals are also components of caustics and dyes. Partly, they may be found also, in disinfectants. Through industrial use and combustion processes they enter into the environment in the form of sludge as liquid or in the form of solid waste. They enter also, the organisms through their respiration tracts because, heavy metals are bound to dust and they get into the food chain and they are able to accumulate within organisms [Lohns 1999]. The following paragraphs give a closer look at some important heavy metals.

Arsenic

Arsenic (As) can be found in the V. main group as 3- and 5-valence element. The most common arsenic natural form is arsenide, e.g. arsenic grid (FeAsS). There are three chemical modifications: the resistant, grey and metallic arsenic, the meta steady, yellow, non-metallic arsenic and the amorphous, hard, black, shiny arsenic.

Arsenic occurs in natural water in the form of Arsenous acid (H_3AsO_3) and its salts. Arsenic is quite widely distributed in natural waters (occurring at levels of 5µg/l or more in approximately 5 percent of those tested). Arsenic gains access to the water environment through mining operations, the use of arsenal insecticides, and from the combustion of fossil fuels, where part of the fallout occurs on aquatic areas. Arsenic exists mainly as its sulphide ore, aresenopyrite. Arsenous oxide (As_2O_3), known as white arsenic, is generated as a by-product of in the smelting of lead, copper and gold ores [Kannan 1991].

Arsenic is used in many ways; as plant protectant, wood protectant and also had been used as chemical warfare agent in the past. It is also used glass production in semiconductor industry and photovoltaic [Watts 1997]. It is also used as an alloying agent for heavy metals in special solders.

Symptoms of acute poisoning are headaches, dizziness, vomiting and serious intestinal poisoning. Characteristics of a chronic poisoning are costiveness or diarrhoea, irritation of the mucosa of eyes and upper respiration tracts, cirrhosis of the liver, damage of kidneys and myocardial muscle. Arsenic is carcinogenic [Lohns 1999]. Other resulting problems are peripheral vascular disease (blackfoot disease), resulting in gangrene, hypertension and ischemic heart disease, liver damage, anaemia and diabetes mellitus [Sawyer et al].

Cadmium

Cadmium (Cd) can be found in the II. subgroup of the list of elements. It is a highly toxic metal.

Cadmium is almost always found as an impurity with Zinc ore. It is usually a by-product from mining, smelting, electroplating, pigment, and plasticizer production can contain cadmium that makes its way into water through effluent discharge from these industries. Cadmium makes gets into the water supplies as a result of deterioration of galvanized plumbing, industrial waste or fertilizer contamination [Nathanson 2003]. Cadmium in the air comes from emissions from fossil fuel use. Cd is used in the manufacture of alloys, electroplating, Ni-Cd batteries and paint pigments. Other sources of Cd in water are Cd –containing industrial wastes. Furthermore, it comes into existence through combustion of coal and oil, during cement production in electroplating factories, while producing batteries and PVC [Watts 1997].

Cadmium is highly toxic and as it is accumulative, it can be accumulated in liver and kidneys. As a result, the function of the kidneys can be disturbed. A carcinogenic effect can not be excluded. Because cadmium compounds are highly toxic, swallowing can cause vomiting disruption of the stomach – intestine – tract, damage of liver and, can cause spasms [Lohns 1999]. A permanent exposure to cadmium contaminated air causes irritation of mucosa and can cause a damage of lungs. By accumulation within the organism, long running damages like a contraction of the skeleton can be possible [Diefenbach 2003].

Even at low levels of exposure over prolonged periods, it causes high blood pressure, sterility among males, kidney damage and flu-like disorders. About 1-2% of ingested and 11% of inhaled Cadmium is retained in the body. There is an inverse relation between the amount of Ca in the body and the absorption of Cd. Since a third of the absorbed Cd is stored in the kidney it is the organ that is affected the most. Cd is a potent enzyme inhibitor and is known to interact with sulph-hydyl (-SH-) groups of several enzymes. Hypertension, respiratory disorders, damage to liver and kidney are the symptoms of Cd poisoning. Cd is also known to be teratogenic in many animal species and carcinogenic to humans.

Chromium

Chromium (Cr) can be found in a lot of minerals. It is a three valence metal. For human beings it is indispensable for life as a trace element. A human absorbs it by eating food, drinking water and a little by breathing.

Chromium is an ingredient of stainless steel but also of other alloys. It is used in leather tanning, explosives, ceramics, paint pigments, photography, wood preservation. Wastes from these industrial units can be a source of water pollution by soluble chromate salts. It is used in the manufacture of alloys, refractories, catalysts, chromic oxide, and chromate salts (used in paints and to produce “cleaning solution” in laboratories) [Sawyer et al]. Fertilizer materials, which at times contain as much as several thousand ppm of Cr, are additional sources of water pollution. In compounds Chromium VI is also used for caustic and as an etching agent. It is also a pigment (chrome yellow with chromium IV and chrome oxide green with chromium III) and used for producing fire prevention agents. Huge amounts of chromium are also applied in electrical industry [Watts 1997].

The danger of chromium VI is caused by its attribute of accumulation in inner organs like liver, kidneys, parathyroid and marrow. Symptoms of poisoning are diarrhoea, fatal damage of kidneys, internal stomach and intestine bleeding and spasms. Six valence chromium compounds are the most toxic ones – they are 100 to 1000 times more toxic than three valence chromium compounds. They cause eczemas and asthmatic reactions, and further, they are rated as carcinogenic too [Lohns 1999].

The adverse effects of Chromium are mainly associated with the hexavalent forms, which are highly toxic to humans. Exposure to hexavalent chromium causes dermatitis, allergic skin reactions and gastro-intestinal ulcers. Cr (VI) is a teratogen and a carcinogen (a substance capable of inducing cancer in an organism). Chromium does not occur as contaminant of concern in plant tissue except at site-specific discharge points. The algae are generally susceptible to the toxicity and accumulation of Cr. Chromium at 10 ppm levels in water is considered to be lethal to several species of algae [Kannan 1991].

Lead

Lead (Pb) is a supple blue-grey heavy metal with a low melting point, a high density, acid resistance and with a chemical stability. Besides, it is easily to machine. Mainly it is used in rechargeable accumulators (especially for car batteries), stabiliser, pigments and casting forms. Furthermore, it is applied in metallurgical industry and of course, in fuel production. Here, the main amount of lead emissions come into the environment. But, this kind of pollution decreases, because of the use of catalysers in automobiles [Watts 1997].

Lead is found in natural deposits, is commonly used in household plumbing materials and water service lines. However lead plumbing or soldering in water lines is no more used [EPA 2006]. Lead is used in the manufacture of pipes, ceramics with lead glazes and alloys used as accumulator plates in storage batteries. Paints, pigments and varnishes, pesticides, lead-borates (used in plastic industries) contain lead. It is also found in anti-knock agents for petrol as well as in petrol itself. Lead can also be found in air and dust. It is rarely found in natural water because of its low solubility therefore its presence in water indicates a possible exposure of the water source to high levels of lead.

It is a well known poison that affects the liver, kidneys, brain, red blood cells, bones and teeth. It has also been speculated to be a carcinogen. Since growing children absorb any lead consumed faster, young children, infants and foetuses are particularly vulnerable to lead poisoning. An amount of lead that would have little effect on an adult can greatly affect a child. Children's mental and physical development can be irreversibly stunted by lead [Skipton 2006]. In youngsters it may result in mental retardation and even convulsions in later life [Sawyer et al]. At low levels lead may not produce any noticeable toxicity in humans and the symptoms can easily be mistaken for flu or other illnesses [Skipton 2006]. Toxicity of Lead is measured by the levels of diffusible forms in tissues especially in blood rather than the total amount of lead in the body. Most of the absorbed Lead is immobilized in the bones, thus not showing and adverse reactions immediately. Bone-Lead concentrations increases with age and any disturbances in osteolysis, tends to liberate the bound-Lead form the skeleton, thus leading to its toxic actions. Chronic exposure to lead causes weight loss, constipation and loss of teeth. Gums may show a blue line due to the deposition of colloidal Pb (PO4) [Skipton 2006]. Lead interferes with the synthesis of Heme in the blood therefore anemia can be the first symptom of chronic lead poisoning [Kannan 1991]. Lead is toxic to the central and the peripheral nervous system. Kidney dysfunction occurs due to the impairment of energy metabolism, leading to expression of Fanconi syndrome characterized by an increased loss of aminoacids, glucose and phosphate in the urine due to the inability of the damaged tubular cells to re-absorb these substances). Iron deficiency or a surplus of vitamin D can markedly increase the adverse effects of Pb toxicity [Kannan 1991].

The small particle size of airborne lead makes it is readily absorbable into the blood stream and the absorption through the gastro-intestinal tract is very low. Considering the high toxicity of lead, even the small amounts absorbed through the GI tract can cause significant damage to the body.

Lead affects soil micro-organisms more among aquatic invertebrates and plants by retarding the heterotrophic breakdown of organic matter. Increase in pH reduces the concentration of available Pb in water which in turn decreases its toxicity to the aquatic biota.

Mercury

Mercury (Hg) is a silver white metal that is liquid as pure element. Mercury is used in the manufacture of vinyl chloride, chlor-alkali (used in the manufacture of chlorine and caustic soda), electrical (in making electrical switches, batteries and fluorescent light bulbs) and electronic (in the manufacture of “long life” alkaline batteries) industries [Kannan 1991]. It is also used in the manufacture of electric apparatus, industrial control instruments, agricultural and industrial poisons, catalysts, preservatives, antifouling paint in thermometers, barometers, manometers, mercury vapour lamps, boiler, turbines and in the manufacture of explosives [Government of India].

As mercury is liquid at ambient temperature, and, as it has got an uniform expansion coefficient and a high density, it is the perfect medium in thermometers, barometers and in manometers. Further, it is used in miniature batteries, calculators, radios, acoustic hearing apparatuses, cameras etc. This acts also as a source of danger because, these batteries come into the residual waste and also, onto waste disposal site of domestic waste. Mercury can be found in mercury-arc lamps, as industrial catalysers and in pharmaceutical industry too. Because of its high toxicity, the use of mercury and its derivates is declining [Watts 1997]. By combustion of coal, fuel or waste and by smelting mercury and its compounds, it infiltrates into the environment.

Its exhalations are as toxic as its compounds, whereas two valence mercury compound are more toxic than one valence mercury compounds. The toxicity of organic mercury compounds is higher than the toxicity of inorganic mercury compounds. However, the toxicity of inorganic mercury compounds increases with their solubility.

By breathing in mercury exhalations or through skin contact, humans get acute mercury poisoning, leading to the symptoms of metal taste, nausea, vomiting, stomach aches, bloody diarrhoea, and damage of kidneys. In most cases, it is fatal. A long run impact of mercury causes headaches, tremor, cystitis and loss of memory [Diefenbach 2003]. There are also compounds like sublimate ($HgCl_2$) that can kill an organism within one day [Lohns 1999].

Inorganic mercury released into the environment is converted to more toxic methyl mercury compounds by the action of certain anaerobic bacteria; this transformation occurs in the sediments and bottom mud of flowing waters [Kannan 1991].

Mercury in its inorganic form attacks mainly liver, kidneys whereas organo-mercurials traverse through the biological membranes and concentrate especially in the brain. Alkyl mercurials are much more toxic than inorganic forms. Alkyl mercurials tend to accumulate when taken in small quantities and eventually attack the nervous system. A concentration of 6 ppm in the brain cells can cause irreversible brain damage. The biological half-life (the time required for something to fall to half its initial value (in particular, the time for half the atoms in a radioactive substance to disintegrate) ethylmercury is much longer (70-74 days) than that of inorganic forms (5 days). Mercury is a teratogen (any agent that interferes with normal embryonic development thereby causing birth defects), capable of inducing abortions and embryonic defects [Kannan 1991].

Grain seeds dressed with agrochemicals accumulate mercury via translocation. Hens fed with mercury pretreated crop-seeds could concentrate the metal in their livers and eggs. Mercury is concentrated up through the food chain; hence even amounts only slightly above those ordinarily found on sediments could be potentially dangerous.

The Minimata outbreak in the Minimata bay of Japan during the 1950s made the world aware of the poisonous effects of mercury [Sawyer et al]. Minimata is a neurological disorder caused by the consumption of methylmercury compounds [Kannan 1991].

Copper

Copper is an essential trace metal that is ubiquitous in the earth’s crust. It occurs primarily as its sulphide or oxide ores. Water pollution by copper results from the discharge of mine tailings and flyash, which also forms a major source of solid Cu-contamination). Fertilizer production and disposal of industrial/municipal sewage wastes represent minor sources of copper in the environment.

Copper is necessary for the normal biological activities of amine oxidase and tyrosinase enzymes. Amino oxidase is involved in the formation of two proteins—elastin and collagen; elastin is the major protein constituent of the walls of large blood vessels and collagen is the proteinaceous component of tendons and bones. The latter Cu-containing enzyme, tyrosinase, is required for the catalytic conversion of tyrosine to melanin, the pigment located beneath the skin protecting it from radiation injuries. People lacking tyrosinase cannot produce melanin and thus would be extremely be sensitive to sunlight and probably be prone to early death. The recommended daily intake of copper ranges from 2 to 3 mg. The impairment of daily ability to absorb copper resulting in its deficiency is called Menke's disease whereas Wilson's disease is its opposite (i.e., excessive accumulation of copper).

Ingestion of 15 to 75 mg of copper causes gastrointestinal disturbances. The intake of large quantities of copper salts may cause hemolysis, hepatotoxic and nephrotoxic effects. Copper toxicity could be aggravated by low dietary molybdenum or zinc [Kannan 1991].

Copper is essential for the synthesis of chlorophylls and for the functioning of certain enzymes. At the same time, at slightly higher levels it can be more toxic to plants than any other heavy metal except mercury; inhibition of growth occurs even at <0.1 mg/l, regardless of test conditions and plant species. Plants generally absorb high amounts of copper in the presence of Ca^{2+} and Mg^{2+} ions, but the uptake is suppressed when H^{+} ions are present in the soil solution. Bluegreen algae are particularly susceptible to copper because copper at high levels inhibits the nitrogen-fixing properties of these algae.

Concentrations near 1.0 mg/l can be toxic to some fish. It tends to be much more of an environmental hazard than human hazard.

Asbestos

Asbestos (from the Greek word „asbestos“: unquenchable) is a collective name for felted, fibred, natural, silica based minerals. In terms of waste and dangers, the most relevant are white asbestos (crysotil) and blue asbestos (crocydolith) because its known harmful effect on humans health. Crysotil takes about 90 % of the whole asbestos consumption so it is the most used asbestos. In general two main groups of asbestos can be distinguished: serpentines and amphiboles. Crysotil, for example, is a fibre serpentine. Despite its long well known carcinogenic effect, it was used over a long period of time (specially in the 70s and 80s). Especially, it was used as building material. Today, in many places its use is banned. Its technical properties make asbestos interesting for the industry [Bayrisches Landesamt 2004]: very tear proof, chemically inert, heat resistant (more than 500˚C), not combustible,

high flexibility, high thermal and electric isolation effect, good absorption and adsorption ability, increasing tensile strength with decreasing diameter, resistance against decomposition, spinable, good bonding property with other materials.

Because of these excellent properties, asbestos was used for making more than 3,000 products. So, it was used in construction industry (asbestos concrete, spraying asbestos, in floor-covering, in screed), for garden furniture and flower boxes, in automotive engineering (breaks and clutches), heat insulation in ships and buildings, heat protection clothes and in hair-dryers [Bayrisches Landesamt 2004].

In the year 1985, 5 million tons asbestos were used all over the world. The use of asbestos decreased to 4,1 million tons a year because of its health risks. However, its use is increasing now because, Russia, Eastern Europe and developing countries use it more in building sector.

The danger of asbestos comes mainly from its dust. Inhalation of short fibre with a length of 0.5 μm maximum, can cause asbestosis or even lung cancer. Acute effects are irritation of mucosas, eyes and respiratory tracts [Lohns 1999].

2.2.7. Non-halogenated dilutions

Petroleum distillates, some aliphatic and aromatic hydrocarbons, alcohols, ketenes, ester and ether belong to the non-chlorinated dilutions. The industry uses them for degreasing of metals, as solvent in dyes, as component of ink in print offices and for “cool cleaning”. The “cool cleaning” process uses solvents instead of hot steam for cleaning and degreasing.

Hydrocarbons are used for dry cleaning, as diluter for dyes and as industrial solvent. Aromatic hydrocarbons, benzene, toluene, xylene, and some alkali benzolenes and special distillates of petroleum belong to this group of substances.

A lot of these substances can be found as component in fuels. Xylene and ethyl benzene are the basic modules for polymer synthesis. The best known petroleum distillate is the dilution petrol. Besides dry cleaning, it is also used in dye diluter [Watts 1997].

One of the most often used ketene dilution is the Acetone (Figure: 2-21). It is a water like clear and combustible liquid. Acetone is easily mixable with water and with a lot of organic dissolvers. Acetone is used as dissolver, as agent for extractions and for synthesises. The toxic effect is relatively low – acetone is a narcotic effective riot agent. Symptoms of poisoning can be mucosa irritation, breathlessness, cough, insensibility, coma or collapse. Damage of liver and kidneys also can occur [Lohns 1999].

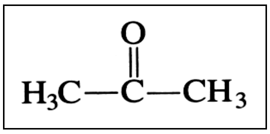


Figure: 2-21 Acetone

Probably, the use of non-halogenated dilutions will increase because, they have similar application ranges like halogenated dilutions but, they are better degradable than the halogenated dilutions. The reason is, that there is no chlorine fixed in the molecular structure.

2.2.8. Halogenated dilutions

Halogenated dilutions are not as highly inflammable as non-halogenated dilutions, they have a higher density and viscosity and better dilution properties.

Their major field of application is in the metal cleaning too. Furthermore, they are used for degreasing and cleaning of parts of machines, microchips and electronic semiconductors. In addition, they are helpful for cleaning motors (e.g. jet motors) and for steam degreasing. The main danger potential is the contamination of the groundwater system. Because of a high density and a good water solubility, these halogenated substances are very mobile in water. The common substances are Methane derivates and Ethane derivates. [Watts 1997]

Chloroform (Trichloromethane) is one known substance of this group (Figure: 2-22). Indeed, it is not so easily mixable with water but dissolvable in most of organic solvents. Especially, for industry it is interesting because, it dissolves fats, oils, resins and caoutchouc very well. Moreover, it is also used in laboratories. In the past, it was a conventional anaesthetic, but nowadays, it is not used because of its toxicity. When it is reabsorbed by the organism it functions as a narcotic, in higher doses, it paralyses respiration or damages liver, heart and sometimes kidneys. Chloroform is an extremely dangerous water pollutant and is carcinogenic [Lohns 1999].

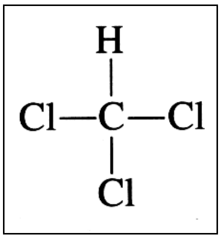


Figure: 2-22 Chloroform

The most important example of ethane derivates is perchloroethene (PER) (Figure: 2-23). 80 % of cleanser producing industry uses PER. It is a dissolver and degreasing agent, it has a low water solubility, it is volatile and, is hardly biodegradable because, it is highly chlorinated. A carcinogenic effect is suspected [Watts 1997].

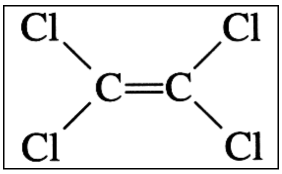


Figure: 2-23 Perchloroethene

Table: 2-2 shows again some selected groups of substances with the appropriate branches of industry in which they accrue:

Table: 2-2 Important groups of substances and their use in industry[7]

Group of substances	**Industrial branch**
Petroleum	automotive engineering, petrol stations, airports, chemical industry, military, refineries
Pesticides	agriculture, market gardens, building sector, wood impregnating facilities
Industrial intermediate products	pharmaceutical industry, agriculture, chemical industry, cleaning etc.
Poly chlorinated biphenyls	electrical industry, automotive engineering, old industrial facilities (transformer oils), wood impregnating facilities
Poly chlorinated Dibenzodioxins and Dibenzofurans	paper industry, chemical industry
Heavy metals	tanneries, wood impregnating facilities, glass producing industry, electronic semiconductor production, dye production, metal refining industry, accumulators production
Asbestos	building sector, automotive engineering, textile industry, plastics industry
BTEX	petrol stations, chemical industry, coking plants, gas works, dry cleaning
Halogenated dilutions	automotive engineering, laboratories, chemical cleaning
Cyanides	Coking plant, gas works

It can be noticed, that there accrue hazardous wastes in a huge variety in nearly all branches of industry and that there is no possibility to avoid use and contact with these substances. To make the meaning of a careful handling with these hazardous substances clear, it is necessary to recognize and consider their toxic and insalubrious effects on the health. The following section shows some possible effects of hazardous materials.

[7] [Watts 1997]

2.3. Harmful impacts of hazardous wastes

2.3.1. Overview of short and long term impacts

Hazardous waste has some special characteristics which make it different from other substances and kinds of waste. The following list gives main properties and dangers of hazardous waste.

- Short term hazards:
    - All sorts of physical hazards, especially:
        - Corrosive
        - High inflammability or risk of explosion
        - Water reactive
        - Oxidising
    - Health hazards, especially:
        - Toxicity by ingestion, inhalation or skin absorption
        - Skin or eye contact hazards, irritant
- Long term hazards:
    - Risks to the environment, to plants, animals and to 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,
      thereby long run risks to agro- and aquaculture

Short term hazards are often directly visible. Because of these immediate risks, there is the need for careful handling of any hazardous substances. Long term hazards are often not directly visible. They cause dangers to individuals and to the whole society in the long run. Therefore, it is important to point out this issue of negative long term effects.

Persistent organic polluters (POP's)

POP's are organic compounds that are resistant to environmental degradation through chemical, biological or photolytic processes. So, they are persistent in the environment in they accumulate in human tissue and thereby they have an significant impact on human health and the environment. So they are very dangerous hazardous substances. The well known herbicide DDT or the TBT, for example, which, is used to protect ships, belong to this group

Problems with this substances arise especially in the long run. Animals or humans absorb it through their nourishment. Then, it will accumulate within the body, will weaken the body and cause diseases. Because of its persistency and the accumulation in human and animal tissue, even an immediate stop of use of POP's will show positive effects only after many years. It means, use of these chemicals will endanger humans and animals and cause thereby costs to society (e.g. in form of medical expenses) for many decades. So an immediate ban is highly recommended.

The following section explains ways of exposure to hazardous waste. This will be followed by a section that gives a short overview of short and also, the long term toxic effects of some most relevant hazardous materials and waste.

Pollution from landfills can go on for centuries[8]

Rate of leachate production	Hazardous waste landfill	Municipal solid waste landfill	Non-hazardous low organic waste landfill	Inorganic waste
Medium: (200mm/annuum)	600 years	300 years	150 years	100 years
High: (400 mm/annuum)	300 years	150 years	75 years	50 years

Estimate of the time (in years) needed before leachate from different landfills can be released without risk to groundwater resources. The time needed to wash out the pollutants depends on the amount of rainwater washing through the waste (leachate production); two scenarios are presented. Calculations are based on a landfill with an average height of 12 m. Nonhazardous low organic waste landfills represent landfills receiving a mixture of commercial waste and non-hazardous industrial waste.

2.3.2. Exposure to hazardous waste

Hazardous substances can enter the human body by many ways. Figure: 2-24 gives an impression about possible flows of hazardous materials. It shows that, it can be difficult to control contamination as soon as the hazardous material enters the environment. Toxic compounds can enter the environment in many ways and in many forms. Once in the environment, chemicals may undergo series of reactions

[8] Source: [Hjelmar et al., 1994] and [EEA 1999]

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

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, nervous and mental disorders. Pesticides and heavy metals are common sources of contamination by bioaccumulation.[9]

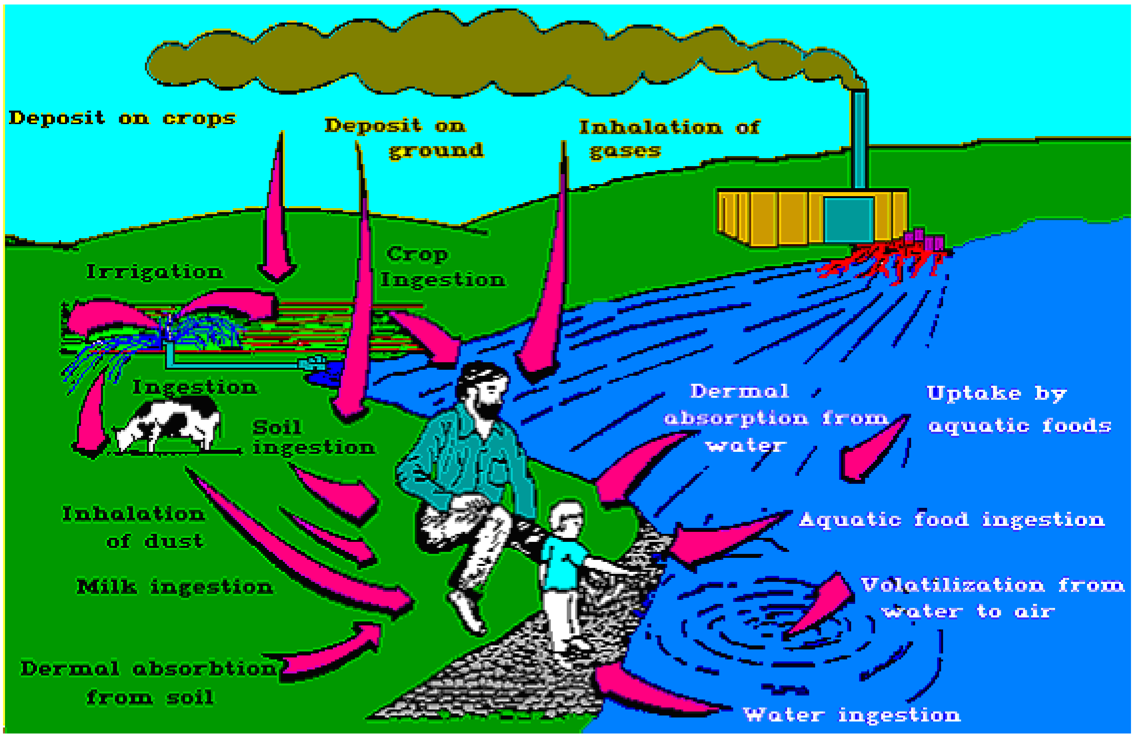


Figure: 2-24 Contamination pathways[10]

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.

[9] [Purdue University]

[10] [Purdue University]

Critical for the endangering potential of a pollutant is its volatility and its mobility from the waste into the environment. The danger of a substance is not only due to its ability to accumulate in the body but, is also due to its transportability from waste to environment and to humans respectively. E.g. immobile pollutants that are fixed by geological formation or, are in interaction with other chemical compounds and therefore are only of a low mobility are less dangerous. So, individual exposure can vary, depending upon concrete situation.

2.3.3. Toxicity of pollutants

There is a wide spectrum of symptoms of poisoning and clinical pictures by the toxic effects of all different harmful substances. But, some poison specific clinical pictures can be distinguished [Bolt 2005]:

- local irritation and cauterising effect,
- narcotic and pre narcotic effects,
- neurotoxic effects,
- damage of parenchymatous organs (liver, kidneys),
- allergisation,
- carcinogenic and mutagenic effects,
- reproduction toxic effects.

2.4. Data collection and important criteria for hazardous waste management

The following section gives an overview of data that should be collected as a base for proper hazardous waste management. As the previous sections could show, not just the properties of the chemical substance is relevant, also the environmental framework influences dangers of hazardous materials. Of course, often it is not possible to collect all necessary data. Especially, the (economic) sensitivity of the hazardous waste issues makes it often impossible to get the necessary data. Because of its high economic relevance, many companies avoid to give data of their hazardous waste generation. Then, it is needed and unavoidable to make some estimations. Collection of data is a first step for successful waste management. It should be supported by a proper legal framework.

2.4.1. Relevant properties of hazardous waste

The following list will give some criteria to identify relevant kinds of hazardous waste. Based on this criteria it is possible to identify relevant types of hazardous materials and to develop measures to tackle the problems originating from the waste. These characteristics have to be taken into account when collection, transportation and disposal activities of wastes are planned. Usually, hazardous waste is a mixed waste and an exact chemical composition is not known. Therefore, it is important to concentrate on relevant properties of the waste.

- **Substances and composition**
  Individual substances of the waste should be known. Very often it will be quite difficult to determine relevant substances but this information is the base for dealing with hazardous waste. So, most relevant substances should be determined.
- **Concentration**
  Concentration of hazardous substances has an important influence on handling and treatment. But, be aware that some substances are highly dangerous even at a low concentration. High concentration especially, of flammable and corrosive materials requires often very special precautionary measures.
- **Physical form** (solid, liquid, vapour)
  Physical form gives some information about the potential for short and long term hazards. Liquid waste has the potential to pollute groundwater and water bodies. Vapour has the potential to spread in a greater region. Be aware that many liquids are volatile. For, solid waste particle size is a relevant criteria. Small particles have often a higher hazard potential. Small particles can form dust that is highly explosive even when the material is not explosive otherwise.
- **Mobility** (volatile, infiltration of soil or to water bodies)
  Based on physical form hazardous substances can have a different mobility. This characteristic is especially relevant for a proper design of a landfill.
- **Persistence** (chemical and biological stability)
  Persistence gives an indication about the long term dangers a material can cause. Consideration of persistence is relevant for treatment especially for landfills.
- **Chemical reactivity**
  Some materials are chemical active like acids, base, salts or inflammable materials. Reactivity is important for handling of the waste. Highly reactive material needs special precautionary measures. Of course, it has also some influence on treatment options. Chemical reactivity has influence on segregation, storage and transportation. So, some materials have to be kept apart. Some materials are reactive with water. They have to be kept dry.
- **Dangers** caused by the substance
  Acute hazards are especially relevant regarding handling, storage and transportation. Long-term hazards determine the treatment of hazardous waste.

- **Quantity**
  Quantity is for several reasons important.
  - Small amount of hazardous waste may cause only small dangers and are therefore, probably negligible. Nevertheless, the sum of many small sources can be huge and therefore, may lead to a dangerous amount of hazardous substances!
  - Small amounts of hazardous waste are often neglected for administrative reasons. Nevertheless, they are dangerous.
  - Quantity has an important influence on collection systems and on treatment options. Many small sources need a different collection than one big source.
  - Quantity has an influence of economics of collection, treatment or recycling.

2.4.2. Sources and tracks of hazardous waste

After the description of main characteristics of hazardous waste and its contamination pathways, it is important to identify waste streams. This helps to tackle the problems at source, to reduce the amount of hazardous waste, to find recycling, treatment and disposal options. Information about waste streams is the base for development of collection systems. So, it is necessary to find in the first step, information about the waste generator (e.g. households, small enterprises, big enterprises) and in the second step, information about the current situation of hazardous waste.

How and where is hazardous waste generated

It is important to collect some information about the processes where hazardous waste is generated, about its pathways and about the kinds of hazardous substances that are generated. To this belongs also information about the type of the waste stream (e.g. liquid, solid, dust).

But, waste generation is not just given. The best way to tackle the issue of hazardous waste is to reduce the amount of waste. By knowing the process of waste generation, it is sometimes possible to interfere and to change the process. First question is thereby, to find out if, the hazardous waste is an unwanted by-product or a leftover from old worn out products. Based on this information, a policy towards waste reduction can be developed.

Often, companies refuse to give information about their current hazardous waste production. Even when they are enforced by law the information can be insufficient and biased. In this case, it is a good idea to look for available data from a similar production process. This can help to give a rough estimate about the hazardous waste situation at source. Mainly, three groups of sources for hazardous waste exist:

- **Waste from large producers**
  Large hazardous waste producers are not the focus of this guidelines. Nevertheless, they

should be mentioned because, they produce the biggest absolute amount of hazardous waste. The variety of hazardous waste is extreme. There are waste mixtures that are very difficult to treat, and well defined waste of known compositions.

- **Waste from small producers**
  It is nearly impossible to give an overview about all hazardous wastes, that are produced by small producers. Small producers often, do not know exactly what chemicals they use and what is the compound of their products and waste. Examples of most important kinds of waste and its originating production processes can be found in the handbook (part II). Because of the huge variety and the unknown composition of hazardous waste from small sources, treatment is often quite difficult. An optimal and efficient treatment process can’t be determined easy. Furthermore, the knowledge of waste treatment and handling in small factories is usually rather limited. Often their waste management is more like, that of households.

- **Waste from consumers and households**
  To hazardous waste from small producers are added, the waste from consumers and households. Especially, batteries, accumulators and electronic waste is generated by households in considerable amounts. The biggest source of waste from households are old worn out products. To tackle the problem, an improvement of the collection system is necessary and also, an extended producer responsibility (see section 5.2.3).

What happens with the hazardous waste now?

Next step of data collection is the evaluation of the current situation of waste disposal. This shows the loopholes in the current system and the most relevant issues. It is important to find out how the hazardous materials enter the environment now and how they endanger people. The following aspects are especially, relevant:

- Illegal disposal
- Reuse or recycling on the spot (in the generation company)
- Reuse or recycling through a third party
- Export or transport to other countries or regions
- Treatment and legal disposal

Qualitative and quantitative estimations can show the most urgent fields of action.

Quantifying Volumes and scope of the hazardous waste management

Based on these information about sources, types, ways and with quantified volumes, the scope of needed hazardous waste management can be determined. Thereby, the toxicity and the scope of dangers play an important role. Depending upon the short and long term dangers caused by improperly handled waste, a priority list can be made. To an hazardous waste management belong not only technical, but also economical, legal and organisational aspects. More about these policy issues and waste management can be found in chapter 5.

2.4.3. Hazardous waste in developed countries

The UNEP (United Nation Environment Programme) estimate the yearly amount of hazardous waste of more than 400,000,000 tons. As an interesting fact, data about hazardous waste varies extremely between different sources. As an example taken, the US who seems to be the main generator of hazardous waste on the globe. The official declared amount of hazardous waste for the year 1980 is 250 Mill. tons. On the other side, the EPA (Environmental Protection Agency) calculated after questioning of 12,478 companies from producing industries for the US an overall amount of 747.4 mill ton for 1986 [Watts 1997]. This amount is three times higher than the officially stated amount . This huge divergence that appear not only in the US, shows that, it is very difficult to estimate amounts of generated hazardous waste. Additionally, there are divergences regarding the classification of hazardous waste between different countries and different systems.

Figure: 2-25 gives an overview of especially, environmental dangerous industrial sectors within the European Union. It shows that even industries like food and beverages cause considerable environmental pollution.

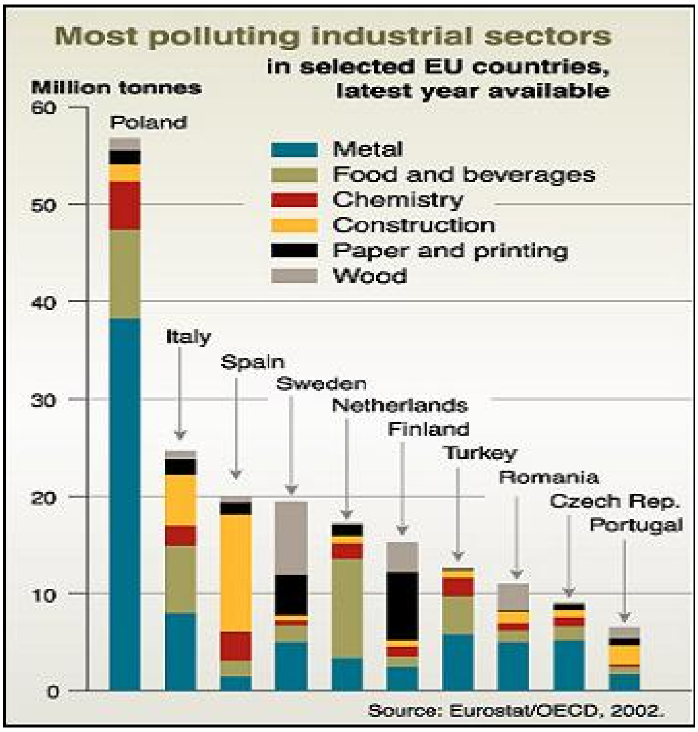


Figure: 2-25 Especially environmentally dangerous industrial sectors in Europe

An overview of different substances that count to hazardous materials are given in Figure: 2-26. With 22 Mill tons Industrial waste accounts to the biggest part. Used oil and base are the second largest group with about 18 mill ton. This is followed by heavy metals, asbestos and acids. Organic compound, especially, dioxin and furan are generated only in small absolute amounts but because of their high toxicity, they are nevertheless, very dangerous.

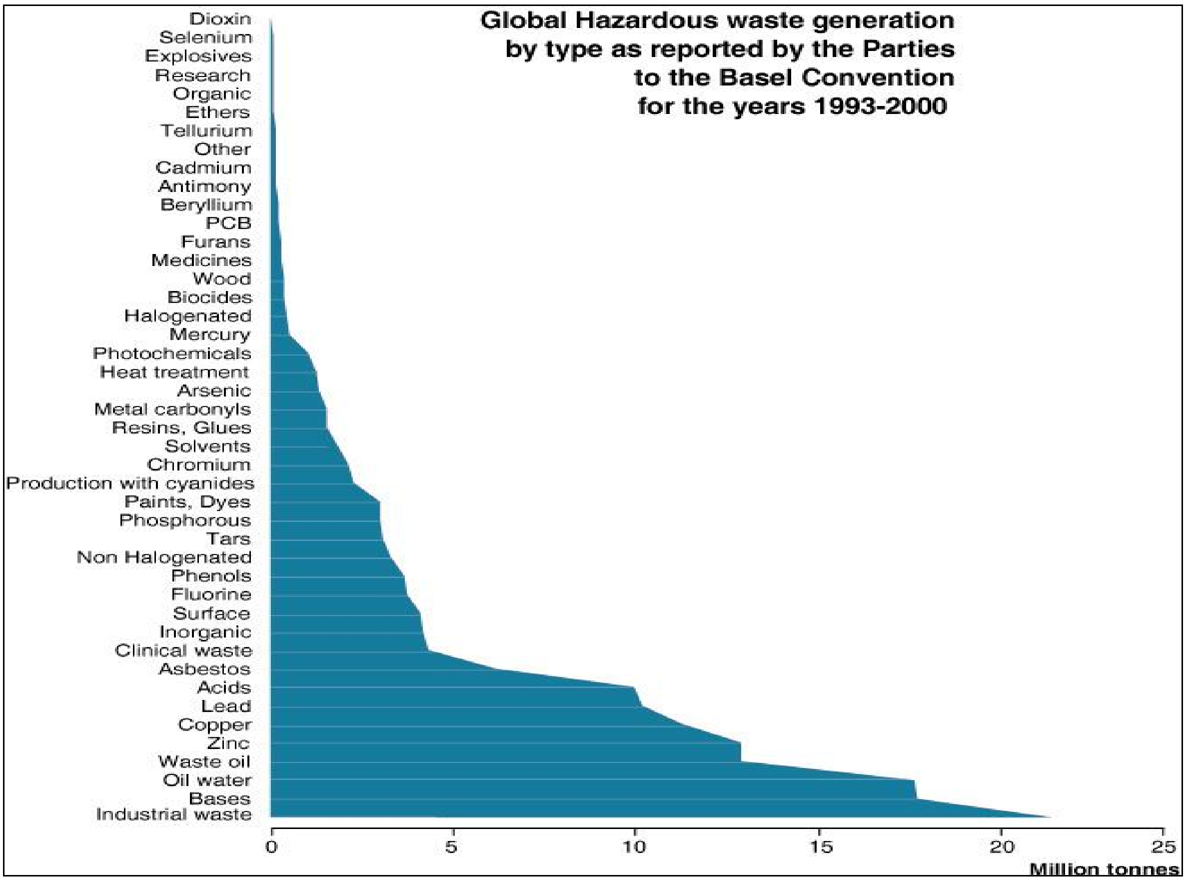


Figure: 2-26 Global hazardous waste generation waste accordingly to different groups[11]

[11] [Basel Convention]

2.4.4. References

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3. Hazardous waste situation in India

3.1. General situation

3.1.1. Hazardous waste producing industries

The most important hazardous waste generating industries in India are [Trade Team 2006]:

- Medical- and Pharmacy industry
- Wreck-Recycling,
- Painting industry,
- Pesticides and Fertilizer industry,
- Oil and oil processing industry,
- Chemical industry,
- Mining.

Thereby chemical industry is the biggest producer of hazardous waste.

The composition of industrial waste in India is changing through changes in industries. In 1990 the amount of slag accrued to about 35 Mill tons per year. Through an shrinking of steel industry nine years later only 7.5 Mill tons per year where produced. Caused by an increased need of energy the amount of fly ash was doubled within this time frame. Also the other industries like paper industry and fertilizer industry increased their waste generation. The overall industrial waste generation was doubled from 1990 to 1999.

In India there are 323 recycling factories for hazardous waste. Thereby 20 of them recycle imported hazardous waste [UNEP 2001, India]. That shows that there is a problem with imported hazardous waste even though it is officially forbidden by the Basel Convention.

3.1.2. Hazardous waste generation in India

In 1984 OECD estimated the amount of hazardous waste in India of about 0.3 Mill ton. Until 1995 it increased up to 4 mill tons. Nowadays it is about 7.2 mill tons. The share of recyclable material is 19.44 %. 72.22 % will be brought to a landfill. Just 1.5 % are treated thermal. Because of the high costs, the technical prerequisites of treatment plants they are not very common in India [CBCB, 2004].

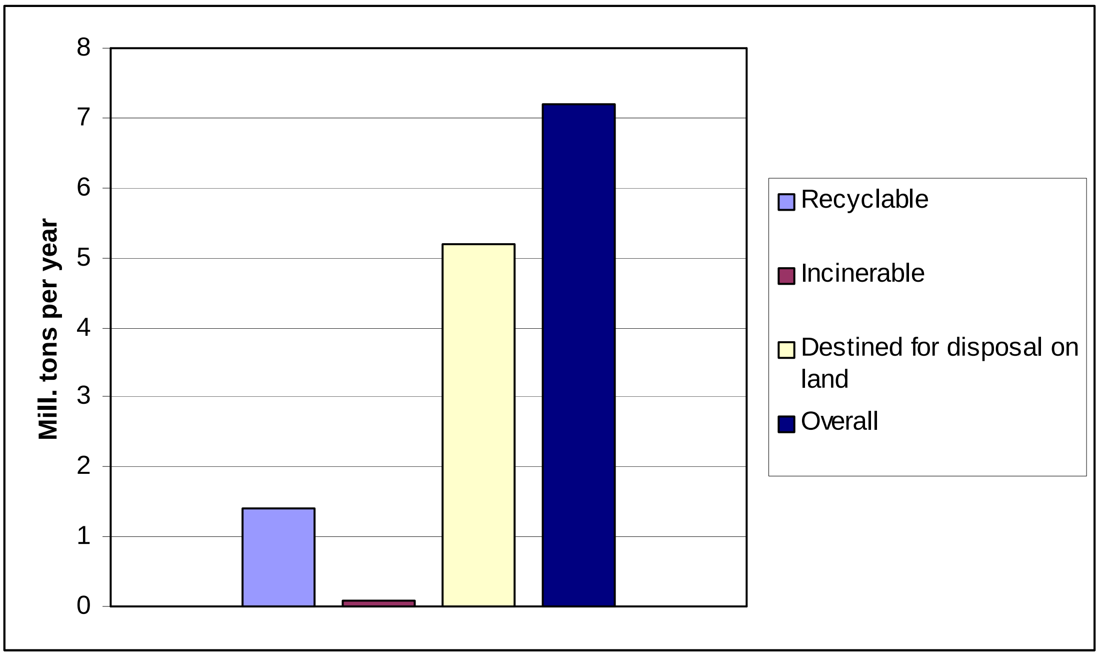

Figure: 3-1 Hazardous waste generation in India[12]

Hazardous waste generation in India varies very much in different states. Table: 3-1 gives an regional overview to hazardous waste generation [UNEP 2001, India]. It states with most amount of generated hazardous waste. This shows that there exist some regions in India where a lot of industries settled that generate huge amounts of hazardous waste. Environmental and health dangers and the need for action is in this regions highest.

Table: 3-1 Regional distribution of hazardous waste generation in 2000

Provinces	Number of hazardous waste generating units	Quantity of waste generated			
		Recyclable	Incinerable	Disposable	Total[13]
Andhra Pradesh	501	61,820	5,425	43,853	111,098
Assam	18	0	0	166,008	166,008
Bihar	42	2151	75	24351	26,577
Chandigarh	47	0	0	305	305
Delhi	0	0	0	0	59,423
Goa	25	873	2,000	3,725	8,742
Gujarat	2,984	26,000	19,953	150,062	430,030
Haryana	309	0	0	31,046	32,559
Himachel Pradesh	116	0	63	2096	2159

[12] [Trade Team 2006]

[13] Total of recyclable, incinerable and disposable will not add up due to waste sold or otherwise disposed.

Karnataka	454	47330	3328	52585	103243
Kerala	151	84932	5069	690014	780015
Maharashtra	3953	847436	5012	1155398	2007846
Madhya Pradesh	183	89593	1309	107767	198669
Orissa	163	2841	0	338303	341144
Jammu und Kashmir	57	0	0	0	1221
Pondicherry	15	8730	120	43	8893
Punjab	700	9348	1128	12233	22745
Rajasthan	306	9487	19866	2242683	2272036
Tamil Nadu	1100	193507	4699	196002	401073
Uttar Pradesh	1020	0	0	0	140146
West Bengal	440	45233	50894	33699	129826

Hazardous waste generation is an economic factor. [Team Trade 2006] estimates the hazardous waste market in 2003 of about 53 Mill Canadian Dollar and an yearly growth of about 7% up to 2010.

3.2. A review of the Legal and Policy Framework

Introduction

This report will attempt to develop a comprehensive framework of the existing legal policies with regard to hazardous waste disposal applicable in India and will consider

1. Statutes and legislations
2. International conventions
3. Indian case law (and those non-Indian judgements as have been followed in Indian judgements).

The first step to be taken when attempting to create a legal framework of hazardous waste disposal policies, is to define hazardous wastes. The problem with such a definition is the rather broad and ever expanding nature of the term.

The scope of this report is not limited to hazardous wastes as specified in the Basel Convention as well as the Hazardous Waste (Management and Handling) Rules, 1989 alone but also includes household wastes, solid wastes, bio-medical wastes, marine and ship wastes, e-wastes, etc; some of which have been excluded from the definitions in the Indian context. Thus, there is a disparity in the definition on the international level (as defined by Basel Convention and other applicable conventions) and the national level (as defined by Hazardous Waste (Management and Handling) Rules, 1989.

Defining hazardous waste

Firstly consider the definition of hazardous wastes as specified in the under Article 2 of the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal, 1989:

> "Wastes" are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

The convention has also included three annexures which complete the definition of "hazardous wastes" by specifying those wastes which shall be considered hazardous. The convention further states that this list is not exhaustive and those substances considered hazardous by national legislations will be recognised by the parties to the convention. However, the convention further states that radioactive wastes and ship wastes, being governed by other international instruments will not be covered by this convention. However, the Convention has included bio-medical wastes, organic and inorganic wastes, electronic wastes, scrap metals and other such materials within its ambit. This ever-expanding definition under the above convention has been accepted by other international agreements.

3.2.1. "Hazardous wastes" in the Indian context

A legal definition of hazardous waste can be found in:

S. 2. (cb) of the Factories Act, 1948,

> "*hazardous process*" means any process or activity in relation to an industry specified to the First Schedule where, unless special care is taken, raw materials used therein or the intermediate or finished products, bye-products, *wastes* or *effluents* thereof would –
>
> (i) cause material impairment to the health of the persons engaged in or connected therewith, or
>
> (ii) result in the pollution of the general environment : Provided that the State Government may, by notification in the Official Gazette, amend the First Schedule by way of addition, omission or variation of any industry specified in the said Schedule;

The word "waste" was further elucidated upon also used in S. 12 of the same Act:

> 12. Disposal of wastes and effluents: (1) Effective arrangements shall be made in every factory for the disposal of wastes and effluents due to the manufacturing process carried on therein.
>
> (2) The State Government may make rules prescribing the arrangements to be made in accordance with sub-section (1) or requiring that the arrangements made in accordance with sub-section (1) shall be approved by such authority as may be prescribed.

Although at the time when this statute was enacted, it was not done in the same spirit as the Environment (Protection) Act, 1986, it is still very important as it discussed effluents, wastes

> and their hazardous nature in keeping with Article 21 of the Constitution which is the founding stone for all environment protection and hazardous waste disposal legislations.

The Environment (Protection) Act, 1986 used the term “hazardous substance” even though it did not refer to “wastes”:

> “hazardous substance” means any substance or preparation which, by reason of its chemical or physico-chemical properties or handling, is liable to cause harm to human beings, other living creatures, plant, micro-organism, property or the environment.

Hazardous wastes was then finally defined by the Hazardous Waste (Management and Handling) Rules, 1989 under S. 3 which states

> “hazardous wastes” means categories of wastes specified in the Schedule.
>
> The schedule lists out a number of chemical, compounds and other wastes than are to be considered as hazardous wastes. The statute further excludes waste water and exhaust gases[14], ship and marine wastes[15] and radioactive wastes.[16]

The Bio-Medical Waste (Management and Handling) Rules, 1998 define “bio-medical wastes” as

> any waste, which is generated during the diagnosis, treatment or immunisation of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals, and including categories mentioned in Schedule I.

The Municipal Solid Waste (Management and Handling) Rules, 1999 define solid wastes as:

> “municipal solid waste” includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes.

The Hazardous Waste (Management and Handling) Amendment Rules 2003 finally developed a definition of the term and went on to define it as

> “hazardous waste” means any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances, and shall include-
>
> (a) wastes listed in column (3) of Schedule-1;

[14] These are governed by the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974) and the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981).

[15] Governed by Merchant Shipping Act, 1958 (44 of 1958).

[16] Governed by Atomic Energy Act, 1962 (33 of 1962).

(b) wastes having constituents listed in Schedule-2 if their concentration is equal to or more than the limit indicated in the said Schedule; and

(c) wastes listed in Lists ‘A’ and ‘B’ of Schedule-3 (Part-A) applicable only in case(s) of import or export of hazardous wastes in accordance with rules 12, 13 and 14 if they possess any of the hazardous characteristics listed in Part-B of Schedule 3”.

Explanation: For the purposes of this clause, -

(i) all wastes mentioned in column (3) of Schedule-1 are hazardous wastes irrespective of concentration limits given in Schedule-2 except as otherwise indicated and Schedule-2 shall be applicable only for wastes or waste constituents not covered under column (3) of Schedule-1;

(ii) Schedule-3 shall be applicable only in case(s) of import or export.

This statute, by subsequent amendments developed the term “hazardous wastes” into a concept which is very similar to the definition under the Basel Convention. In fact, after amendments, this statute has adopted similar criteria as the Basel Convention to identify hazardous wastes, namely,

Explosive, Flammable Liquids, Flammable Solids, Substances or wastes liable to spontaneous combustion, Substances or wastes which, in contact with water emit flammable gases, Oxidizing, Organic Peroxides, Poisons (Acute), Infectious substances, Corrosives, Liberation of toxic gases in contact with air or water, Toxic (Delayed or chronic), Ecotoxic, Capable by any means, after disposal, of yielding another material.

Thus, with time the definition of the same has been ever expanding and evolving, trying to keep up with technological advancements. The concept of electronic wastes has been included in the same fashion as the Basel Convention, and other such previously unthought-of wastes have now been included.

However, it is evident that the existing definition of the term is repetitive and there is no consonance between the various statutes and their provisions. Recent cases of ship-breaking and chemical accidents have further evinced this lack a clearer and wider definition of hazardous waste, and more importantly, a more definite interpretation of the same term by courts.

After a Public Interest Litigation was filed by the Research Foundation for Science, Technology and Natural Research Policy alleging that illegal imports of hazardous wastes were happening in port areas the Supreme Court intervened, resulting in the setting up of the High Powered Commission headed by Menon in 1997. This Commission after considering all the data available on the subject came out with the following definition of the term:

Any substance, whether in solid, liquid or gaseous form, which has no foreseeable use and which by reasons of any physical, chemical, reactive, toxic, flammable, explosive, corrosive, radioactive or infectious characteristics causes danger or is likely to cause danger to health or

> environment, whether alone or when in contact with other wastes or environment, and should be considered as such when generated, handled, stored, transported, treated and disposed of. This definition includes any product that releases hazardous substance at the end of its life, if indiscriminately disposed of.

Now that a comprehensive legal definition of the term within the existing framework has been established, the existing legislations that deal with hazardous waste, solid waste and all other forms of waste that may be understood in this context to fall under the umbrella of hazardous waste shall be examined.

3.2.2. Existing statutes which deal with hazardous wastes

Environment (Protection) Act, 1986:

This statute was the first statute to introduce the concept of hazardous substances with regard to the environment specifically. Although previous statutes have dealt with hazardous wastes, none of them spoke of damage to the environment specially and it is under this statute that all the further provisions that deal with hazardous wastes have been created. This Act was enacted probably as a reaction to the Bhopal Gas Disaster. This legislation was made to serve as a general thumb rule while providing for the creation of more specific guidelines to deal with the various environmental problems. S. 4 of the Act lists out the powers and functions of the Central Government which give it the power to make rules with regard to hazardous wastes (in the present context):

> (1) Subject to the provisions of this Act, the Central Government, shall have the power to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing controlling and abating environmental pollution.

Further, the Act also provides under the same Section,

> (3) The Central Government may, if it considers it necessary or expedient so to do for the purpose of this Act, by order, published in the Official Gazette, constitute an authority or authorities by such name or names as may be specified in the order for the purpose of exercising and performing such of the powers and functions (including the power to issue directions under section 5) of the Central Government under this Act and for taking measures with respect to such of the matters referred to in sub-section (2) as may be mentioned in the order and subject to the supervision and control of the Central Government and the provisions of such order, such authority or authorities may exercise and powers or perform the functions or take the measures so mentioned in the order as if such authority or authorities had been empowered by this Act to exercise those powers or perform those functions or take such measures.

Further, with specific relevance to hazardous substances the Act lays down under S. 6 that

(c) the procedures and safeguards for the handling of hazardous substances;

(d) the prohibition and restrictions on the handling of hazardous substances in different areas;

Also, under S. 8 it is laid down as

8. Persons handling hazardous substances to comply with procedural safeguards: No person shall handle or cause to be handled any hazardous substance except in accordance with such procedure and after complying with such safeguards as may be prescribed.

Finally, the Act further goes on to give wide powers to the Central Government with regard to complaints under this Act, where without the permission of the Government, no court can take cognizance of the offence (S. 19). Also, no civil court can entertain a suit under this Act (S. 22). The rules and orders made under this Act override all other existing legislation, except with regard to punishment where the other legislation will prevail (S. 24). The Act also vests in the Central Government the power to make rules in accordance with S. 25, but these rules shall be laid before each house of the Parliament for consideration (S. 26). The government can delegate it powers of making rules under S. 25 to State Governments or any other authority subject to any rules or regulations (S. 23).

Environment (Protection) Rules, 1986:

This legislation was created by the exercise of Ss. 6 and 25 of the Environment (Protection) Act, 1986 and specifies the role of Central and State Pollution Board echoing the provisions of the aforementioned Act while creating specific duties upon the Central Government and specifying threshold limits for pollutants and other such guidelines. The stature makes a specific mention of hazardous substances:

13. Prohibition and restriction on the handling of hazardous substances in different areas:

(1) The Central Government may take into consideration the following factors while prohibiting or restricting the handling of hazardous substances in different area is-

(i) The hazardous nature of the substance (either in qualitative or quantitative terms as far as may be) in terms of its damage causing potential to the environment, human beings, other living creatures, plants and property;

(ii) the substances that may be or likely to be readily available as substitutes for the substances proposed to be prohibited or restricted;

(iii) the indigenous availability of the substitute, or the state of technology available in the country for developing a safe substitute;

(iv) the gestation period that may be necessary for gradual introduction of a new substitute with a view to bringing about a total prohibition of the hazardous substance in question; and

(v) any other factor as may be considered by the Central Government to be relevant to the protection of environment.

(2) While prohibiting or restricting the handling of hazardous substances in an area including their imports and exports the Central Government shall follow the procedure hereinafter laid down-

(i) Whenever it appears to the Central Government that it is expedient to impose prohibition or restriction on the handling of hazardous substances in an area, it may, by notification in the Official Gazette and in such other manner as the Central Government may deem necessary from time to time, give notice of its intention to do so.

(ii) Every notification under clause (i) shall give a brief description of the hazardous substances and the geographical region or the area to which such notification pertains, and also specify the reasons for the imposition of prohibition or restriction on the handling of such hazardous substances in that region or area.

(iii) Any person interested in filing an objection against the imposition of prohibition or restrictions on the handling of hazardous substances as notified under clause (i) may do so in writing to the Central Government within sixty days from the dale of publication of the notification in the Official Gazette.

(iv) The Central Government shall within a period of ninety days from the date of publication of the notification in the Official Gazette consider all the objections received against such notification and may impose prohibition or restrictions on the handling of hazardous substances in a region or an area.

Hazardous Wastes (Management and Handling) Rules, 1989:

This was the first statute created as response to the hazardous waste problem, nationally and internationally. It was created as a response to the Basel Convention and echoes many of the latter's provisions. It was also created in the exercise of Ss. 6, 8 and 25 of the Environment (Protection) Act, 1986. This legislation has two functions, one dealing with the disposal and handling of hazardous wastes nationally and secondly with regard to the import and export of hazardous wastes and their *transboundary movement*[17] which deals with international law. This statute also serves as a cementing of the provisions of the Basel Convention in India.

[17] R. 3 of the Rules define transboundary movement as any movement of hazardous wastes or other wastes from an area under the national jurisdiction of one country to or through an area under the national jurisdiction of another country or to or through an area not under the national jurisdiction of any country, provided at least two countries are involved in the movement.

Under the first function, the Rules provide for the collection, handling, storage and disposal of the hazardous wastes. Under S. 4 of the Rules, the duty is upon the occupier or the producer/owner of the hazardous waste to see to its disposal and handling as per the regulation and authority of the State Pollution Control Board (SPCB):

> 4. Responsibility of the occupier for handling of wastes:
>
> (1) The occupier generating hazardous wastes listed in column (2) of the Schedule in quantities equal to or exceeding the limits given in column (3) of the said Schedule, shall take all practical steps to ensure that such wastes are properly handled and disposed of without any adverse effects which may result from such wastes and the occupier shall also be responsible for proper collection, reception, treatment, storage and disposal of these wastes either himself or through the operator of a facility.
>
> (2) The occupier or any other person acting on his behalf who intends to get his hazardous waste treated by the operator of a facility under sub-rule (1), shall give to the operator of a facility, such information as may be specified by the State Pollution Control Board.

Every occupier generating hazardous wastes must either own or have access to a facility for collection, reception, treatment, transport storage and disposal of such wastes without which he will not be granted permission to handle hazardous wastes (R. 5). This facility must meet with the specifications laid down by the SPCB not satisfying which, the SPCB can withhold, suspend or cancel authorisation (R. 6). R. 7 states that the hazardous material must be suitably labelled and packed under any existing specification by the Central Government. The occupier is also under the duty of identifying a suitable area (subject to the approval of the SPCB) for disposal of the waste material (R. 8).

R. 11 lays down very clearly, echoing the Basel convention that no waste can be imported for the purposes of dumping and disposal. Import is permitted only if the waste is to be recycled and reused as raw material and this also, only upon examining the merit of such use by the SPCB.

Hazardous Waste (Management and Handling) Amending Rules, 2000:

In this amending legislation, many changes were made to the original Rules. Rule 4 was altered by substituting the following to sub-rule 1:

> (1) The occupier and the operator of a facility shall be responsible for proper collection, reception, treatment, storage and disposal of hazardous wastes listed in Schedule 1, 2 and 3.

The following was added:

> (3) It shall be the responsibility of the occupier and the operator of a facility, to take all steps to ensure that the wastes listed in schedules 1, 2 and 3 are properly handled, and disposed of without any adverse effects to the environment.

Other major changes in the Rules included the specifications for the packaging under Rule 7, as well as making an Environment Impact Assessment necessary when finding a suitable disposal site by the state Government, operator of a facility or association of occupiers.

Another important change is under R. 11 where the words “dumping *and* disposal” was changed to “dumping *or* disposal”.

The following provision was also added

> 12. Import and Export of Hazardous Wastes for recycling and reuse: (1) Import and/or export of hazardous wastes rule *3(i)(c)* shall only be permitted as raw material for *recycling* or reuse.
>
> Another major change to this rule was that the Ministry of Environment and Forests became the nodal authority for import of hazardous waste and confirmed that for all transboundary movement, the Basel Convention shall be complied with.
>
> 13. Import of Hazardous Waste: (1) Every occupier importing hazardous waste shall apply to the State Pollution Control Board, one hundred twenty days in advance in Form-6 for permission to import along with a minimum fee of rupees thirty thousand payable to Ministry of Environment and Forests, Govt. of India for *imports up to five hundred metric tonnes* and for every *additional* five hundred metric tonnes *or part thereof of waste imported an additional sum of rupees five thousand will be payable.*

This above provision has been critics as it has created a loophole for the import of hazardous wastes for a paltry sum when compared to the profits to be made from this industry.

Another major addition is

15. Illegal Traffic: (1) The movement of hazardous wastes from or to the country shall be considered illegal:

> i. if it is without prior permission of the Central Government; or
>
> ii. if the permission has been obtained through falsification, misrepresentation or fraud; or
>
> iii. it does not conform to the shipping details provided in the document;

(2) In case of illegal movement, the hazardous wastes in question;

> i. shall be shipped back *within thirty days* either to the exporter or to the exporting country;
>
> ii. shall be disposed of within thirty days from the date of off-loading *subject to inability to comply with Sub-rule 2(i) above.*
>
> 1. In case of illegal transboundary movement of hazardous wastes, the occupier exporting hazardous waste from the country or the exporter exporting hazardous waste to the country and importer importing hazardous waste into the country shall ensure that the wastes in

question is safely stored and shipped or disposed off in an environmentally sound manner within thirty days from the date of off-loading;

2. The exporting country shall bear the costs incurred for the disposal of such wastes.

1. Liability of the occupier, *transporter* and operator of a facility:

(1) The occupier, *transporter* and operator of a facility shall be liable for damages caused to the environment resulting due to improper handling and disposal of hazardous waste listed in schedule 1, 2 and 3;

1. The occupier and operator of a facility shall also be liable to reinstate or restore damaged or destroyed elements of the environment;

2. The occupier and operator of a facility shall be liable to pay a fine as levied by the State Pollution Control Board *with the approval of* the Central Pollution Control Board for any violation of the provisions *under* these rules.

Finally, with regard to appeal, the following rule is now applicable:

18. Appeal - (1) An appeal shall lie, against any order of grant or refusal of an authorisation by the Member-Secretary, State Pollution Control Board or any officer designated by the Board to the Secretary, Department of Environment of the State Government by whatever name called.

1.Every appeal shall be in writing and shall be accompanied by a copy of the order appealed against and shall be presented within thirty days of the receipt of the order passed.

Hazardous Waste (Management and Handling) Amending Rules, 2003:

A significant change made to the Rules by this amending order, was that a concise definition of hazardous waste was developed as illustrated before.

Under rule 8, with regard to disposal sites, the amending rule makes the state government, owner of a facility or association of occupiers jointly and severally responsible for the identification and use of the disposal site.

Another important addition to the Rule 16 which places the burden of compensation upon the occupier, following the polluter pays principle:

(2) The occupier and operator of a facility shall also be liable to reinstate or restore damaged or destroyed elements of the environment at his cost, failing which the occupier or the operator of a facility, as the case may be, shall be liable to pay the entire cost of remediation or restoration and pay in advance an amount equal to the cost estimated by the State Pollution Control Board or Committee. Thereafter, the Board or Committee shall plan and cause to be executed the programme for remediation or restoration. The advance paid to State Pollution Control Board or Committee towards the cost of remediation or restoration shall be adjusted once the actual cost

of remediation or restoration is finally determined and the remaining amount, if any, shall be recovered from the occupier or the operator of the facility.

Rule 19, which has been added by the amending Rules, gives wide powers to the CPCB with regard to registration of recyclers and refiners and renewal of the same. However, the CPCB is required to receive a compliance report from the applicants and proof of the same, along with proof that the recycling facilities meet stipulated standards.

Rule 20 is another important addition which creates certain threshold limits for auction and sale of wastes for recycling. It has created 10 tons as a threshold limit, below which the provisions of the same do not apply i.e the sub rule requires that if wastes are more than 10 tons, they must be sold to a registered recycler only, implying that 9 tons and less need not be sold to the same, neither is it applicable to all wastes except those specified.

Rule 21 specifies the technological requirements for recycling or refining and stresses on the need for “environmentally sound technologies” which shall be dealt with later.

Finally, the amending statute has made changes and revised the schedules to the existing Rules and has added a list of “hazardous characteristics” of wastes, as well as a list of authorities and their corresponding duties.

Overall, the Hazardous Waste Rules has greatly evolved from its original structure and has gone on to include many important provisions and has refined many vague concepts and definitions. However, some procedural loopholes remain, more to do with threshold limits set by the statute nonetheless, the statute has with every amendment become more inclusive and broad, taking into account technological advancements.

Batteries (Management and Handling) Rules, 2001:

This statute deals specifically with batteries,[18] which has been considered in the present instance as batteries form a great part of hazardous wastes and even though it has not been specifically dealt with by the Hazardous Waste (Management and Handling) Rules, 1989, it would fall within the meaning of hazardous waste as lead is a major source of pollution and has been included in the Hazardous Waste (Management and Handling) Rules, 1989, and therefore logically lead wastes from batteries should also be considered as hazardous wastes. Possibly, the legislators created a specific statute for lead batteries itself because of the care and specific guidelines required for disposing off lead batteries and the fact that it is not an industrial waste, but is used by households and commercially. This, therefore puts lead batteries in the middle- it cannot be covered by the Municipal Solid Waste Disposal Rules because lead wastes are hazardous and therefore, a separate legislation was possibly created.

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[18] R. 3 of the rules defines 'battery' as lead acid battery which is a source of electrical energy and contains lead metal.

The main feature of the Rules is that it imposes a duty upon the manufacturer, importer, assembler and re-conditioner with regard to safety, handling, awareness and disposal of batteries. R. 4 states the duties of the above:

(i) ensure that the used batteries are collected back as per the Schedule against new batteries sold excluding those sold to original equipment manufacturer and bulk consumer(s);

(ii) ensure that used batteries collected back are of similar type and specifications as that of the new batteries sold;

(iii) file a half-yearly return of their sales and buy-back to the State Board in Form- I latest by 3e June and 3 0 December of every year;

(iv) set up collection centres either individually or jointly -at various places for collection of used batteries from consumers or dealers;

(v) ensure that used batteries collected are sent only to the registered recyclers,

(vi) ensure that necessary arrangements are made with dealers for safe transportation from collection centres to the premises of registered recyclers ;

(vii) ensure that no damage to the environment occurs during transportation;

(viii) create public awareness through advertisements, publications, posters or by other means with regard to the following

a) hazards of lead;

b) responsibility of consumers to return their used batteries only to the dealers or deliver at designated collection centres; and

c) addresses of dealers and designated collection centres.

(ix) use the international recycling sign on the Batteries;

(x) buy recycled lead only from registered recyclers; and

(xi) bring to the notice of the State Board or the Ministry of Environment and Forests any violation by the dealers.

A similar responsibility is laid on the dealer to ensure safe collection and handling of used batteries under R. 7. Rule 8 lays a different sort of responsibility on the recycler of batteries, where it is his duty to spread awareness to the general public about the hazards of lead and used batteries. R. 10 makes the consumer responsible to the extent that he must dispose off the batteries in a safe manner as prescribed by the manufacturer or the local authority (SPCB, which is required to file a compliance status report to the CPCB every year).

Thus, this statute makes the various parties involved in the transaction of lead batteries at every stage responsible at different degrees, but nonetheless involved in the process of waste disposal.

Municipal Solid Wastes (Management and Handling) Rules, 2000:

This statute deals with the disposal of municipal- household and commercial wastes and includes a wide range of materials and processes excluded by other statutes. These rules are important as hazardous wastes are not created only by industries- many highly hazardous materials are disposed off daily by households and commercial establishments like paints, varnishes and other potentially toxic materials.

This statute is important as it also introduces the concept of segregation[19] of wastes within the ambit of wastes. The importance of this statute is that it recognizes the dangers of household wastes, the dangers improper landfills which could result in pollution of groundwater and general standard of living of all people in urban areas, including slum areas which receive a specific mention in the Schedule.

> “Biodegradable waste” is defined by the Rules as a substance that can be degraded by micro-organisms. Municipal solid waste is defined by the same as commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes.

In the present instance the main duty lies upon the municipal authority and not any private body. R. 4 (1) states

> (1)Every municipal authority shall, within the territorial area of the municipality, be responsible for the implementation of the provisions of these rules, and for any infrastructure development for collection, storage, segregation, transportation, processing and disposal of municipal solid wastes.

R. 5 states that the State Government shall have he final overall responsibility with regard to solid waste disposal. While R. 6 lays down the duty of the SPCBs and CPCB which is to check the compliance status of the disposal activities as well as grant authorization for suitable landfills etc. The CPCB is charged with the duty to oversee and organize the State Boards.

The compliance criteria include:

1.Setting up of waste processing and disposal facilities

2.Monitoring the performance of waste processing and disposal facilities

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[19] “Segregation” is defined by the Rules: to separate the municipal solid wastes into the groups of organic, inorganic, recyclables and hazardous wastes.

3.Improvement of existing landfill sites as per provisions of these rules

4.Identification of landfill sites for future use and making site(s) ready for operation.

It is also interesting to note that the schedule to the Rules which lays down the guidelines for management of municipal wastes prohibits manual handling of waste and in unavoidable circumstances protective gear must be provided.

Two very important cases have come up in the Supreme Court with regard to municipal wastes and some very important duties of the municipal bodies were specified.

In the first case, *Dr. B.L. Wadehra v. Union of India and Others*[20] the court held that it was the duty of the municipal body to maintain standards of cleanliness, despite the fact that "It is highlighted in the affidavit that about 45% of the total population of Delhi is living in slums, unauthorised colonies and clusters. There are about 4, 80,000 jhuggies in Delhi. According to a rough estimate about 6 persons stay in each jhuggi. They throw their garbage on the road on nearby dustbins." The obligatory functions of the body are specified in the Delhi Municipal Act under S. 42. Thus, the municipal body has to use any means necessary to achieve levels of cleanliness and hygiene.

In the case of *Almitra H. Patel and Another v. Union of India and Ors.*[21] the court observed that, "Domestic garbage and sewage is a large contributor of solid waste. The drainage system in a city is intended to cope and deal with household effluent. This is so in a planned city. But when a large number of inhabitants live in unauthorised colonies, with no proper means of dealing with the domestic effluents, or in slums with no care for hygiene the problem becomes more complex." Similar to the latter case, the court held that it was the duty of the Municipal corporation to "ensure that the relevant provisions of the Municipal Corporation of Delhi Act, 1957, New Delhi Municipal Council Act, 1994 and the Cantonments Act, 1924 relating to sanitation and public health prohibiting accumulation of any rubbish, filth, garbage or other polluted obnoxious matters in any premises and/or prohibiting any person from depositing the same in any street or public place shall be scrupulously complied."

Although it is disturbing that the courts have considered the problems of slum dwellings as the major source of solid waste and garbage, it is to be noted that the courts have not considered this as an excuse for the Municipal corporation from not performing their duty.

Bio-Medical Waste (Management and Handling) Rules, 1998:

Although bio-medical waste is recognized by all relevant statutes as hazardous waste, the instant legislation has an overriding effect on all others (which acknowledge this fact). This is because of the

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[20] (1996)2 SCC 594.

[21] (2000)2 SCC 166.

dangerous nature of bio-medical wastes and effects it may have are very different from other chemical or scrap wastes.

The duty of correct disposal of bio medical wastes rests on the occupier of a facility which creates bio medical waste. The occupier is responsible for treatment, disposal, segregation, transportation, packaging and storage as prescribed by the concerned authority. In the case of bio medical wastes, the authority does not lie in the CPCB or SPCB, but the State governments are required to create an authority or a body which will oversee the correct disposal. The Rules also lay down standard colour codes, symbols, processes of disposal and tests to be conducted and other such standards

It is also pertinent to note that treated bio medical waste can be treated as municipal solid waste under the Municipal Solid Wastes (Management and Handling) Rules, 2000 but the present statute has an overriding effect upon the former.

Bio-Medical Waste (Management and Handling) Amendment Rules, 2003:

this statute makes some very important changes. Firstly, an additional responsibility is laid on the enforcing authority under Rule 7 (1)

> (1A). The prescribed authority for enforcement of the provisions of these rules in respect of all health care establishments including hospitals, nursing homes, clinics, dispensaries, veterinary institutions, Animal houses, pathological laboratories and blood banks of the Armed Forces under the Ministry of Defence shall be the Director General, Armed Forces Medical Services.

Another very important change is that the Ministry of Defence has been made a concerned authority as well under this statute and the same shall constitute an Advisory committee with regard to all health care facilities run by the Armed forces. Interestingly, this statute was established under the Environment (Protection) Act, 1986 and does not ordinarily concern the Ministry of Defence.

Recycled Plastics Manufacture and Usage Rules, 1999:

This statute lays down guidelines with regard to plastic bags especially in the context of foodstuffs and regulations for the same. Plastics should also fall within the purview of hazardous wastes, because of its non-biodegradable nature and the extent to which it has perpetrated households and common usage. Thus, a separate Act to govern plastics is not only in order but also necessary because of the above reason. However, this Act should be applicable along with the Municipal Solid Wastes Disposal Rules which also obliquely deal with plastics, as it deals with segregation of organic and inorganic wastes. It must be noted, however, that this instant statute does not deal with disposal of plastics as wastes, but deals with recycling guidelines. Therefore the above mentioned statute should be used for guidelines with regard to plastic disposal.

4. Prohibition of usage of carry bags -or containers made of recycled plastics: No vendor shall use carry bags or containers made of recycled plastics for storing, carrying, dispensing, or packaging of foodstuffs.

5. Conditions of Manufacture of carry bags and containers, made of plastics: Subject to the provisions of rule 4, any person may manufacture carry bags or containers made of plastics if the following conditions are satisfied, namely-.

(a) Carry bags and containers made of virgin plastic shall be in natural shade or white;

(b) Carry bags and containers made of recycled plastic and used for purposes other than storing and packaging foodstuffs shall be manufactured using pigments colourants as per IS:9833:1981 entitled "List of pigments and colourants for use in plastics in contact with foodstuffs, pharmaceuticals and drinking water".

6. Recycling: Recycling of plastics shall be undertaken strictly in accordance with the Bureau of Indian Standards specification: IS 14534: 1998 entitled "The Guidelines for Recycling of Plastics".

The above rules sum up the gist of the statute which also specifies that the minimum thickness of a bag made of virgin plastic or recycled plastic shall not be less than 20 microns. It also states that the Plastic Industry Association shall have the power to make self regulatory rules.

Manufacture, Storage and Import of Hazardous Chemical Rules, 1989:

This statute defines a very important term- "Threshold quantity" means,-

(i) in the case of a hazardous chemical specified in Column 2 of Schedule 2, the quantity of that chemical specified in the corresponding entry in Columns 3 & 4;

(ii) in the case of hazardous chemical specified in Column 2 of Part I of Schedule 3, the quantity of that chemical specified in the corresponding entry in Columns 3 & 4 of that part;

(iii) in the case of substances of a class specified in Column 2 of Part 11 of Schedule 3, the total quantity of all substances of that class specified in the corresponding entry in Column 3 & 4 of that part.

This statute is self explanatory and specifies the duties of the occupier of a facility with regard to chemicals which are potentially hazardous substances that can have far reaching implications.

4. General responsibility of the occupier during industrial activity: (1) This rule shall apply to,-

(a) an industrial activity in which a hazardous chemical, which satisfies any of the criteria laid down in Part I of Schedule I and is listed in Column 2 of Part II of this Schedule is or may be involved; and

(b) isolated storage in which there is involved a threshold quantity of a hazardous chemical listed in Schedule 2 in Column 2 which is equal to or more than the threshold quantity specified in the Schedule for that chemical in Column 3 thereof.

(2) An occupier who has control of an industrial activity in term of sub-rule (I) shall provide evidence to show that he has,-

(a) identified the major accident hazards; and

(b) taken adequate steps to -

(i) prevent such major accidents and o limit their consequences to persons and the environment;

(ii) provide to the persons working on the site with the information, training and equipment including antidotes necessary to ensure their safely.

The Rules also has guidelines for notification of a major chemical accident, the selection of sites, annual reports of compliance which are very important in this field, and most importantly deals with import of hazardous chemicals. An important difference to note is that the Hazardous Waste (Management and Handling) Rules, 1989 deal with hazardous wastes while the present statute deals with import of hazardous chemicals which are very different but the present statute has been included in this inventory because of the link between the two concepts and the potential hazards of the same. This statute does not ban import of hazardous chemicals but only lays down guidelines for their transport, possible occurrence of accidents etc (Rule 18).

Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996:

The Bhopal Gas Tragedy and the many other accidents have shown the necessity for a statute that will ensure preparedness when a chemical accident occurs. According to R. 3 of the Rules, “Chemical accident” means an accident involving a fortuitous, or sudden or unintended occurrence while handling any hazardous chemicals resulting in continuous, intermittent or repeated exposure to death, or injury to, any person or damage to any property but does not include an accident by reason only of war or radio-activity.

This statute provides for the establishment of a Central Crisis system which shall make stipulations etc and manage chemical accident occurrences (R. 3).

R. 4 provides for a more specific Central Crisis Group which is the nodal organization for chemical accident situations. They shall set up a control room, take steps to ensure action upon the occurrence of such an accident, and create awareness about such hazards. Other duties include continuous monitoring of the situation, preparedness against the occurrence and preparing progress reports with regard to the clean up process.

The statute also provides for setting up District and Local Crisis Groups which shall perform similar functions and are set up for actions of an urgent or emergency nature as well as provide safety information to the public.

Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro-Organisms Genetically Engineered Organisms or Cells, 1989:

This statute deals with “micro-organisms” that include all the bacteria, viruses, fungi, mycoplasma, cells lines, algae, protodones and nematotes indicated in the schedule and those that have not been presently known to exist in the country or not have been discovered so far.

It controls and organizes the same, with the enforcing authority which are the Recombinant DNA Advisory Committee (IXDAC), Review Committee on Genetic Manipulation (RCGM), Institutional Bio-safety Committee (IBSC), Genetic Engineering Approval Committee (GE.AC), State Biotechnology Co-ordination Committee (SBCC) and the District Level Biotechnology Committee (DLC). Although the CPCB does not play a part here, theses Committees must work in close consonance with the Ministry of Environment and Forests as the environmental impact of genetic research and hazardous micro-organisms is large.

The following Rule forms the crux of the statute as it lays down duties and liabilities of various parties.

> 7. Approval and Prohibitions etc.
>
> (1) No person shall import, export, transport, manufacture, process, use or sell any hazardous micro organisms of genetically engineered organisms/substances or cells except with the approval of the Genetic Engineering Approval Committee.
>
> (2) Use of pathogenic micro-organisms or any genetically engineered organisms or cells for the purpose of research shall only be allowed in laboratories or inside laboratory area notified by the Ministry of Environment and Forests for this purpose under the Environment (Protection) Act, 1986.
>
> (3) The Genetic Engineering Approval Committee-shall give directions to the occupier to determine or take measures concerning the discharge of micro organisms/genetically engineered organisms or cells mentioned in the Schedule from the laboratories, hospitals and other areas including prohibition of such discharges and laying down measures to be taken to prevent such discharges.
>
> (4) Any person operating or using genetically engineered organisms/micro-organisms mentioned in the schedule for scale up or pilot operations shall have to obtain license issued by the Genetic Engineering Approval Committee for any such activity. The possessor shall have to apply for license in prescribed proforma.

> (5) Certain experiments for the purpose of education within the field of gene technology or micro organism may be carried out outside the laboratories and laboratory areas mentioned in sub-rule (2) and will be looked after by the Institutional Bio-Safety Committee.

Apart from the above, the Rules also provide for guidelines for grant of approval, emergencies and accidents, as well as penalties for intentional or unintentional contravention of the Rules.

Public Liability Insurance Act, 1991:

This Act could also be said to be a reaction to the many chemical disasters and industrial accidents that have occurred over the years. S. 2 (a) of the Act defines “accident” as

> involving a fortuitous or sudden or unintended occurrence while handling any hazardous substance resulting in continuous or intermittent or repeated exposure to death of, or injury to, any person or damage to any property but does not include an accident by reason only of war or radio-activity.

The main thrust of this statute is that it places no-fault liability upon the owner of the facility in case of an accident, as is obvious from the above definition of accident. Further, S. 3 of the Act say:

> 3. Liability to give relief in certain cases on principle of no fault.--(1) Where death or injury to any person (other than a workman) or damage to any property has resulted from an accident, the owner shall be liable to give such relief as is specified in the Schedule for such death, injury or damage.
>
> (2) In any claim for relief under sub-section (1) thereinafter referred to in this Act as claim for relief), the claimant shall not be required to plead and establish that the death, injury or damage in respect of which the claim has been made was due to any wrongful act, neglect or default of any person.

However, a loophole in this statute is that the central government may exempt the state and central governments and corporations governed by them from such a liability. This may be in exercise of sovereign immunity, but in a country where so many profit making corporations are owned by the government, such a provision is unproductive.

3.2.3. Other Relevant Legislations:

Water (Prevention and Control of Pollution) Act, 1974:

This deals with the conservation of water resources, and checking the dumping of hazardous effluents into water sources and seepage into water tables etc.

Atomic Energy Act, 1962:

This deals with the treatment and handling of radioactive wastes.

S. 11 of Customs Act, 1962:

is also of relevance as it deals with exportation of good and government control with regard to those goods that are of a harmful nature.

> 11. Power to prohibit importation or exportation of goods:
>
> (1) If the Central Government is satisfied that it is necessary so to do for any of the purposes specified in sub-section (2), it may, by notification in the Official Gazette, prohibit either absolutely or subject to such conditions (to be fulfilled before or after clearance) as may be specified in the notification, the import or export of goods of any specified description.
>
> (k) the protection of human, animal or plant life or health;
>
> (m) the conservation of exhaustible natural resources
>
> (r) the implementation of any treaty, agreement or convention with any country

3.2.4. Problems within the existing legal framework

1. One of the main components missing within the hazardous waste law framework is the absence of suitable legislation for electronic waste disposal. Undoubtedly, it was included in the more recent amendment to the Hazardous Waste Management Rules, but mere addition is not sufficient. No specific guidelines or duties have been created with regard to this area, nor has there been any legislation with regard to recycling of the same.
   It would be relevant to note that there has been no mention of electromagnetic wastes, and wastes generated from electricity. Undoubtedly this has not been recognised by the Basel convention either, but the Basel Convention is not meant to be an exhaustive list applicable to all countries by itself. It encourages countries to explore areas of research and include other potentially dangerous substances within its fold.

2. Although “explosive” substances have been classified as hazardous, there has been no specific mention of *Diwali* firecrackers and pyrotechnics, which is a major cause for pollution every year. The Indian Explosives Act is silent on this regard, and since the basic legislative

framework already exists, ordinances need to be passed to combat the massive amount of waste and pollution generated annually.

3. Many of the statutes have created a minimum threshold, whereby any waste product below a certain weight or volume will not be governed by the statute. This provision fails to take into account the fact that some of these materials are hazardous per se and secondly there is no statistical data to show that these substances are *not* major sources of waste coming from many sources, not necessarily from few sources.

4. Too many powers are granted to some agencies and there is no proper procedure to ensure that these agencies are performing their function satisfactorily. Undoubtedly, there must be room for some official discretion but where there are such laws, there must also be a mechanism within this legislative framework to keep the authority in check as they perform the biggest role in efficient waste disposal policy making.

5. There is a significant absence of any mention of the armed forces in all the above statutes. Even though they have not been explicitly excluded, there is no indication that these statutes apply to military activities. As of today, there is no specific policy dealing with the kind of hazardous waste generated by military activities and all ecological conservation is at micro-level [Rao 2005], On the other hand, the United States Department of Defence actually does possess an environmental policy, especially with regard to treatment, storage and disposal of hazardous wastes.

   The increasing amount of defence-related wastes has become a major reason for concern, causing the International Standards Organisation (ISO) to adopt an industry standard for environmental protection system called EMS, ISO 14001. It is a voluntary EMS standard that provides a framework to move from reactive and fragmented responses to environmental issues common to compliance based environmental programmes. At the same time the framework provides for a proactive approach that facilitates early identification of impacts, liabilities and opportunities.[22] This standard has been adopted by the US Department of Defence as well as the Australian Defence Forces. It has been suggested that the Indian Defence forces also adopt the same standard, considering the enormous part they have with regard to hazardous wastes.

[22] *ibid.*

3.2.5. International Conventions Applicable in India

Basel Convention on the Control of Tranboundary Movement of Hazardous Wastes and their Disposal, March 1989

This Convention was adopted because of the growing global concerns over hazardous waste disposal and the many international issues involved as well. As the hazardous waste recycling industry is a thriving industry in the developing countries, many other countries proceeded to send their wastes to these countries and "dump" them for far lesser costs than safely disposing it in their own country and also, the lack of stringent disposal laws made this easier in developing countries. Thus, the Basel Convention aims at two parallel processes- decrease the amount of hazardous wastes by adopting environmentally sound technologies and other methods and also to prevent the import and export of hazardous wastes and stop the exploitation of developing countries in this sphere.

The convention places 2 kinds of obligations on all signatories- general and specific.

The convention lays down that if a party chooses to prohibit import or export of certain materials (even those that have not been mentioned in the Convention); this shall be respected by all other parties. It also places the obligation on all nations to ensure that waste production is brought sown to a minimum, and which is produces is disposed off safely without any threat to human life or the environment and also to reduce all transboundary movement of hazardous material, while creating appropriate laws and administrative changes for controlling illegal transboundary movement of hazardous wastes. "Transboundary movement" means any movement of hazardous wastes or other wastes from an area under the national jurisdiction of one State to or through an area under the national jurisdiction of another State or to or through an area not under the national jurisdiction of any State, provided at least two States are involved in the movement.

The convention also lays down guidelines for transboundary movement completely at the instance of the importing party. The provision of re-import has been added as a safe guard so that the exporting party fulfils all obligations failing which, the wastes can be sent back. Finally, the convention stresses on the need for international co-operation and sharing environmental expertise and technological support.

The Basel Convention is the one of the main sources of hazardous waste law in India and has been stressed upon as a thumb rule for hazardous waste in the Hazardous Waste (Management and Handling) Amending Rules, 2000. It has also been relied upon in the landmark judgement *Research Foundation for Science Technology and Natural Resources Policy v. Union of India*[23] which became a foundation case for hazardous waste policy in India.

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

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

Reaffirming the Declaration of the United Nations Conference on the Human Environment, adopted at Stockholm on 16 June 1972, and seeking to build upon it, the Rio Declaration resulted in a set of principles which enunciate environmental protection with principles like sustainable development which is one of the central thrusts of the Declaration.

> Principle 10: Environmental issues are best handled with participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities
>
> Principle 15: In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
>
> Principle 16: National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.
>
> Principle 19: States shall provide prior and timely notification and relevant information to potentially affected States on activities that may have a significant adverse transboundary environmental effect and shall consult with those States at an early stage and in good faith.

The above principles are the most relevant provisions for the present discussion. Information about hazardous material, precautionary principle, polluter pays principle and principle against transboundary movement of pollutants respectively form the gist of the above principles. The above declaration has been referred to in the judgement *Research Foundation for Science Technology and Natural Resources Policy v. Union of India*[24] delivered by Y. K. Sabharwal J, especially with regard to the precautionary principle and the polluter pays principle. They have also been referred to in the case A.P. *Pollution Control Board v. Prof. M.V. Nayudu (Retd.) and Ors*[25] which cements the above principles and their applicability in India.

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

[25] (1996) 5 SCC 718.

Stockholm Convention on Persistent Organic Pollutants, 2001

This 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 to this convention must keep the Basel convention in mind and cooperate as closely with the parties to this convention. This article also deals with the abolition of transboundary movement of wastes as well as stresses on the need to develop ways of reducing wastes.

Although this convention has not been specifically referred to in any text of judgement, 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, 1973 (MARPOL):

The International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted on 2 November 1973 at IMO and covered pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage. The Protocol of 1978 relating to the 1973 International Convention for the Prevention of Pollution from Ships (1978 MARPOL Protocol) was adopted at a Conference on Tanker Safety and Pollution Prevention in February 1978 held in response to a spate of tanker accidents in 1976-1977. (Measures relating to tanker design and operation were also incorporated into the Protocol of 1978, relating to the 1974 Convention on the Safety of Life at Sea, 1974).[26] 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. All oil carrying ships are required to be capable of operating the method of retaining oily wastes on board through the "load on top" system or for discharge to shore reception facilities.

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. The following excerpts are from the same legislation:

> 21. Improperly discharging ballast:
>
> (1) No ballast or rubbish, and no other thing likely to form a bank or shoal or to be detrimental to navigation, shall, without lawful excuse, be cast or thrown into any such port or into or upon any place on shore from which the same is liable to be washed into any such port, either by

[26] http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258

ordinary or high tides, or by storms or land-floods[28] [and no oil or water mixed with oil shall be discharged in or into any such port, to which any rules made under clause (ee) of sub-section (1) of section 6 apply, otherwise than in accordance with such rules].

(2) Any person who by himself or another so casts or throws any ballast or rubbish or any such other thing [28][or so discharges any oil or water mixed with oil], and the master of any vessel from which the same is so cast, [29][thrown or discharged], shall be punishable with fine which may extend to five hundred rupees, and shall pay any reasonable expenses which may be incurred in removing the same.

(3) If after receiving notice from the conservator of the port to desist from so casting or throwing any ballast or rubbish or such other thing[28] [or from so discharging any oil or water mixed with oil], any master continues so to cast,[30] [throw or discharge the same], he shall also be liable to simple imprisonment for a term which may extend to two months.

(4) Nothing in this section applies to any case in which the ballast or rubbish or such other thing is cast or thrown into[28] [or the oil or water mixed with oil is discharged in or into] any such port with the consent in writing of the conservator, or within any limits within which such act may be authorised by the[2] [Government].

22. Graving vessel within prohibited limits: If any person graves, breams or smokes any vessel in any such port, contrary to the directions of the conservation, or at any time or within any limits at or within which such act is prohibited by the[2] [Government], he and the master of the vessel shall for every such offence be punishable with fine which may extend to five hundred rupees each.

23. Boiling pitch on board vessel within prohibited limits: If any person boils or heats any pitch, tar, resin, dammer, turpentine, oil, or other such combustible matter on board any vessel within any such port, or at any place within its limits where such act is prohibited by the[2] [Government], or contrary to the directions of the conservator, he and the master of the vessel shall for every such offence be punishable with fine which may extend to two hundred rupees each.

It must be noted that this legislation applies only to the above 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 a legislation could be enacted based on MARPOL as well as the above Act, a suitable legislation can be enacted.

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

Under Article 2 (general obligations), parties undertake to give full and complete effect to the provisions of the Convention and the Annex in order 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, individually or jointly with other Parties, 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.[27]

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

3.2.6. Principles of Environment Protection

Right to Life:

Enunciated in Article 21 of the constitution, this right forms the basis for all environmental protection principles. “Environmental concerns have been placed at same pedestal as human rights concerns, both being traced to Article 21 of the Constitution of India. It is the duty of this Court to render justice by taking all aspects into consideration.”[28] Thus hazardous waste disposal and the right to life of those being affected by the hazardous wastes are inalienable. Even the Directive Principles of State Policy in the Constitution moves towards sustainable development and the right to health for all (Articles 39(b) and (c) and 47). In Ratlam Municipality v. Vardhichand[29] Krishna Iyer J said,

“Where Directive Principles have found statutory expression in Do’s and Don’ts the Court will not sit idly by and allow municipal government to become a statutory mockery. The law will relentlessly be enforced and the plea of poor finance will be poor alibi when people in misery cry for justice. The dynamics of the judicial process has a new ‘enforcement’ dimension not merely through some of the provisions of the Criminal Procedure Code (as here), but also through activated tort consciousness.”

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[27] http://www.imo.org/Conventions/mainframe.asp?topic_id=867.

[28] YK Sabharwal J, Research Foundation for Science Technology and Natural Resources Policy v. Union of India, Writ Petition (Civil) 657 of 1995 [With SLP (C) No.16175 of 1997 and Civil Appeal No.7660 of 1997]. See also A.P Pollution Control

[29] AIR 1980 SC 1622.

Precautionary Principle:

A very important part of the Rio Declaration as principle 15, this has been upheld in India by the A.P. Pollution Control Board v. Prof. M.V. Nayadu[30] where it was discussed in detail by M. Jagannadha Rao J. the Learned Judge commented that earlier on, the concept was based on the `assimilative capacity' rule as revealed from Principle 6 of the Stockholm Declaration of the U.N. Conference on Human Environment, 1972. He felt that "the said principle assumed that science could provide policy-makers with the information and means necessary to avoid encroaching upon the capacity of the environment to assimilate impacts and it presumed that relevant technical expertise would be available when environmental harm was predicted and there would be sufficient time to act in order to avoid such harm."[31] However, in the 11th Principle of the U.N. General Assembly Resolution on World Charter for Nature, 1982, the emphasis shifted to the `Precautionary Principle', and this was reiterated in the Rio Conference of 1992 in its Principle 15.

Polluter Pays Principle:

This was also upheld by the Rio Declaration as principle 16, and it is echoed in the Basel Convention as well as the Environment (Protection) Act, 1986 and the various rules made hereunder. All principles of compensation liability where the polluting party, or the occupier is required to make good the damage caused to the environment is an exercise of this principle. *Vellore Citizens' Welfare Forum v. Union of India and others*[32] was another landmark judgement where these principles were considered. Kuldip Singh, J. after referring to the principles evolved in various international Conferences and to the concept of `Sustainable Development', stated that the Precautionary Principle, the Polluter Pays Principle and the special concept of Onus of Proof have now emerged and govern the law in our country too, as is clear from Articles 47, 48-A and 51-A(g) of our Constitution and that, in fact, in the various environmental statutes, such as the Water Act, 1974 and other statutes, including the Environment (Protection) Act, 1986, these concepts are already implied. He observed, "In view of the above-mentioned constitutional and statutory provisions we have no hesitation in holding that the *Precautionary Principle* and the Polluter Pays Principle are part of the environmental law of the country." This judgement has now become an applicable part of Indian law.[33]

Onus of Proof:

This is another concept that has emerged with the above two concepts in the Rio Declaration and other international instruments. This was also debated on by Kuldip Singh J in the *Vellore Citizens' Welfare*

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[30] (1996) 5 SCC 718.

[31] Para 29.

[32] 1995(5) SCC 647.

[33] See also Indian Council for Enviro-Legal Action and Others v. Union of India and Others (1996) 3 SCC 212.

Forum v. Union of India and others case[34]. Kuldip Singh, J. stated, "The 'onus of proof' is on the actor or the developer/industrialist to show that his action is environmentally benign…The 'onus of proof' is on the action or the developer/industrialist to show that his action is environmentally benign." He also stated that the two above principles have led to the question of onus of proof and therefore, the three principles are connected and a part of each other.

In consonance with this, the Environment (Protection) Act, 1986 and the Rules made under it, echo this principle where the burden of proof and the duty of environmental protection is of vested in the occupier or the manufacturer.

Strict and Absolute Liability:

This principle, with regard to hazardous waste was debated in *the Research Foundation for Science Technology and Natural Resources Policy v. Union of India case*.[35] In this case, the petitioner demanded exemplary damages from the respondent party which lead to the strict liability and hazardous waste disposal debate. The principle of strict liability first emerged in British law in the case *Rylands v. Fletcher* (1868) where, if a person brings a dangerous thing on his land, then he is liable for any damage caused by it unless the damage was unforeseeable due to an act of God. However, in *M.C. Mehta and Anr. v. Union of India and Others*[36] a Constitution Bench has held that this rule evolved in the 19th century at a time when all the developments of science and technology had not taken place cannot afford any guidance in evolving any standard of liability consistent with the constitutional norms and the needs of the present day economy and social structure. Thus the principle of absolute liability emerged in India, where even the excuse of unforseeability and act of God are not accepted. Any person carrying on a business involving dangerous objects for profit is responsible for any liability following thereafter. This principle was later followed in the Bhopal Gas Tragedy Case (1984). This was cemented by the *Research Foundation for Science Technology and Natural Resources Policy v. Union of India*[37] where Sabharwal J. stated,

"An enterprise which is engaged in a hazardous or inherently dangerous industry which poses a potential threat to the health and safety of the persons working in the factory and residing in the surrounding areas owes an absolute and non-delegable duty to the community to ensure that no harm results to anyone. The enterprise must be held to be under an obligation to provide that the hazardous or inherently dangerous activity in which it is engaged must be conducted with the highest standards of safety…if the enterprise is permitted to carry on a hazardous or inherently dangerous activity for its

[34] 1995(5) SCC 647.

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

[36] (1987) 1 SCC 395.

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

profit, the law must presume that such permission is conditional on the enterprise absorbing the cost of any accident arising on account of such activity as an appropriate items of its overheads."

Other legal principles:

There are many other tortious principles such as negligence and nuisance which are also applicable to hazardous waste disposal, however the former principles of strict liability, polluter pays principle etc are nothing but enhanced forms of nuisance and negligence law. Also, the law of negligence would be useless in cases where strict liability applies as negligence requires that the fault of the party be proven which should not be required for hazardous waste disposal at all instances. However, cases of public nuisance which is a criminal offence and actionable under S. 133 of the Code of Criminal Procedure can be applied as it criminalizes the offence and ensures adequate legal protection.

All the above principles have been enunciated by the apex court.

3.2.7. New trends in the judiciary with regard to hazardous waste management:

The *Research Foundation for Science Technology and Natural Resources Policy v. Union* of India (Writ Petition (Civil) 657) of 1995 brought to the judiciary's notice the state of hazardous waste disposal in India. Alarmed by the situation of waste dumping, the court ordered a High Powered Committee (HPC) to be constituted with Prof. M.G.K. Menon as its Chairman, dated 30th October, 1997. The Committee comprised of experts from different disciplines and fields and was required to examine all matters in depth relating to hazardous waste. The detailed report submitted by the Menon committee was used to examine the situation of 133 barrels of hazardous waste oil lying at Nhava Sheva Port.

On 22nd January, 2004 a Monitoring Committee[38] was appointed by the Supreme Court to make a report on the state of hazardous waste disposal facilities and other plans in the various states in the country with regard to the same. The Committee came out with many reports on hazardous waste disposal, ship breaking etc, and in these reports the Committee examined the condition and compliance status of the procedures that are necessary for safely disposing hazardous waste materials. The SCMC found that most states had defunct facilities and out of date technologies and that very few industries had compliance reports. All this data was used by the Supreme Court in coming to a decision in the above mentioned judgement.

This forming a committee to investigate and obtain data may be a new and welcome trend by the apex court, especially with regard to environment related cases where the facts, statistics and empirical data

[38] Dr. N. H. Hosabettu, Director (HSMD), Ministry of Environment & Forests (MoEF) and Member Secretary, Monitoring Committee was constituted by the Supreme Court vide Order dated 14th October, 2003.

speak for themselves. It also helps in bringing to light the inaction on the part of state agencies, and possible remedies. This action can certainly not be seen as judicial activism or the Supreme Court interfering with executive policy matters as it is the duty of the judiciary to ensure the functioning of the executive, which is exactly the purpose of a monitoring committee.

The case of the Clemenceau[39]

The French ex-was ship Clemenceau has been traded between many hands before it was sent along towards India in a desperate attempt by the French authorities to get rid of the liability the ship had become. It was host to deadly array toxic contaminants including at least 130 tons of asbestos.

In 2003, the German steel giant Thyssen-Krupp won the contract to trade and scrap Clem. It was estimated that the amount to be gained from the iron scrap from the ship was around USD 4 million.

The ‘location’ clause of the contract was discussed to allow some of the decontamination work to be carried out in India which was an illegal clause under EU and French laws because the export of asbestos and other hazardous materials to India forbidden under Indian national laws, as well as the Basel Convention. Since the end of 2004, a coalition of French and Indian NGO’s tried to find out exactly how much hazardous materials was onboard the ship. They also fought plans to export the Clemenceau to India in the French courts. However, July 2005, the courts abdicated responsibility and the Civil Court of Paris declared that it was not competent to judge as the contract related to “an administrative decision concerning the destination of war material.”

The Clemenceau case in France: On 22nd February 2005, the French Civil Court of Paris (TGI Tribunal de Grande Instance) declared that the Claim was admissible to start a court case against the export of the Clemenceau. The claim was instituted by *Ban Asbestos France* and *Andeva*. The main issue was the denouncement of the contract because of illegal traffic in hazardous waste. On 15th March 2005, the decision of French Civil Court of Paris, the TGI Court (Tribunal de Grande Instance of Paris) was that the claim was admissible but the Civil Court was not competent. The issue was reserved to the Administrative Court. On 22nd March 2005 after an appeal by the *Ban Asbestos* and *Andeva*, the President of the Civil Appeal Court in Paris took the ordinance that the Clemenceau had to stay in France for the time being. “The immediate departure of the Clemenceau to India constitutes a danger in relation to the rights of the plaintiffs to achieve the asbestos removal.”

The Appeal Court in Paris declared that the Civil Court as nevertheless being competent on the asbestos decontamination claim of the plaintiffs. The claim could then be reintroduced at the Civil Court.

On 5th July 2005, the Second Decision of French Civil Court of Paris (TGI Court) the claim was declared as admissible, but the Civil Court was not competent. The issue was to be reserved at the

[39] Facts of the case taken from “The Saga of the Clemenceau”, Greenpeace Briefing.

Administrative Court. The justification was that, although the dismantling “contract” is a “private contract” between the French State and the German Company SDI, the ex-military vessel the Clemenceau was still to be considered as war material. This meant that the decision leading to the contract was an “administrative decision” concerning the destination of war material.

The Clemenceau case in India: On 14th October 2003, the Supreme Court Monitoring Committee on Hazardous Wastes was appointed by Supreme Court of India (vide order in Writ Petition No.657/1995). On 5th March 2005, the Order and Direction of the Supreme Court Monitoring Committee (SCMC) of India was published as a consequence of the Gujarat Control Pollution Board (GCPB). The recommendations of the committee were that the Supreme Court’s order of 14th October 2003(Writ Petition No.657/1995) should be followed and that so long as the Clemenceau carried asbestos and other toxic wastes, it should be disallowed from entering Indian Territory.

The Supreme Court in its order dated 14th October 2003 (Writ Petition No.657/1995) had occasion to consider the activity of ship breaking along the *Alang* coast of Gujarat. In the said order, the Court has provided detailed guidelines for regulating the entry of ships for breaking and for ensuring that the rights of the workers, coastal ecology and provisions of the Basel Convention are not violated by the activity.

1) On *shipbreaking*, the Court in the said order accepted the recommendations of the High Powered Committee (Menon Committee) on Hazardous Wastes as under:

“Before a ship arrives at port, it should have proper consent from the concerned authority or the State Maritime Board, stating that it does not contain any hazardous waste or radioactive substances. AERB should be consulted in the matter.”

2) The Court also laid down that:

“The ship should be properly decontaminated by the ship owner prior to the breaking. This should be ensured by the PCBs.”

3) In the same case, Supreme Court judged,

“Before a ship arrives at port, it should have proper consent from the concerned authority or the State Maritime Board, stating that it does not contain any hazardous waste or radioactive substances. The ship should be properly decontaminated by the ship-owner prior to the breaking.”

Thus, the 2003 judgement became a victory for the environmentalists with regard to the Clemenceau as the French authorities were clearly violating the Basel convention by trying to illegally export hazardous material. The lackadaisical attitude of the courts further showed that the French government authorities may have colluded with the private parties in order to get rid of the toxic ship.

Today however, the Norwegian ship “Blue Lady” faces the same predicament as the Clemenceau. In fact, in October 2003, The Basel Convention Parties (including Turkey, Greece and France) met in

Geneva for the week to discuss the issue of end of life ships (the OEWG-II working group). An important decision was taken concerning end of life ships and was held that they have to be considered as waste under the Basel Convention*: 'Noting that a ship may become waste, in accordance with Article 2 of the Basel Convention [...]'.*

The following are the most important cases which have developed environmental principles (and have been referred to in this report):

Research Foundation for Science Technology and Natural Resources Policy v. Union of India, Writ Petition (Civil) 657 of 1995 [With SLP (C) No.16175 of 1997 and Civil Appeal No.7660 of 1997].

Vellore Citizens' Welfare Forum v. Union of India and others, 1995(5) SCC 647.

A.P. Pollution Control Board v. Prof. M.V. Nayudu (Retd.) and Ors., (1996) 5 SCC 718.

Deepak Nitrite Ltd. v. State of Gujarat and Others, (2004) 6 SCC 402.

M.C.Mehta and Anr. v. Union of India and Others, (1987) 1 SCC 395.

M.C. Mehta v. Union of India and Shriram Foods and Fertilizers, 1986(2) SCC 175

Indian Council for Enviro-Legal Action and Others v. Union of India and Others, (1996) 3 SCC 212.

M.I. Builders Pvt. Ltd. v. Radhey Shyam Sahu, 1999 SOL Case No. 394.

K.M. Chinnappa In T.N. Godavarman Thirumal v. Union of India, 2002 SOL Case No. 556.

Dr. B.L. Wadehra v. Union of India and others, (1996)2 SCC 594.

Almitra H. Patel and Another v. Union of India and Ors, (2000)2 SCC 166.

Ratlam Municipality v. Vardhichand, AIR 1980 SC 1622.

People's Union for Civil Liberties v. Union of India & Anr. (1997) 3 SCC 433.

3.3. Water quality in the vicinity of the Mavallipura illegal solid waste dump

3.3.1. Background

In recent times, in the context of growing environmental consciousness in India, Solid Waste Management (SWM) has gained a lot of attention. A couple of important judgments regarding scientific Solid Waste Management -- *Dr. B. L. Wadehra vs. Union of India and others and Almitra Patel vs. Union of India* – led to the enactment of the Solid Waste Management Rules (2000) by the Ministry of Environment and Forests. With the passage of these SWM Rules, Solid Waste Management, that was until then perceived as an essentially municipal function, came under the regulatory powers of state and central pollution control authorities. This shift also signalled the importance of appropriate Solid Waste Management vis-à-vis the Environment. The significance lies in the fact that, when effectively done, SWM can reduce the spread of diseases drastically as well as prevent environmental pollution.

In addition, these judgments also propelled activity in the direction of setting up of solid waste management facilities based on country wide standards. In these judgments, the Supreme Court ruled that for Class I cities (cities with population of over 100,000), scientifically designed landfills had to be established December 2003, and that a failure to meet this deadline would be interpreted as Contempt of Court. Judgments and rules are one thing, reality is another matter altogether.

3.3.2. Garbage dumping in Mavallipura

About 20 km north of Bangalore city, close to Yelahanka town and the Yelahanka Air Force Base, there is a village called Mavallipura. With the tacit approval of Bangalore Mahanagara Palike (BMP), every day since May 2003, about 200 truckloads of municipal solid waste from some of the northern wards of Bangalore are being dumped on 20 acres of land belonging to one Mr. Bylappa from Mavallipura. On average, each truckload of waste weighs about 2.5 to 3 tons. The leachate from the dump is allowed to stagnate in a ditch next to the dump and slowly finds its way into surface and ground water aquifers. Over the years all drinking water sources in the vicinity have been adversely affected, and the threat looms large of contaminating the Arkavathy river, a major drinking water source of Bangalore. It is in this river basin that the Mavallipura dump is located.

Note that a dump is different from a landfill in the way the waste is disposed off. A landfill is a constructed by digging out the earth to form a very large ditch which is provided with an impermeable lining and a leachate collection system to prevent ground water contamination. An outlet for gases formed during decomposition is also provided. A dump in contrast does not have any of these provisions and therefore causes serious air, soil and water pollution.

Water pollution is the far more serious problem because the leachates (containing all kinds of toxic material given the composition of waste generated by a city like Bangalore) seep into the ground and possibly reach the aquifers that are likely to be used as a source of drinking water (among other purposes) by people residing in the area. Theoretically, while the water from the aquifers could be treated for making it potable, in reality, the treatment processes are expensive and therefore it may not be an economically viable option to treat the water and the aquifer may have to be abandoned if the contamination is too high for the safety of those who consume the water.

In Mavallipura, the dumping is carried out next to a forest area and a Eucalyptus plantation. Adjoining the dumping site is agricultural land where crops like *ragi* (finger millet), *avarekaalu* (field beans) and flowers are cultivated. Dogs, cattle, cats, crows are some of the animals seen in the vicinity of this area. Vultures are recent additions to the bird population of this area. Additionally, in the vicinity of Mavallipura, there are a few tanks (which are large surface water bodies created to harvest rain in an interlinked pattern) which are part of a chain of lakes/tanks that join the Arkavathy river. Two of these tanks, the Mavallipura Tank and the Koramana Kunte tank, are downstream from the waste dump and hence are polluted by the leaching of pollutants and toxic material from the dump.

Figure: 3-2 Leachate pond next to the Mavallipura dump

As can be expected, this open dumping (and burning) of garbage has resulted in serious environmental pollution including contamination of water bodies here. The villagers of Mavallipura rely on groundwater in this area for their drinking water and cooking needs and face serious health consequences.

This report is an analysis of the water quality in this area (based on water samples taken here), and the health hazards posed by the contaminants present in this water. The principle objective of water quality testing undertaken by us is to examine if there has been a contamination of groundwater sources due to the all the waste that is being continuously dumped on Bylappa’s land. The water quality test gives an estimate of the level of contamination in the ground water sources of drinking water and this is useful in assessing the risk of health hazard to the villagers of Mavallipura.

3.3.3. Sampling

Six grab samples of water around the Mavallipura waste dump were tested for various parameters including bacteriological characteristics, heavy metals, pH, Hardness and Total Dissolved Solids among others. The samples include three borewell water samples one of which has been used as the control (reference sample which is indicative of the natural water quality in the absence of contamination), one from an open well, one leachate sample and one from a tank. The distances of the samples from the dump are given below.

Sampling points

1. Borewell water from Muniswamappa's Gladiolus flower farm located ~500 m at lower terrain w.r.t. to the waste dump.
2. Borewell water from Anand's farm ~200m from the dump at similar to lower terrain w.r.t. to the dump.
3. Open well from Hanumanthrayappa's farm ~300 m from and at lower terrain w.r.t. to the dump.
4. Sample from leachate pond next to the municipal solid waste dump (~100 m from the dump).
5. Mavallipura lake/tank at Devraj's field ~300 m from and at lower terrain w.r.t. to the dump.
6. Borewell water from FRLHT campus (from a tap near the security room at the gate) – CONTROL from ~500 m at higher terrain from the dump.

Figure: 3-3 Open well rendered useless because leachate overflow from waste dump

Methodology

The samples were collected in new 5 litre jerry cans (though the requirement was only 2 lt for analysis). The cans were rinsed with the sample before collecting the sample. For the leachate pond sample, the sample water was transferred to the can using a new funnel and a mug while using gloves for the hands.

The samples were collected and submitted to Essen & Co., Bangalore by 2 pm on the 1st of June, 2006. The samples were submitted for analysis of 31 parameters including physical, chemical, biological, and heavy metal analysis. The parameters are in accordance with those listed under IS 10500 for drinking water. A copy of the list of parameters and the limits for the same has been obtained.

Parameters tested

1. Colour, Hazen Units, Max	**17. Phenolic Compounds as C_6H_5OH, mg/l, Max**
2. Odour	**18. Mercury as Hg, mg/L, Max**
3. Taste	**19. Cadmium as Cd, mg/L, Max**
4. Turbidity	**20. Arsenic as As, mg/L, Max**
5. pH Value	**21. Cyanide as CN, mg/L, Max**
6. Total Hardness as $CaCO_3$, mg/L, Max	**22. Lead as Pb, mg/L, Max**
7. Iron as Fe, mg/L, Max	**23. Zinc as Zn, mg/L, Max**
8. Chloride Cl, mg/L, Max	**24. Chromium, Cr^{+}6,mg/L,Max**
9. Residual Free Chlorine, mg/L, Min.	**25. Alkalinity, mg/L, Max**
10. Total Dissolved Soilds, mg/L, Min	**26. Aluminium as Al, mg/L, Max**
11. Calcium Cl, mg/L,Max	**27. Boron as B, mg/L, Max**
12. Copper as Ca, mg/L, Max	**28. Magnesium as Mg, mg/L, Max**
13. Manganese as Mn, mg/L, Max	**Bacteriological characteristics:**
14. Sulphate as SO_4, mg/L, Max	**29. MPN Coliform Bacteria, 100 ml, Max**
15. Nitrate as NO_3, mg/L, Max	**30. Fecal Coliform Bacteria/100ml**
16. Fluoride as F, mg/L, Max	**31. E.Coli Bacteria per 100**

Results of the water quality analysis

The leachate and the control sample have been used as the samples of reference since the leachate would obviously have the highest amounts of contaminants and the control sample the least. The control sample in this case was taken from a ground water source that is at an elevation from the waste dumpsite and all the other samples (4) are at lower terrain from the dump.

For the following parameters, one or more samples had concentrations higher than the desirable limit (according to IS 10500 standard): Odour, taste, turbidity, total hardness, chloride, TDS, Cadmium, Lead, Alkalinity, Magnesium, MPN Coliform

For the following parameters, one or more samples had concentrations higher than the maximum permissible limit (according to IS 10500 standard) or maximum allowable limit (according to other water quality standards): pH, Calcium, manganese, Fluoride, Total hardness, chloride, TDS.

Composition of water contaminated by waste dump leachate

Typically, water contaminated with leachate from household waste has high sulphate, chloride, ammonia, BOD, TOC and suspended solids from fresh wastes.

The sources of contaminants and potential health impacts on humans and the animals and the impact on plants of these parameters are discussed below:

Figure: 3-4 Rag pickers scouring for recyclables

Colour, Odour and Taste

These physical characteristics are important for aesthetic reasons. Although they do not cause any direct harmful health effects, most people would object to drinking water that offends their sense of sight, smell or taste. The water may be coloured due to the presence of dissolved or suspended colloidal particles. In natural waters, the colouring is primarily due to decaying leaves, microscopic plants, or suspended soil particles. Surface waters may have colouring due to highly-coloured waste-waters like dye wastes and wastes from pulping operations.

Odour is measured in terms of threshold odour number. Decaying organic matter imparts the smell of rotten-eggs because of Hydrogen sulphide gas that is produced during decomposition.

Two water samples have colour above permissible limit. One sample is the leachate sample to which the permissible limit is not applicable and the other is the Mavallipura tank sample. The colour in this sample could be because of the suspended soil particles since the tank is very shallow and the sample was collected after rain. None of the other samples show disagreeable colour.

pH

pH is the term used to express the intensity of the acid or alkaline condition of a solution. It is a measure of the hydrogen ion concentration. The pH scale contains values ranging from above 0 (strongly acidic) to under 14 (strongly basic). Hydrogen ions are formed when water dissociates into hydrogen and hydroxyl ions. The allowable concentration range for the survival of most biological life is quite narrow [Nathanson 2003]. All samples but one are slightly alkaline but within the desirable limit.

Alkalinity

Alkalinity is the capacity of a water sample to neutralize an acid. The main reason for alkalinity of a water sample is the presence of carbonate, bicarbonate and hydroxides. Alkalinity buffers fluctuations in pH and is therefore important to aquatic life which is sensitive to pH especially organisms that use external fertilization for reproduction.

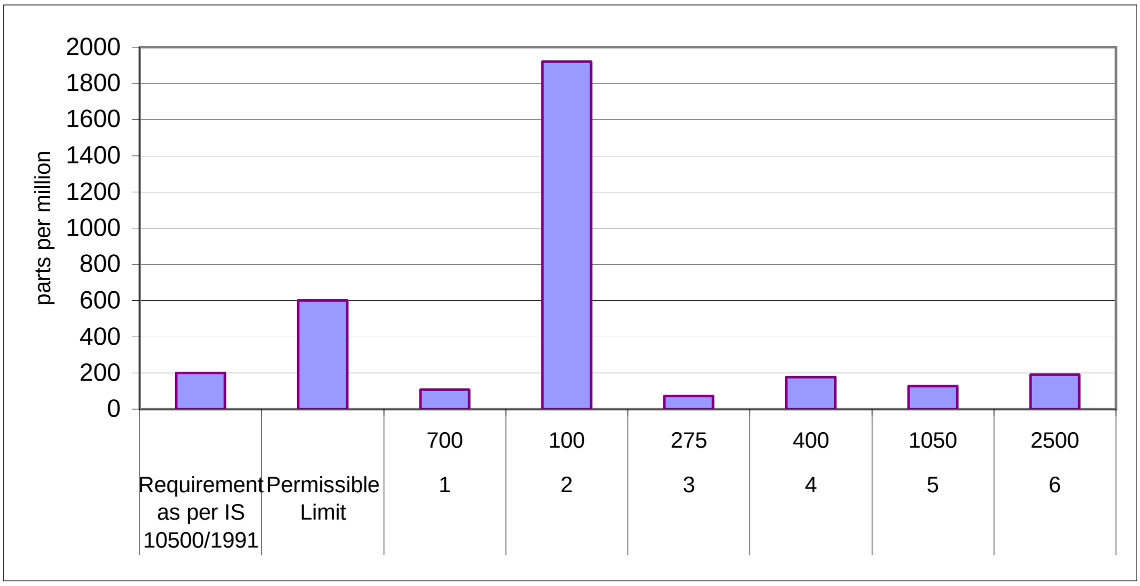

Figure: 3-5 Mavallipura Water Quality Results - Alkalinity

Total Dissolved Solids

The total solids in a water sample consist of total dissolved and total suspended solids. Total dissolved solids are materials in the water that will pass through a filter with a 2.0 µm or smaller nominal average pore size. The material retained by the filter is the total suspended solids. In potable waters, most of the dissolved matter consists mainly of inorganic salts, small amounts of organic matter, and dissolved gases. The hardness increases with total dissolved solids.

The amount of dissolved solids present in water is a consideration in the water's suitability for domestic use. In general, water with a total-solids content of less than 500 mg/l is most desirable for such purposes. Higher total solids content imparts taste to the water and often has a laxative and sometimes the reverse effect upon people whose bodies are not used to higher levels. Water with high dissolved solids content has an adverse impact on irrigated crops, plants and grasses.

The total dissolved solid content in the leachate is well above the permissible limit. The open well sample has dissolved solid content more than the desirable limit.

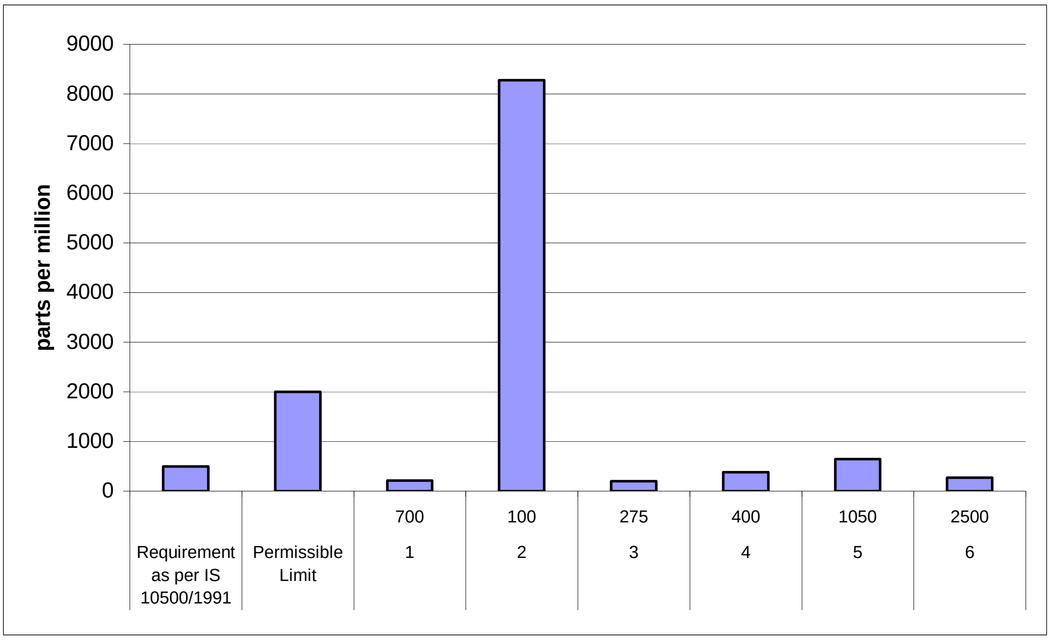

Figure: 3-6 Mavallipura Water Quality Results - Total dissolved solids

Turbidity

Turbidity in water is caused by suspended particles that absorb light. Clay, silt tiny fragments of organic matter and microscopic organisms are some of the substances that cause turbidity. Suspended particles can provide hiding places for harmful micro-organisms and thereby affect the quality of water. Turbidity hampers the disinfection process in a waste treatment plant. Turbidity is also unacceptable for aesthetic reasons [Nathanson 2003]. Filtration of water is rendered more difficult and costly when turbidity increases [Sawyer at al].

As can be expected the turbidity is very high in the leachate since it is the water that percolates through a soil and that carries substances in solution or suspension. The Mavallipura tank sample is also turbid beyond the permissible limit. This sample could be turbid because the sample was collected after rains.

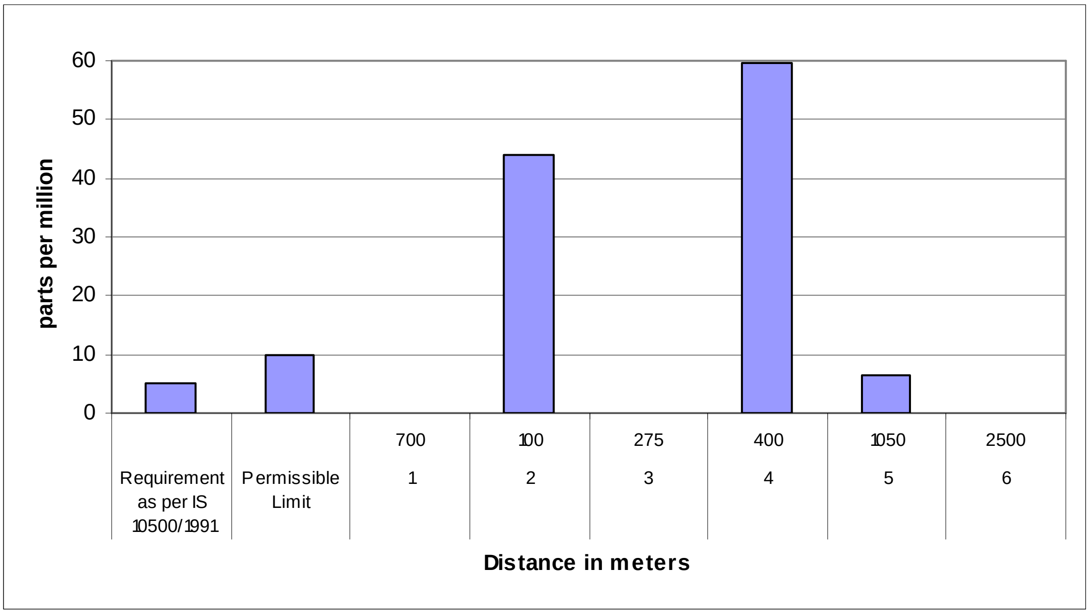

Figure: 3-7 Mavallipura Water Quality Results - Turbidity

Total Hardness

Hardness is the caused by bicarbonates, chlorides and sulphates (mainly of Ca, Mg and Na) dissolved in water. The hardness caused by bicarbonates is called carbonate hardness or temporary hardness; it cannot be removed by heating. The hardness caused by sulphates and chlorides if Ca and Mg is called permanent hardness since it cannot be removed by heating. Hardness in water hinders lathering of soap/detergent. Salts present in hard waters get deposited alongside water pipers, cooking utensils and water heaters causing inconvenience and maintenance problems. Water with a total hardness greater than 500 ppm is considered hazardous to human health.

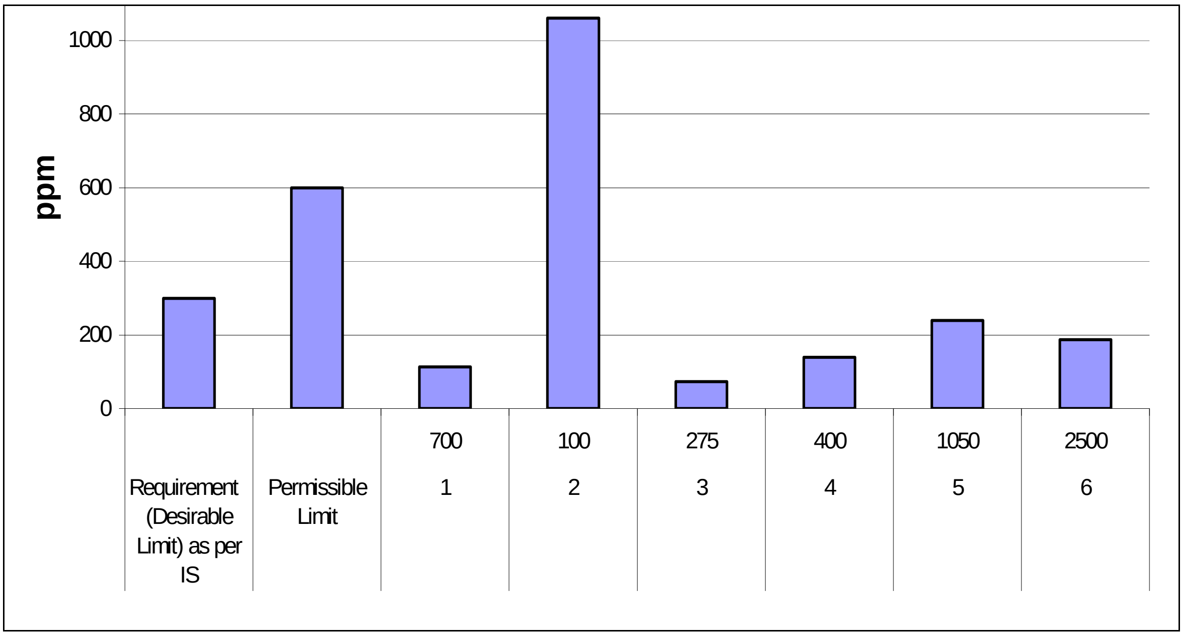

Figure: 3-8 Mavallipura Water Quality Results- Total hardness

Only one sample is above the desirable limit but within the permissible limit. Total hardness in the leachate sample is much higher than the permissible limit but it is not considered as a source of drinking water therefore this limit is not applicable to it.

Calcium (Ca) and Magnesium (Mg)

Calcium and Magnesium are the two most common minerals that cause hardness in water. The degree of hardness increases as the amount of Ca and Mg increase in water. Ca and Mg enter water when water passes through soil and water and it dissolves very small amounts and hold them in solution [Sawyer et al]. Even though the human body requires 0.7 to 2.0 grams of calcium per day as a food element excessive amounts can lead to kidney and gall bladder stones. High concentrations of calcium hinder many industrial processes. Calcium also serves an important role in the health of bodies of water. In natural water it is known to reduce the toxicity of many chemical compounds on fish and other aquatic life [Skipton 2006].

		Requirement (Desirable Limit) as per IS 10500/1991	Permissible Limit in the absence of Alternate source	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4	Sampling point 5	Sampling point 6
				700 m	100 m	275 m	400 m	1050 m	2500 m
Calcium	ppm	75	200	28.05	120.24	18.03	35.27	63.32	46.89
Magnesium	ppm	30	100	10.69	184.71	6.8	12.63	19.93	17.01

Table: 3-2 Mavallipura Water Quality Results- Calcium and Magnesium

Iron and Manganese

Iron exists mainly in soils and minerals mainly as insoluble ferric oxides and iron sulphides (pyrite) It occurs in some areas also as ferrous carbonate (siderite) which is very slightly soluble. Since ground waters usually contain significant amounts of carbon dioxide, appreciable amounts of ferrous carbonate may be dissolved by the reaction shown in the equation

$$FeCO_3(s) + CO_2 + H_2O \longrightarrow Fe^{2+} + 2HCO_3^-$$

This takes place similar to how calcium and magnesium carbonates are dissolved. However, iron problems are prevalent where it is present in the coil as insoluble ferric compounds. Iron does not dissolve easily in waters with dissolved oxygen even when there are appreciable amounts of carbon dioxide.

As far as known, humans suffer no harmful effects from drinking waters containing iron and manganese. Such waters, when exposed to the air so that oxygen can enter, become turbid and highly unacceptable from an aesthetic viewpoint, owing to the oxidation of iron and manganese to Fe(III) and Mn(IV) state, which can form colloidal precipitates. Oxidation rates may be increased by the presence of certain inorganic catalysts or through the action of microorganisms. Both iron and manganese interfere with laundering operations, impart objectionable stains to plumbing fixtures, and cause difficulties in distribution systems by supporting growths of iron bacteria Iron also imparts a taste to water supplies which is detectable at very low concentrations.

Manganese exists in the soil principally as manganese dioxide, which is very insoluble in water containing carbon dioxide. Under reducing (anaerobic) conditions, the manganese in the dioxide form is reduced (from an oxidation state of IV to II), and solution occurs, as with ferric oxides.

Manganese is used in ceramics, dry battery cells, electrical coils and iron alloys. Burning of fossil fuels (coal, oil) is the main source of Mn in the environment. The use of manganese in some fertilizers contributes further to air and water pollution [Kannan 1991].

Ground waters that contain appreciable amounts of iron or manganese or both are always devoid of dissolved oxygen and are high in carbon dioxide content. Wells producing good-quality water, low in iron and manganese, start producing poor-quality water when organic wastes have been discharged on the soil around or near the well, thereby creating anaerobic conditions in the soil.

The iron and manganese problem in impounded surface supplies has been correlated with reservoirs that stratify, but occurs only in those which anaerobic conditions develop in the hypolimnion (the bottom most layer of a thermally stratified lake) [Sawyer et al].

Both the iron and manganese content in the all the samples is much below the permissible limit and desirable limits.

		Requirement (Desirable Limit) as per IS 10500/1991	Permissible Limit in the absence of Alternate source	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4	Sampling point 5	Sampling point 6
				700 m	100 m	275 m	400 m	1050 m	2500 m
Iron as Fe	ppm	0.3	1	0.05	0.12	0.05	0.1	0.07	0.05
Manganese	ppm	0.1	0.3	0.03	0.41	0.03	0.26	0.04	0.07
Boron	ppm	1	5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table: 3-3 Mavallipura Water Quality Results- Iron, Manganese and Boron

Boron (B)[40]

Borates are widespread, naturally occurring substance found mainly as an inorganic compound in sediments and sedimentary rock. It is released to the environment slowly in low concentrations by weathering processes. Boron is neither transformed nor degraded in the environment, although changes in the specific form of boron and its transport may occur, depending on environmental conditions. Although few data are available quantifying boron releases from industrial sources, it is estimated that natural weathering releases more boron to the environment worldwide than do these industrial sources [Butterwick et al. 1989]. Releases of boron to the environment occur from the production and use of boron and boron-related compounds.

Natural weathering of boron-containing rocks is a major source of boron compounds in water [Butterwick et al. 1989]. The quantity of boron released varies widely with the geographic variations in boron-rich deposits. Boron compounds are released to water in municipal sewage from perborates in detergents, and in wastewaters from coal-burning power plants, copper smelters, and industries using boron. Borate levels above background may be present in runoff waters from areas where boron-containing fertilizers or herbicides were used [Butterwick et al. 1989; Nolte 1988; Waggott 1969).

Boron has been detected in surface water and groundwater at hazardous waste sites.

Boron is naturally released to soil and water by rainfall, weathering of boron-containing minerals, desorption from clays and by decomposition of boron-containing organic matter. Man-made sources include application of boron-containing fertilizers or herbicides, application of fly ash or sewage sludge as a soil amendment, the use of waste water for irrigation or land disposal of boron-containing industrial wastes [Butterwick et al. 1989; Hollis et al. 1988; Mumma et al. 1984; Nolte 1988; Rope et al. 1988]. No quantitative data were located regarding man-made releases of boron compounds to soil. Landfilling or land application is a common disposal method for sewage sludges.

Transport and Partitioning

Borates are relatively soluble in water, and will probably be removed from the atmosphere by precipitation and dry deposition [EPA 1987]. Boron readily hydrolyzes in water to form the electrically neutral, weak monobasic acid H BO and the monovalent ion B (OH). In concentrated solutions, boron may polymerize, leading to the formation of complex and diverse molecular arrangements. Rai et al. (1986) concluded that because most environmentally relevant boron minerals are highly soluble in water, it is unlikely that mineral equilibria will control the fate of boron in water. Waggott (1969), for example, noted that boron is not significantly removed during the conventional treatment of wastewater. Boron may, however, be co-precipitated with aluminium, silicon, or iron to form hydroxyborate compounds on the surfaces of minerals [Biggar and Fireman 1960]. Water borne

[40] See ATSDR 2005

boron may be adsorbed by soils and sediments. Adsorption-desorption reactions are expected to be the only significant mechanism that will influence the fate of boron in water [Rai et al. 1986]. The extent of boron adsorption depends on the pH of the water and the chemical composition of the soil. The greatest adsorption is generally observed at pH 7.5-9.0 [Keren et al. 1981; Keren and Mezuman 1981; Waggott 1969]. Bingham et al. (1971) concluded that the single most important property of soil that will influence the mobility of boron is the abundance of amorphous aluminum oxide. The extent of boron adsorption has also been attributed to the levels of iron oxide (Sakata 1987), and to a lesser extent, the organic matter present in the soil [Parks and White 1952], although other studies [Mezuman and Keren 1981] found that the amount of organic matter present was not important. The adsorption of boron may not be reversible in some soils. The lack of reversibility may be the result of solid-phase formation on mineral surfaces [Rai et al. 1986], and/or the slow release of boron by diffusion from the interior of clay minerals [Griffin and Burau 1974]. Partition coefficients such as adsorption constants describe the tendency of a chemical to partition from water to solid phases. Adsorption constants for inorganic constituents such as boron cannot be predicted a priori, but must be measured for each soil-water combination.

Effects on Plants animals and Humans

Available data for boron are given elsewhere [Rai et al. 1986]. In general, boron adsorption will be most significant in soils that contain high concentrations of amorphous aluminium and iron oxides and hydroxides such as the reddish Ultisols in the south-eastern United States. It is unlikely that boron is bio concentrated significantly by organisms from water. A bio concentration factor (BCF) relates the concentration of a chemical in the tissues of aquatic and terrestrial animals or plants to the concentration of the chemical in water or soil. The BCFs of boron in marine and freshwater plants, fish, and invertebrates were estimated to be less than 100 [Thompson et al. 1972]. Experimentally measured BCFs for fish have ranged from 52 to 198 [Tsui and McCart 1981]. These BCFs suggest that boron is not significantly bio concentrated.

Ingestion of boron from food (primarily fruits and vegetables) and water is the most frequent route of human exposure, but occupational exposures to boron dusts may be significant. Boron is also a component of several consumer products, including cosmetics medicines and insecticides.

Boron in water is completely absorbed by the human system, but it does not accumulate in body tissues [Waggott 1969]. No other experimentally measured BCFs were located.

Transformation and Degradation

Water: Elemental boron is inert in the presence of water. Boron compounds rapidly transform to borates, the naturally occurring form of boron, in the presence of water. No further degradation is possible. Borate and boric acid are in equilibrium depending only on the pH of the water. If dissolved in atmospheric water, the standard borate-boric acid equilibria are established.

Soil: Most boron compounds are transformed to borates in soil due to the presence of moisture. Borates themselves are not further degraded in soil. However, borates can exist in a variety of forms in soil. Borates are removed from soils by water leaching and by assimilation by plants.

HEAVY METALS

Metals that have high atomic weight are called heavy metals and are capable of causing damage to living tissue even at low concentration. They are therefore considered trace contaminants. Air-borne heavy metals are more toxic than when consumed through water as they are more readily absorbed through the respiratory system into the bloodstreams.

The heavy metals that could be a potential heath hazard in this case are Lead and Cadmium. Metals such as Calcium, Magnesium and Manganese although in higher than desirable concentrations in some of the samples, are not a cause for concern as they do not cause health problems. For some further details about heavy metals and their health effects, see section 2.2.6.

Heavy metals tend to be more soluble in acidic water. In aquifers and soils that have pH buffering capacity like in this case and under oxidizing conditions they are readily absorbed or exchanged by clays, oxides and other minerals. But the typical fatty acid content of landfill leachate creates acidic conditions favourable for dissolution of heavy metals.

The water samples tested were all slightly alkaline. Despite this the levels of Cadmium was found to be above the permissible limit in 2 samples i.e., the Mavallipura Tank sample which is the nearest surface water body to the dump and the leachate pond.

Lead

Most of the water samples collected around the Mavallipura dump showed slightly more basic pH so that unless the water is exposed to high levels of lead it is not likely to have a proportionally high concentration of Pb.

Leafy vegetables such has lettuce, spinach, potatoes and beans are likely to absorb more lead, whereas fruiting crops such as tomatoes, corn, beats, bringal and chilli do not pick up any appreciable amount of lead through their root systems at all. The organic content in the soil has been found to be inversely proportional to the rate of uptake of lead in soil. It has been found that in soils containing large quantities of organic matter i.e., >40-50%, the lead uptake is nil even when the Pb concentration is as high as 3000 ppm. Therefore it is advisable to use organic manure in places that are exposed to high levels of lead [Kannan 1991].

		Requirement (Desirable Limit) as per IS 10500/1991	Permissible Limit in the absence of Alternate source	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4	Sampling point 5	Sampling point 6
				700 m	100 m	275 m	400 m	1050 m	2500 m
Mercury	ppm	0.001	0	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	ppm	0.01	0	<0.01	0.05	<0.01	0.03	<0.01	<0.01
Arsenic	ppm	0.05	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cyanide	ppm	0.05	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	ppm	0.05	0	0.03	0.30	0.03	<0.01	<0.01	<0.01
Zinc	ppm	5.00	15	2.22	0.10	0.04	0.04	0.02	0.04
Copper	ppm	0.05	1.5	<0.01	0,05	<0.01	<0.01	<0.01	<0.01
Chromium	ppm	0.05	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table: 3-4 Mavallipura Water Analysis – Heavy Metals

Cadmium

Two samples, the leachate and the Mavallipura tank water show concentrations that are higher than permissible limit. The Mavallipura tank is down stream from the leachate pond and therefore the presence of high levels of cadmium is an indication that the leachate may have contaminated this surface water body which is one of the nearest to it.

Copper (Cu)

None of the samples show significant amount of copper and the copper concentrations are well within the permissible limit.

Mercury (Hg)

None of the samples show significant amount of mercury and the mercury concentrations are well within the permissible limit.

Arsenic (As)

The worst arsenic-related drinking water probems have occurred in West Bengal in the late 1980s. Because of dense populations and lack of access to safe drinking water, 4 million tubewells were installed in the 1970s in Bangladesh to tap better-quality groundwater sources. While this resulted in halving a high infant mortality rate, in 1993 the tubewell water was found to contain high levels of arsenic, at places reaching up to 3000 µg/L. Around 5000 patients were identified with arsenic-related health problems in West Bengal [Sawyer et al].

None of the samples show significant amount of arsenic and the arsenic concentrations are well within the permissible limit.

Zinc (Zn)

Zinc is used in the manufacture of dry batteries, construction materials, pigments and printing processes. It is also used for protective coatings on iron, steel, brass and alloys. Municipal refuse and automobiles (tire wear, fuel additives, brake linings and motor oils) serve as additional pollution sources. Agricultural use of $ZnSO_4$ – containing pesticides and fungicides may be yet another source of zinc in the environment.

Zinc is an essential trace metal to all organisms, as it is necessary for the functioning of various enzymes. It is normally present in the body in metallo-enzymes and other enzymes that take part in the synthesis of DNA, proteins and insulin. Thus zinc is necessary for the normal functioning of the cell, including protein synthesis, carbohydrate metabolism, cell division and growth. 15 mg and 10 mg of zinc is the recommended daily allowance for an adult and a child respectively. Large does of zinc salts (220-440 mg of Zn as $ZnSO_4$) cause gastro-intestinal disorders including vomiting and diarrhoea.

Fishes exposed to zinc generally accumulate it in the gills, gut and liver. Older fishes seem to be highly resistant to zinc poisoning compared to the young ones. Accumulation does not occur in many invertebrates. Under most conditions Zn is less toxic than Hg, Cd, Cu, Cr, Ni or As to aquatic invertebrates [Kannan 1991].

Zn plays a very important role in plant nutrition, it being a component of a number of metallo-enzymes1 (enzymes in which metals may be a co-factor or may be incorporated into the molecule is a metallo-enzyme).

None of the samples show significant amount of zinc and the zinc concentrations are well within the permissible limit.

Aluminium (Al)

Aluminium is produced in the largest quantities in India. Aluminium is used extensively for canning, food packaging, and as a foil for covering and preserving foodstuffs. Contamination of the environment with aluminium may result from the indiscriminate disposal of aluminium products and wastes.

Aluminium at levels 15 µg/ml in water causes anorexia, decreased activity, gill hyperplasia (an abnormal increase in tissue growth caused by excessive cell division) and mortality in fishes. Aluminium in its dissolved form is more toxic than the suspended form.

Aluminium is injurious to plants, when the soil pH is less than 5 Aluminium in soil injures crop roots, making them stubby and brittle The affected roots are thick and lack fine branching, thus cannot efficiently absorb water or nutrients seedlings are more susceptible to the toxic effects of aluminium than are more toxic than suspended form.

INORGANIC COMPOUNDS

		Requirement (Desirable Limit) as per IS 10500/1991	Permissible Limit in the absence of Alternate source	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4	Sampling point 5	Sampling point 6
				700 m	100 m	275 m	400 m	1050 m	2500 m
Sulphate	ppm	200	400	10.31	9.87	8.91	15.63	12.34	17.35
Nitrate	ppm	45	No Relaxation	18.05	15.03	15.37	1.08	2.22	0.73
Chloride Cl	ppm	250	1000	20.49	2127.00	35.98	96.96	229.92	20.99
RF Chlorine	ppm	0.2	_	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride	ppm	1	1.5	0.33	1.30	0.34	0.95	0.6	0.49

Table: 3-5 Mavallipura Water Test Results- Inorganic Compounds

Cyanide (CN)

Cyanide occurs as free cyanide (CN^-), cyanide salts (e.g., NaCN) or other complex cyanides (e.g., metallocyanides)

Principal sources of cyanides in the environment are the metallurgical and ore extraction industries. Sodium and Potassium cyanides are used in the extraction of gold and silver ores. Calcium cyanide is used as a fumigant. Gold mines and iron and steel manufacturing units are the main contributors or cyanide in the environments. Other sources include petrochemical, metal electroplating & finishing, photographic processing and combustion from various solid wastes.

Cyanide radicals (radical: two or more atoms bound together as a single unit and forming part of a molecule) are produced by numerous plants. Only free cyanide has toxicological effects. At acutely toxic levels, cyanide is respiratory poison. Cyanide is toxic to enzyme systems. Cyanide causes problems in the oxidation of nitrogen in the anaerobic conditions in wastewaters that contain large amounts of organic matter or nitrogenous wastes. In the presence of cyanide, nitrogenous substances are incompletely oxidized to nitrite rather than completely to nitrate. Nitrate is a potent inducer of methemoglobinemia (A condition of the blood in which there are large amounts of methemoglobin which is an altered hemoglobin which does not carry oxygen.) in humans; this condition leads to the reactions in the red blood cells that reduce their oxygen-carrying capacity. The same condition causes physiological stress in animals [Kannan 1991].

Cyanide gains access to water environment through the discharge of rinse waters from plating operation and from refinery and coal coking waste waters. The cyanide ion has a relatively short half-life (The time required for the amount of a reactant to decrease to half its initial value) because it can serve as a source of energy for anaerobic bacteria, provided the concentration is kept below its toxic threshold to them.

Sulphate as SO_4

The sulphate ion is one of the major anions (positively charged ions) occuring in natural waters. It is important in public water supplies because of its cathartic (strongly laxative) effect on humans when it is present in excessive amounts. Sulphate is important even in industrial water supplies because of the tendency of water containing appreciable amounts of sulphate to form hard scales in boilers and heat exchangers. Sulphate poses odour problems because of the formation of hydrogen sulphide with water in the absence of oxygen (anaerobic conditions) and nitrate. It tends to corrode sewers as well.

Chloride (Cl)

Chloride occurs in all natural waters in widely varying concentrations. The chloride content of water increases with increase in the mineral content of the water. River and ground waters usually have high concentrations of chloride whereas upland and mountain water sources have very low concentrations of the same. There are many ways in which chloride salts gain access to natural waters. The water with its high solubility dissolves chloride from topsoil and deeper formations. Spray from the ocean is carried inland as is carried inland as droplets or as minute salt crystals, which result from the evaporation of the water in the droplets. These sources constantly replenish the chloride in inland areas where they fall4. The presence of relatively high chloride concentration in fresh water (about 500 mg/L or more) may be an indication of sewage pollution. Salt (NaCl) used in foods, is excreted with body wastes; sewage carries these chlorides into the receiving waters. Chlorides from roadway deicing salts may enter the groundwater as well as streams and lakes.

Chloride in reasonable concentrations is not harmful to humans. At concentrations above 250 mg/l it gives a salty taste to water, which is objectionable to many people.

The chloride content of waters used for irrigation of agricultural crops is important since chloride content along with salinity at the root zone of irrigated plants makes it difficult for crops to take up water due to osmotic pressure differences between the water outside the plants and within the plant cells [Sawyer et al].

The chloride content in the leachate is very high and above the permissible limit and another sample, which is from an open well, is above the desirable limit as per IS 10500 standards for drinking water.

Nitrate as NO_3

Nitrates are nitrogen-bearing molecules that are essential for the formation of proteins in plants since plants other than legumes cannot absorb free nitrogen from the atmosphere. Proteins are made up of carbon, hydrogen, oxygen and nitrogen and are necessary for growth and development and for various metabolic processes. Hormones, enzymes and haemoglobin in humans are made up of proteins. Nitrates are added to the soil as fertilizers (ex: sodium nitrate and ammonium nitrate) to increase crop yield. Plants accumulate and retain the excess available nitrate in the soil in their tissues.

In doses between 5 to 10 mg/kg of bodyweight does not produce any significant toxic effects in humans. But at levels of 20mg/kg of bodyweight could be lethal. Rather than nitrate itself, the metabolic products of nitrates produce toxicity.

NO3 ------> NO2 ------> N2O2 ------> NH2OH ------> NH3

Nitrate Nitrite Nitric oxide Hydroxylamine Ammonia

Nitrite and Hydroxlamine are inducers of Methemoglobinemia. It is a condition wherein ferrous iron in the blood is oxidised and thereby loses its oxygen-carrying capacity which leads to hypoxia and death. Monogastric animals have relatively high tolerance to nitrate since reduction to nitrate in their bodies is minimal. Human babies are at a high risk of nitrite toxicity because they do not have free HCl in their stomach and therefore nitrate is readily reduced to nitrite by the bacteria in the stomach and the duodenum [Kannan 1991].

Sources of nitrate water apart from fertilizers are sewage, soil and mineral deposits [Nathanson 2003].

Fluoride as F

Fluroides such as HF, SiF_4 and H_2SiF_6 are emitted by phosphatic fertilizer manufacturing plants and aluminium reduction processes. Flouride-containing minerals are often used in and thus may be released from brick steel, glass, pottery, tile and ferro-enamel works. Fluoride as a particulate and HF as a gaseous air pollutant are highly toxic and irritating. Only a fraction of the fluoride entering the body is excreted and the a larger amount of it is retained in the body. Fluorides are mainly deposited in the body in bones and teeth. As soon as the skeleton is saturated with fluoride, it starts to accumulate in the soft tissues as well. Overdose of ppm fluorides i.e., 2 ppm levels in drinking water in temperate regions and 0.4-0.7 in tropical regions may lead to mottling of enamels and bones. Fluorides cause respiratory failure, fall in blood pressure and general paralysis. Continuous ingestion of non-fatal doses of fluorides causes permanent inhibition of growth. A few cases of 'crippling flurosis' have been reported in China and India at places where the surface water have been contaminated upto 10 ppm of fluoride. This type of fluorosis is characterised by hypermineralization of the skeleton, body outgrowths (exostoses) and calcificatio of ligaments. These conditions are followed by painful joints and immobilisation.

Many plants apricot, gladiolus, peach and prune are extremely sensitive to HF eve nat concentrations as low as 0.02-0.05 ppm. Orange and lemon rees exposed to fluoride emissions produce smaller yields while gladiolus turn brown or die on exposure to fluorides. More than 2 dozen plants are known to synthesize fluroacetate which is a highly toxic and is used in rodenticides.

Livestock have been the main victim of fluoride poisoning as a result of ingestion of contaminated vegetation. Natural background levels of fluorides in most freshwater streams are in the range of 0 to 0.2 ppm while other data show levels as high as 2-3 ppm may fairly be common in waters contaminated by human activities1.

The fluoride concentrations in the water sample are well within the permissible limit in all samples except the leachate where it is above the permissible limit.

Figure: 3-9 Smoke emanating from the dump

Phenolic Compounds as C_6H_5OH

Phenolic compounds are a class of chemical compounds consisting of a hydroxyl group (-OH) attached to an aromatic hydrocarbon group. Common examples of Phenolic compounds or phenols are phenol, BHT (butylated hydroxyltoluene, cresols, Xylenols, 4-Nonylphenol, picric acid, polyphenols etc. Phenolic Compounds are below the detection limit.

Transport of contamination in ground water

The subsurface movement of a contaminant is influenced by the moisture of content of the unsaturated zone. Non-reactive contaminants are transported by advection and hydrodynamic dispersion. Advection is the component of solute movement attributed to transport by the flowing ground water.

Hydrodynamic dispersion occurs as a result of mechanical mixing and diffusion. A continuous pollution source will produce a plume whereas a single point source will produce a slug that grows with time as the plume moves in the direction of groundwater flow. The chemical and biochemical reaction that can alter contaminant concentration in groundwater are acid-base reactions, solution-precipitation reactions, oxidation-reduction reactions, ion pairing or complexation, microbiological processes and radioactive decay. Adsorption attenuates or retards a dissolved contaminant in ground water.

Coliform bacteria

The presence of E.coli in water is used as an indicator of fecal contamination originating from the intestine of warm-blooded animals which includes humans. E.coli belongs to a class of bacteria called the coliform bacteria. The term Coliform bacteria includes the genera Escherichia and Aerobacter some of which are found even in soil. Therefore there is a presumptive and a confirmed test for the presence of the broad category of total coliforms and fecal coliforms respectively and a completed test for the presence of E.Coli. The MPN or Most Probable Number Test gives us an approximate number of coliform organisms present in a volume of water thereby indicating the extent of fecal contamination.

All the samples tested, except the control sample, show higher than permissible numbers of total coliform bacteria. As per standards under the IS 10500 only 10 coliforms per 100ml and those under US Water Quality Act (1965), only water with less than 50 coliforms per 100ml is suitable for drinking. This indicates the contamination of the water source by an outside source. However, all samples are negative for the presence of fecal coliforms and E.Coli. The contamination could be an indicator for the probable presence of other pathogenic bacteria.

Further study

The health problems faced by the residents of Mavallipura (since the dumping began) as found during the health camps conducted by FRLHT need to be studied more thoroughly. An epidemiological survey is immediately required in parallel with a thorough analysis of environmental parameters such as water quality, air quality and soil quality. Soil quality is important to plant life and soil microbiology. The consequences of heavy metal contamination can be felt not only through consumption of contaminated water but also by consuming plants that take up heavy metals.

Figure: 3-10 Solid waste segregation and processing unit under construction next to the dump

The dump has brought with it flies and other insects that have disturbed the ecology in the area and crop plants suffer the lack of pollinators. Large doses of pesticides have to be used so that crops can grow normally. Vultures and kites have also been introduced newly into the local ecology. How the dumping of waste has affected the ecology in the area and whether this change can cause a permanent damage needs to be studied.

Conclusion

There are many contaminants that can potentially contaminate the water sources as indicated by the very high levels of certain parameters in the leachate sample since it is through the leachate that the contaminants from the waste dump is likely to reach the water sources. In the report, such parameters that are above the permissible limits in one or more samples and those that can pose a serious health risk, such as bacterial infection and heavy metal contamination, are discussed in greater detail.

It is evident from the test results that there is contamination of ground water as surface water shown by the level of Cadmium in Mavallipura tank which is down stream from the leachate pond. The ground water samples as well as an open water sample that are used for drinking show only high coliforms numbers but do not show the presence of E.coli which implies that there is no contamination with sewage.

3.4. Mercury releases from coal fired power plant Raichur, Karnataka

Figure: 3-11 Raichur thermal power station

3.4.1. Introduction

Raichur Thermal Power Station is a pulverized coal based power plant run by Karnataka Power Corporation Limited (KPCL). Indian coals are known to have very high ash contents — almost 40-45 per cent. An estimated 100 million tonnes of fly ash are collectively generated from India's thermal power plants per year. Of this, 80 per cent is fly ash and 20 per cent bottom ash.

The coal for RTPS is obtained from Singareni coalmines in Andhra Pradesh and transported using railroad. The coal is then pulverized and fed into furnaces that convert water into steam. The steam runs the turbines to produce electricity. Currently, there are seven units with a peak capacity of 210 MW each. Each unit has its own cooling tower, which are visible from Raichur city. About one thousand million cubic feet of the required water is obtained from the Krishna River; although some of the water is recycled due to water shortage in the river. Typically, each unit produces about 5 MU per day and hence the capacity of a fully functioning RTPS is about 35 MU per day.

The thermal power plant was chosen to be in the Raichur area because of the area’s proximity to railroads and availability of water from the Krishna River. In addition, the land for the plant was cheaply available in Raichur. However, it is precisely because of the proximity of the plant to the city and to the river, that the environmental impacts of the plant have an adverse effect on human and river ecology in the area.

3.4.2. Coal for power plant

The Singareni coal has very high fly-ash content (30-40%). RTPS uses about 3200 tons of coal per unit per day. So each unit of RTPS generates 1280 tons of ash assuming an ash content of 40%, with a total generated ash of about 9000 tons per day and in the process generating about 1.5 million tonnes of fly ash annually. Twenty percent of this ash is wet bottom ash, which is simply let into the river as it is considered to be safer than fly ash. Thus, about 1800 tons of bottom ash is simply let loose into the nearby Krishna River every day at full operating conditions at RTPS. It is important to note that this ash usually contains trace heavy metals and radioactive elements that could be dangerous to public health.

The fly ash released during burning process of coal in thermal power plants disperses in air, which enters into the surrounding environment and known to pollute the surrounding area. Fly ash thus entered the environment deposits on leaves of trees, crop plants affecting the physiological process of the plants resulting in poor yield of the crop plants which in turn results in low returns to the farmers. The fly ash and heavy metals in it affects the health of human and livestock causing cancer, breathing problem by entering into the respiratory track of human beings and animals and skin diseases resulting in decreased work force.

The fly ash is precipitated out of the air by electrostatic elements in the furnaces. Some of the fly ash is being utilized by cement industries in north Karnataka. Although it works fairly well, about 2% of the ash gets into the atmosphere. But, around 180 tons of ash could be released into the atmosphere near Raichur every day. These suspended particles can affect respiratory health of humans and can lead to lung cancer and other respiratory disorders including silicosis. In addition mercury released from coal is largest cause of pollution in the region.

Table: 3-6 Chemical Composition of Indian Fly Ash

Constituent	Percentage Range (%)
Silica (SiO_2)	49-67
Alumia (Al_2O_3)	16-29
Iron Oxide (Fe_2O_3)	4-10
Calcium Oxide (CaO)	1-4
Magnesium Oxide (MgO)	0.2-2
Sulphur (SO_3)	0.1-2
Loss of Ignition	0.5-3.0

3.4.3. Management of Fly ash

RTPS, in collaboration with the Indo-Norwegian Environment Programme (INEP), has set up CASHUTEC, a technology demonstration centre, in Raichur. The centre aims to demonstrate the varied applications for fly ash in the construction sector including fly-ash bricks, blocks, interlocking pavers and mosaic tiles.

Table: 3-7 Ash Utilisation in RTPS[41]

2004-2005	64.82%
2003-2004	56.00%

The Centre for Ash Utilisation Technology and Environment Conservation (CASHUTEC), situated adjacent to the Raichur Thermal Power Station (RTPS), produces mosaic tiles using the same procedure as that for the conventional ones, the difference is in the ingredients used.

Figure: 3-12 Bagging Facility for fly ash transport to cement plants

Figure: 3-13 Bricks from fly ash

A significant quantity of fly ash is being used in place of cement; doing so, almost 30 per cent of cement has been saved without compromising on the tile quality. In fact, tests show that tiles made

[41] Source: Karnataka power corporation

with a mix of cement and fly ash are stronger than those made with cement alone, and can be used for heavy-duty floors as well.

The conventional method used to dispose both fly and bottom ash is to convert them into wet slurry, and dump them into specially built ash-ponds around the thermal plants. While this may solve immediate disposal needs, it is fraught with long-term environmental problems.

Fly ash is a very fine powder and is known to pollute air and water, cause respiratory problems when inhaled and reduce yields when it settles on leaves and crops in agriculture fields around the power plant.

Ash-ponds require large tracts of land that could otherwise be used for agriculture. Water consumption also goes up while converting ash to slurry. Dumping of fly ash pollutes groundwater, as it contains many salts and metals, which, when dissolved in rainwater, can contaminate the groundwater.

Although India has stringent policies to support the fly ash utilization and the established uses of fly ash, the overall fly ash utilisation in India stands at about 15 per cent of the quantity generated. Efforts are on to improve the situation according to authorities at RTPS.

3.4.4. The problem of mercury releases from Coal Fired Thermal Power Stations

A review of literature presents that the release of mercury from coal fired thermal power stations is indeed a major yet little recognized problem. This is particularly so in India, wherein, even today, regulatory agencies consistently deny the problems caused by mercury releases.

According to Mukherjee and Zevenhoven 2006, “at present, 80-90 million tons of fly ashes are generated from 85 existing coal based thermal power plants. Coal contains trace metals of which mercury is most toxic for humans and aquatic fauna. The problem of mercury in the society is not new, but in recent years the Indian subcontinent has gained the reputation of being "a dumping ground for mercury". This study focuses on mercury in fly ash and its releases to the atmosphere and soils cross the country. The utilisation of coal ash in India is also addressed although it is still in its nascent stage. About 10% of produced fly ashes are used in India whereas in Western countries its use is typically over 70%. Regulations from India's Ministry of Environment and Forestry should increase coal fly ash utilisation, although this would require that cost-effective new technology is put to use. As to the release of Hg from ashes disposed of in the environment, the scarce literature suggests that this is negligible or zero, and less problematic than wet or dry deposition of Hg from flue gases [Mukherjee and Zevenhoven 2006].

Even as this problem is study so minimally, it is a recognised fact that thermal power stations are the second largest emitters of mercury in India. As the coal is combusted, mercury gets vaporized and released into the atmosphere. Since there are no commercially viable mercury capture technologies, India by and large ignores the scale of this problem. The installed capacity of coal fired power plants has increased from just 800 MW in 1974 to 50,000 MW in 1995, and is set to expand by another 50,000 MW by 2010. Of the 250 million tones of coal annually, the 75 power plants in India account for over two thirds of the consumption. Though mercury is found in traces of 0.04 to 0.7 mg/kg, the large volumes consumed in power plants make it a significant hazardous pollutant.

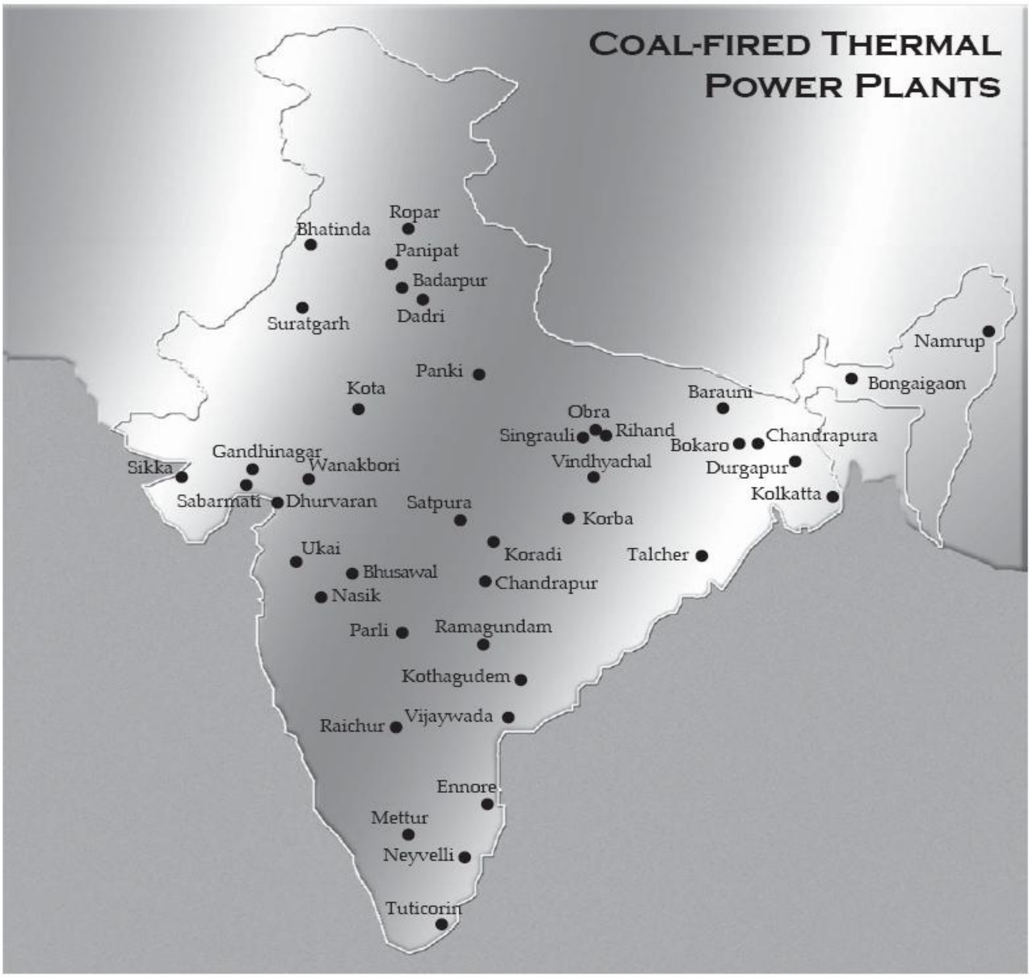

Figure: 3-14 Coal-Fired Thermal Power Plants in India[42]

According to a study entitled Mercury in India, by Toxics Link, the Central Pollution Control Board revealed that from the 11 coal samples analyses, mercury concentrations averaged 0.272 ppm (with ranges between 0.09 to 0.487 ppm). Even as this data is inadequate, the lack of a serious approach recognizing mercury as a significant hazardous pollutant from coal fired thermal power plants.

The US has recognized the high levels of threats from the release of mercury and has aggressively promoted mercury control programmes. There is also a widespread enactment of state and federal laws to contain mercury releases from coal fired power plants, an action that is also a result of lawsuits brought forward by environmental groups.

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[42] Source: Toxics Link, Mercury in India

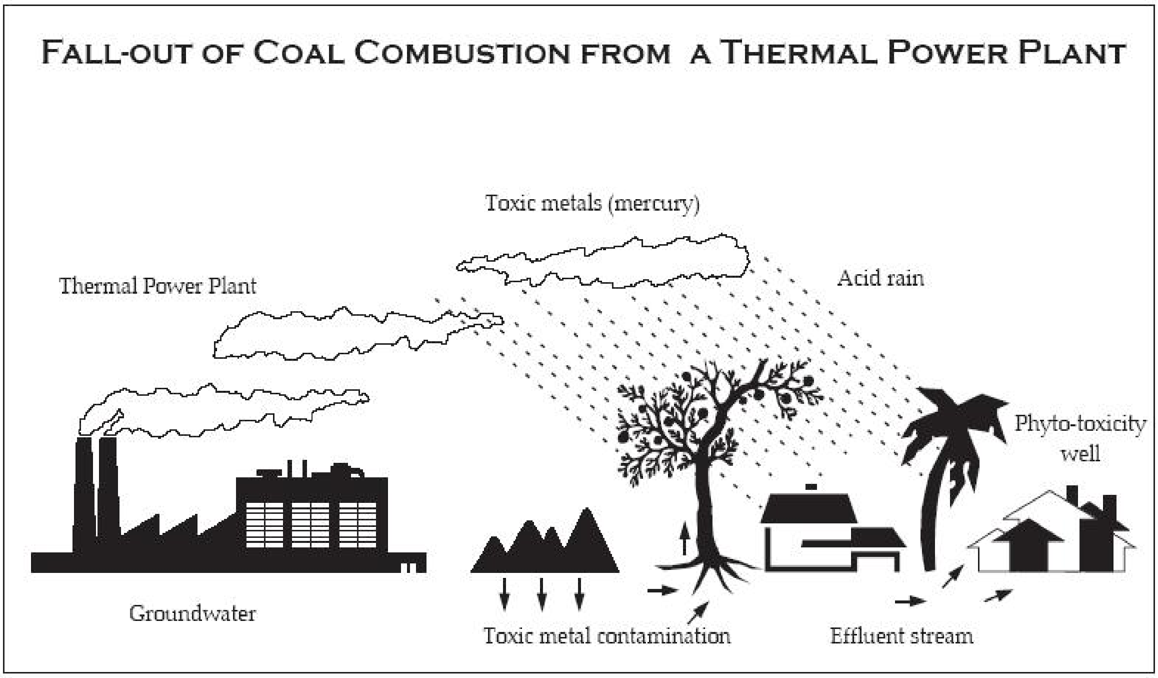

Figure: 3-15 Fall-out of coal combustion from a thermal power plant[43]

[43] Source: Toxics Link, Mercury of India

3.5. Electronic Waste Management Issues in India

3.5.1. Electronic Waste in Bangalore Karnataka

Bangalore, one of the biggest metropolitan areas of India has risen as a major hub of Information Technology. About a third of the USD 22 billion IT related software revenue generated in India, is from Bangalore. This has resulted in over 400 major companies being located here with up to 400,000 jobs being created directly linked to IT and IT enabled services. In addition to software production, BPO and related companies are registering in large numbers everyday. This has produced a huge burden in electronic waste being disposed from the discarded computers and electronic components.

ESG has been monitoring and documenting the current situation in Bangalore and many reports suggest that there is a serious problem with the management and disposal of the e-waste produced. With a constant upgrade of hardware to catch up with software developments, thousands of used computers are being phased out. In the lack of an organized system for management and disposal of these computers, the existing problem of other electronic wastes is being compounded manifold.

By some accounts it is estimated that up to 8,000 tonnes of only computer waste is being generated annually in Bangalore, and of this, only about 1,000 tonnes is being processed [Deccan Herald 2005] . Even here there is no room for comfort as only a third of the e-waste processed is being done in a thorough manner with the intention of recovery and reuse and minimal disposal after taking all environmental and occupational safety measures. E Parisara Pvt. Ltd, a e waste processing facility commissioned in 2005 has a capacity of 1 tonne/per day. At the same time in the highly unregulated informal sector, largely consisting of home based processing units, without any safeguards, over 2 tonnes of e-waste is being processed daily. This is exposing hundreds of families to high degrees of exposure to hazardous wastes and is potentially contaminating entire communities, especially in densely populated low income areas in the core city.

It is estimated that there could be more than 1000 different toxic substances harmful to human and animal life that are being released into the environment by such electronic waste. Iron, lead, mercury, nickel, cadmium, chromium, copper and a variety of plastics are being released into the environment, and the quantum disposed is expected to increase tenfold in the next fifteen years.

Currently regulation and proper disposal system are lacking and recyclers sell most second hand parts for reassembly or burn them in illegal dump yards near and outside residential areas of Bangalore. They even dispose them along with municipal waste. This releases toxic and carcinogenic substances into the air and water. For instance, barium found in e-waste, could damage the heart and liver while other chemicals such as beryllium found in computer motherboards and cadmium in chip resistors and semiconductors are poisonous and could lead to cancer. Chromium in floppy disks, lead in batteries and computer monitors and mercury in alkaline batteries and fluorescent lamps also pose severe health risks.

3.5.2. Legislative Framework and Electronic Waste

India is a signatory of the Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal, which came into force in 1992. The environmental stipulations in developed world have been by and large stringent. The EU's WEEE (waste from electrical and electronic equipment) directive makes for its member countries to compulsorily purchase minimum 75% used electronic goods from consumers within the EU area. Even countries in Asia viz. Japan, South Korea and Taiwan also have taken the similar steps.

The Basel Convention signed by several countries, including India, prohibits the export of hazardous material from OECD (an organization of 30 rich countries) member countries to the non-member countries, India being a non-member. Lead is one such material which is extensively used in soldering for PCBs. EU has already banned the use of lead based soldering from 1 Jan 2007 and in Japan it is already in force. It also compels manufacturers to use 50-60% recycled material in electronics.

While such strong measures are being adopted at the manufacturing end in order to minimise involvement of hazardous material, the problem in India is one of weak regulation and thus much needs to be achieved to reach such levels of regulation and management of e-waste.

In India, we have a host of environmental legislation that is intended to check indiscriminate disposal of wastes into environment and ensure the well being of human and other life on the earth. The acts that could be related to electronic waste are:

Public Liability Insurance Act 1991

This Act provides immediate relief to the person(s) adversely affected from an industrial accident. According to the Act, an industry handling any of the scheduled chemicals, beyond its given threshold quantity should take a compulsory insurance policy and the money should be used to provide compensation to the affected person.

Factories Act 1948 (amended till 1987)

This act provides for the maximum permissible limits of certain work environment pollutants that emanate from industrial activities. Accordingly there may be several contaminants arising out from manufacturing or recycling of electronic components and are listed in this Act. These listed contaminants may be ammonia, chlorine, chromic acid & chromates, copper fumes, ethylamine, fluorides, formaldehydes, HCl, hydrogen peroxide, lead, methyl alcohol, nitric acid, phosphoric acid, sodium hydroxide, sulfuric acid, toluene and trichloroethylene. However the enforcement of the rules is very poor in India and there are very few industries who really monitor these levels in their work environment.

Environment Protection Rules 1986 (amended till 2004)

There is no direct standard, which can address pollutants from an electronics manufacturing or recycling industries. Currently, some drafts for regulation of electronic waste in India are being reviewed. However certain PCB units fall in electroplating category and are therefore required to abide by the effluent disposal norms as given in Schedule I of Environmental Impact Assessment Notification. The parameters covered under these rules for their maximum permissible limits are the pH, temperature, oil & grease, suspended solids, cyanide, ammonical nitrogen, total residual chlorides, cadmium, nickel, zinc, hexavalent chromium, total chromium, copper, lead, iron and total metal. But to a large extent electroplating industries remain unmonitored, and their compliance has not at all been rigorously addressed by the regulatory agencies.

The Hazardous Waste (Management & Handling) Rules, 2003

This deals with handling and disposal of toxic and hazardous wastes generated from electronic component manufacturing. Apart from these, there are no specific regulations for disposal of e-waste in force. Even the salvage and recycling operations are not regulated which is primarily responsible for the environmental damage that is caused by e-waste. Landfilling of e-waste is also unregulated which results in their being disposed off in municipal landfills which in turn leads to leaching of toxic and hazardous materials to the soil and groundwater.

3.5.3. Case study under SACODI Initiative: E-Parisara

E-Parisara is a Private recycling unit set up by Mr. P. Parthasarathy with technical support from the scientists of Indian Institute of Science, Bangalore. It is situated in a 2 acre plot at Dobbspet Industrial area which is about 35 kms north of Bangalore. Close to this processing facility is the proposed hazardous waste disposal site of the Karnataka State Pollution Control Board, being established in collaboration with GTZ of Germany.

E-Parisara is a completely organized centre for disassembling a variety of e waste. It primarily secures its ewaste from eight IT companies in Bangalore. The companies are Sony, IBM, Tata Elexsi, Philips, ABB, Lucent Technologies, GE and also Bosch. While these companies in Europe and elsewhere provide their e-waste free to the processing centres, they do so on commercial terms to E-Parisara. As a result E-Parisara has to buy the e-waste from these companies for a nominal amount based on contractual agreements. Interestingly, the largest IT companies in India, such as Infosys and Wipro, do not avail of E-Parisara services, and it is unclear whether they have any proper processing facilities for the waste they generate.

E-Parisara has organized its various tasks to ensure high efficiencies of recovery of various metals and materials. As a result the need to dispose hazardous materials is minimized. The unit employs about 35 people, most of who are from the neighbouring villages, and not skilled. The effort has been to impart skills illiterate or semi-literate men and women, and thus provide them livelihood options. In fact, rather than going into a high degree of mechanization, which is expensive, the choice here has been to develop indigenous processes which are labour intensive, but safe. Regular medical check ups are mandatory for all employees and they are all provided with safety equipment like gloves, masks and visors and ear muffs (in noisy situations) as protective measures.

There are clear sections involved in the overall process. Units involve breakdown of motherboards, processing of mobile phones, breakdown of Cathode Ray Tubes in closed chambers, recovery of precious metals in processes involving chemical and mechanical separation, hazardous elements such as Nickel, Cadmium and also steel, glass, plastics and metals like aluminium.

As there is no scientific disposal site for hazardous waste yet, E-Parisara is collecting the hazardous waste and holding it with them till HAWA (Hazardous Waste Management Project of KSPCB supported by German Technical Cooperation (GTZ)) set up an hazardous waste disposal unit here in the same industrial area of Dobbspet.

In the setting up of this facility, against normal expectations, Mr. P. Parthasarathy did not receive much help from financial institutions and the government. Financial institutions were wary about the feasibility of this project, especially as there were no precedents in the country. Government regulatory institutions were a bit lethargic as there was no law mandating regulation of e-waste. It was by sheer persuasion that he has managed to convince various authorities in supporting his venture and it now remains a major centre for learning and research on the processing, recovery and disposal of e-waste in India.

3.5.4. Background note on environmental management for electronic waste in India

Introduction

With the advent in information technology, there has been a manifold increase in the pace of all activities of our life. While on one hand electronic communication has saved environment by dramatically reducing paper usage, on the other, it has also caused widespread environmental damage due to the use of toxic materials in the manufacture of electronic goods. Almost all electronic equipments used nowadays, be it the computers, TV sets, VCRs, CD players, cellular phones, stereos, fax machines, copiers, or microwave ovens use a variety of thousands of small electronic/electrical components for their manufacture and the waste thus arising during their manufacture or disposal is of great environmental concern.

What is e-waste

The electronic waste can arise from two sources:

1. From the manufacturing of electronic components such as PCB (printed circuit board), semiconductors, capacitors, CRT (cathode ray tube) glass and picture tubes, electro galvanized audio parts, PVC/metal sheets etc.
2. From the disposal of used electronic equipments and the components used in it.

The first category may cause problem due to disposal of spent chemicals into environment in various forms whereas the second one poses threat due to unscientific destruction and disposal of expired electronic goods.

Need for e-waste Management

Almost all electronic components use persistent bio-accumulative toxins and heavy metals such as zinc, copper, cadmium, mercury, barium, asbestos, tin plates, arsenic, PVC, lead, and cadmium as one of their ingredients. Different types of hazardous solvents and chemicals such as formaldehyde, EDTA, other acids & alkalis, various gases, epoxy resin, etc. are used in the manufacturing process. The residuals of these toxins, through ground/surface water, ambient air or food chain, reach our body system and pose a far reaching impact on internal organs such as lungs, kidneys, central and peripheral nervous systems and may also cause birth defects, asthmatic bronchitis, cancer, acute and chronic effects etc. to name a few. The environmental health significance and the bodily organs affected by commonly found contaminants in electronic units are given as under:

Lead:	Brain, kidney and reproductive system, convulsions in later life
Mercury:	Heart, brain, CNS, kidney; known to cause Minimata Disaster in Japan
Cadmium:	Kidney, flu like disorder, high BP, sterility among males; known to cause Itai-Itai disease in Japan
Barium	Muscular and Cardiovascular disorder, kidney damage
Chromium:	Skin disorder, liver damage, known to be carcinogenic
Copper:	Toxic to aquatic life and microorganisms
Nickel/cobalt:	Carcinogenic
Silver:	Darkening of the skin and eyes
Zinc:	Bad taste
Solvents:	Mostly Carcinogenic
Cyanide:	Highly toxic

Apart from having a damaging effect on human health, it is important to realize the effects of these toxicants on the entire biological ecosystem. Accumulation of toxins in the biological systems could accelerate the extinction of species which ultimately would impact the future of the human race on earth.

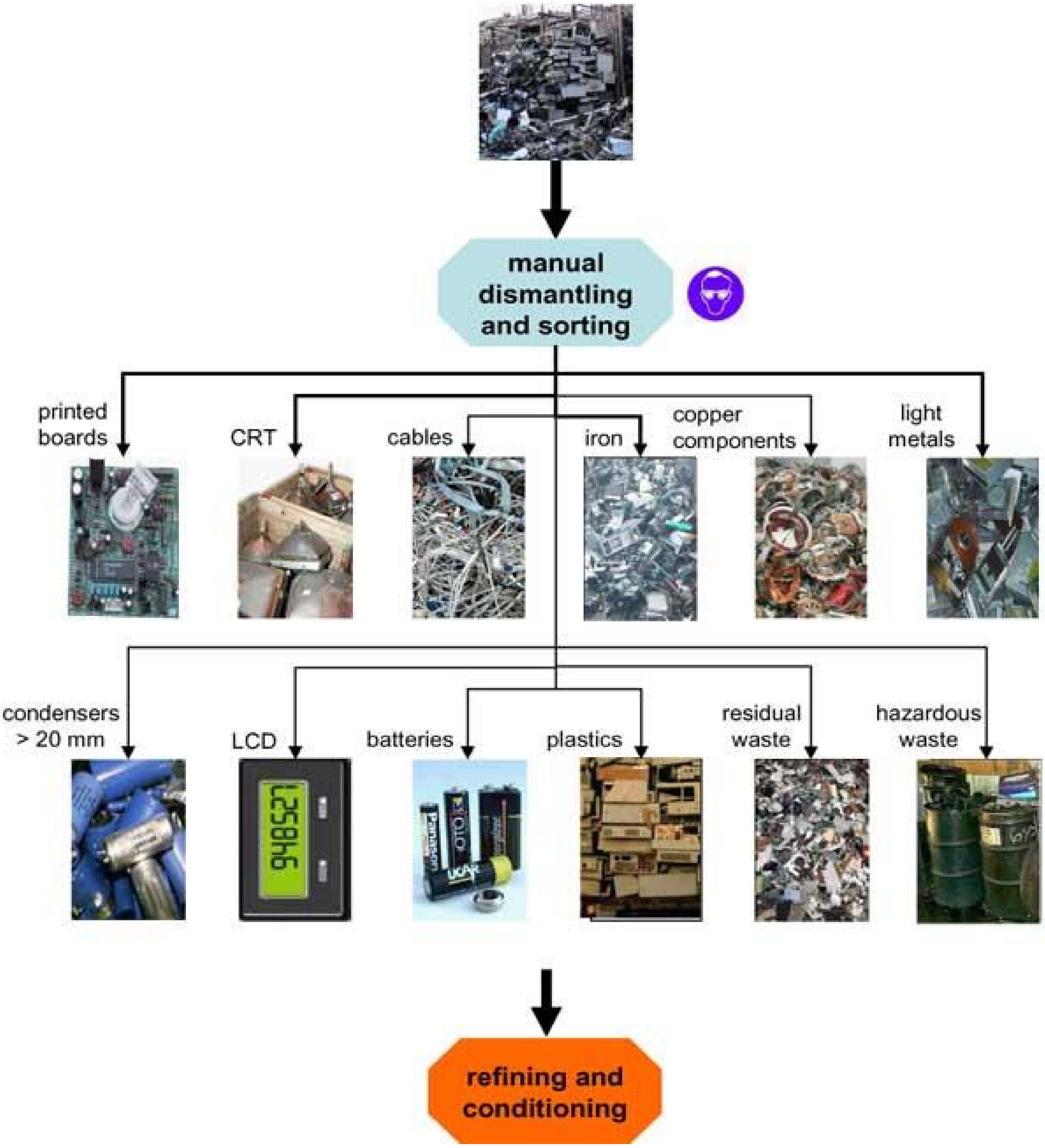

Figure: 3-16 Manual Sorting of Electronic Waste[44]

Sources of e-waste

The industries involved in manufacturing components for electronic industries such as semiconductors, PCB, cathode ray tube, etc. use hazardous and toxic chemicals for processing the

[44] Source: EMPA

goods. The excess, un-reacted amount of chemicals generated from process makes the e waste. Though the industries involved in making these components are in organized sector, the lack of modern manufacturing technologies, awareness among facility operators, inadequate government policies and poor enforcement of environmental regulation in the country, the untreated e-waste quite often finds its easy way into the environment.

Another type of e waste comes from electronics recycling industries. The salvage operations of used electronic equipments and in turn their inbuilt components are primarily done by unorganized & unauthorized small units in India, mainly because of cheap labour abundance. According to an estimate, India has close to 2 million obsolete computers currently and this figure counts to be 315 million for world over. The computer parts such as monitor, keyboard, CPU, floppy drive carry precious materials such as gold, silver, copper, platinum, lead, cadmium and mercury which attract the attention of recyclers for their economic value (there is predominantly lead and cadmium in PCB; lead oxide and barium in monitors and cathode ray tube; mercury in switches and flat screens; brominated fire retardants in PCB, plastic casings, cables & PVC insulation; cadmium in batteries; PCB (polychlorinated biphenyl) in older capacitors & transformers). The salvage operations by way of hammering, burning and acid application gives rise to undesirable pollutants in liquid, gaseous and solid forms, besides exposing workers to inhumane and unsafe conditions.

In addition to the domestic production of electronic scrap, a huge quantity of used (usually obsolete) electronic equipments especially the PCs are received from some developed countries like the US and also the Middle East on pretext of charity which soon lands up as a backyard waste. The cheap quality ‘use & throw’ type electrical and electronic items especially from China is also compounding to the problem. According to an estimate, the average waste generation per computer is:

Lead: 1.75 kg/computer

Cadmium: 2.8 g/computer

Mercury: 0.57 g/computer

As discussed earlier, the electronic industry offers environmental threat at two stages, one during manufacture of small, tiny electronic components and the two during their ‘end of life disposal’. This section therefore discusses the possible control measures that an industry can take up in order to safeguard its environment in both the stages.

Cleaner Technologies in Manufacturing:

Most of the Indian PCB industries use electroless copper plating for plating through holes in PCB sheet. The process employs hazardous chemical like formaldehyde and EDTA (chelating agent), involves more number of chemical sub processes and hence more ware rinses. Carbon or black hole technology is one of the several environment friendly alternatives available for this process. This process does not require the use of hazardous chemicals or chelating agents, avoids multiple sub processes and thus lesser water rinses. All this makes the technology more productive and economical. In case of multi-layer PCB, the drilled holes are cleaned to prepare them for plating. Epoxy polymer smear left in the holes is then oxidized and removed with the help of permanganate solution, which generates manganese dioxide sludge. However the permanganate from this sludge can be regenerated by oxidation of manganate using electrolysis or ion transfer.

In semiconductor manufacturing, RCA 1 & 2, which is an ODS, is used as cleaning agent to remove organic impurities. This if replaced by ozonated cleaning, will save heavy amount of water and can pay back in two years.

Solder stripping is another area where lead needs to be prevented from going into the environment. The bath can be subjected to diffusion dialysis for recovery of acid contaminated with metal that enhances the bath life and reduces the pollution load. The diffusion dialysis process separates acid from its metallic contaminants.

In CRT glass industry, CRT panel contains lead, arsenic and fluorine as raw materials. A technology has now been developed which does not use these elements and moreover heavily reduces the generation of furnace slag and particulate emission.

All the industries with conventional technology use large quantity of water for rinsing operations. The metal recovery by means of ion exchange process or reverse osmosis can not only save in the cost of raw material but can also save on huge quantity of water. Similarly energy conservation also has a good opportunity in these industries. Energy efficient lamps, natural illumination, excess heat recovery, de-rating motors, using variable speed motors instead of fixed speed, optimizing process requirements etc. can save reasonable amount of energy. Thus the minor process modifications or practicing cleaner technologies in these industries can help them reduce water and power consumption both. Better technological alternatives like liquid crystallized displays and plasma screens can further help reducing waste and save water and energy.

Close operational control also proves to be very useful in improving the efficiency of manufacturing system. Practices to be implemented include close process supervision, preventive maintenance, efficient material handling, waste segregation and pre-treatment and overall monitoring. Good design of equipment, substitution of chemicals, cleaner technologies, appropriate checklists, internal guidelines, training to staff, their motivation etc. can also prove to be very useful.

Cleaner Technologies at Disposal Stage:

Several companies are involved in taking utmost care to use environment friendly technology at manufacturing stage itself and are running R&D programmes to find substitutes for hazardous substances further. At the same time there are companies like Intel, Nokia, HP who buy back the used material and send it for authorized recycling.

There are also dedicated companies now who take this menace as a business opportunity and have set up plants to recycle electronic waste. There are different technologies practiced to recycle waste. In one of the technologies, scrap is sorted manually, sheared mechanically, reacted chemically and exposed thermally to recover the useful material. The scrap is subjected to temperature up to 800° C so that even the tough plastics are also melting. Compatalizers are added to enable polymers make the new products. In another technology called Ultra High Shearing, the scrap is subjected to very high mechanical shearing so that the chemical bonds between different polymers are broken beyond its limit of incompatibility to form new polymers. This technology has advantage of avoiding use of chemical. The technologies are further been developed. However in any of the technology, foolproof destruction of confidential R&D information, proprietary software and similar type of hardware is ensured.

Suggested Measures

So far we have found that a large quantity of waste is generated during manufacturing of electronic components, which is dominated by SMEs in India. However these SMEs may not always be interested to invest in cleaner technologies or stringent operational control mainly due to the three reasons: (a) lax enforcement of environmental law in India; (b) stiff competition and rapid decline in price of white goods in market (c) lack of awareness on investment returns from environmental management. Therefore following recommendations needs to be adopted by the small, medium & large industries and the regulatory bodies:

- SMEs or industries involved in manufacturing of electronic equipments should carry out environmental assessments of their entire system before freezing their design or starting their operations or even during the manufacturing stage to explore possibility of waste minimization and resource conservation.
- The concept of 4 R (reduce, reuse, recover and recycle) should be popularized amongst manufacturers and consumers.
- Eco labeling of electronic components/items should be introduced. Fiscal benefits can be given to those complying or penalty can be levied to those not complying.
- Buy back for old electronic equipments should be made mandatory using market based instruments. Large companies should purchase the used equipments back from customers and ensure proper treatment and disposal of sludge by authorized reprocessor only. They should also give an account of the waste being generated by their ’Exchange Offers’ to State Pollution Control Boards.
- Large companies, manufacturing final products such as PC, TV, refrigerators etc. are more into assembling various electronic components. They are not involved in manufacture of basic components (PCB, CRT, semiconductor etc.), which indeed is a potentially polluting process and is

done by SMEs. These large industries should opt for green concepts in their supply chain and the life cycle concepts and should purchase the components from environmental friendly process/industry only.

- Environmental Tax can be levied on electronic equipments, which can be used for investing in technology up-gradation in electronic components manufacturing units (mostly SME) and developing common hazardous waste TSDF (treatment, storage and disposal facility) for them.
- Local authorities should be made aware and trained on the gravity of unauthorized waste recycling.
- Importing computers and other white goods for charity or reuse in India should be prohibited as the chances of their misuse
- The expanse of pollution control technologies permitted for depreciation (for income tax purpose) should be expanded so as to encourage industries investing more on pollution control.

Table: 3-8 Hazardous materials in e-waste

Substances	Occurrence In E-waste	Health Hazardous
Polychlorinated Biphenyls	Condensers, Transformers	Causes cancer, damages the immune, reproductive and endocrine systems.
Tetra Bromo Biphenol (TBBA)	Fire retardants for plastics (Thermoplastic components, cable insulation)	Can cause long term health problems.
Ploybrominated Biphenyls (PBB)	It is the most widely used flame retardant in printed wiring boards and covers for components.	Acutely poisonous when burned.
Polybrominated Diphenyl Ethers (PBDE)	Found in many products in most homes and businesses, including furniture, TVs, stereos, computers.	Can cause long term health problems.
CFC	Found in cooling units	Combustion of halogenated substances may cause toxic emissions hazardous to human health.
PVC	Cable insulation	Burning of cables may release chlorine, which is converted to dioxins and furans.
Arsenic	Small quantities in the form of gallium arsenide within light emitting diodes	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer
Barium	Getters in CRT	May release explosive gases like hydrogen if wetted
Beryllium	Power supply boxes which contain silicon controlled rectifiers and beamline	Long term exposure to beryllium can increase the risk of developing lung cancer in people. Long term exposure

Substances	Occurrence In E-waste	Health Hazardous
	components.	to Beryllium causes an inflammatory reaction in the respiratory system. This condition is called chronic beryllium disease (CBD)
Cadmium	Found in rechargeable NiCd batteries, fluorescent layer in CRT screens, printer inks and toners, photocopying machines (photodrums)	Acutely poisonous and injurious to health.
Chromium VI	Data types, floppy disks	Acutely poisonous, long term health problems and allergic reactions.
Gallium Arsenide	LED, light emission diode	It is considered highly toxic and carcinogenic.
Lead	Found in CRT screens, batteries, printing wiring boards	It damages the nervous, circulatory systems, the kidneys and also causes disabilities in children.
Lithium	Lithium batteries	Releases explosive gases like hydrogen when wetted.
Mercury	Found in fluorescent layers, LCDs, alkaline batteries and mercury wetted switches.	Causes long term health problems.
Nickel	Found in rechargeable NiCd batteries or NiMh batteries and electron gun in CRTs	May cause allergic reactions
Rare Earth Elements like Yttrium and Europium	Found in the fluorescent layer of CRT screens.	Causes irritation of the skin and eyes.
Selenium	Found in old photocopying machines.	Has adverse health effects.
Zinc Sulphide	Interior of CRT screens.	Zinc Sulphide among other compounds of Zinc is known to be the main cause of metal fume fever. Among its symptoms are headache, fever, chills, muscle aches and vomiting. Metal fume fever occurs in workplace environments involving welding, melting and smelting processes. The fume is irritating to the upper respiratory tract
Toner Dust	Found in toner cartridges for laser printers/copiers.	Causes health risks when dust is inhaled.

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3.6.2. Indian Laws and international conventions

Indian laws

Atomic Energy Act, 1962

Batteries (Management and Handling) Rules, 2001

Bio-Medical Waste (Management and Handling) Rules, 1998

Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996

Customs Act, 1962

Environment (Protection) Act, 1986

Environment (Protection) Rules, 1986 (amended till 2004)

Factories Act 1948 (amended till 1987):

Hazardous Wastes (Management and Handling) Rules, 1989

Hazardous Waste (Management and Handling) Amending Rules, 2000

Hazardous Waste (Management and Handling) Amending Rules, 2003

Manufacture, Storage and Import of Hazardous Chemical Rules, 1989

Merchant Shipping Act, 1958

Municipal Solid Wastes (Management and Handling) Rules, 2000

Public Liability Insurance Act, 1991

Recycled Plastics Manufacture and Usage Rules, 1999

Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro-Organisms Genetically Engineered Organisms or Cells, 1989

Water (Prevention and Control of Pollution) Act, 1974

Relevant international conventions

Basel convention http://www.basel.int

International Convention for the Control and Management of Ships' Ballast Water and Sediments

Rio Declaration on Environment and Development

Stockholm Convention on Persistent Organic Pollutants, 2001

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

4. Hazardous waste situation in Vietnam

4.1. Economic development and some industrial indicators

Rapid economic growth

Vietnam is a country with an area of approx 329,000 km^2. It has a fast growing population of approx. 82 million (average growth rate of 1.5%/year). 75% of the population live in rural and 25% in urban areas.

In 2004 GDP per capita in the year was 553 USD. Thereby the economy enjoys a rapid economic growth. The following table gives an overview of growth rates in different sectors.

Table: 4-1 Growth rate in year 2001-2005 of industry sector (1994's fixed cost)[45]

Industrial sector	Growth rate (%)
Total	12.45
Exploration Industry	9.61
Basic Industry	16.44
1. Mechanical	18.47
2. Metallurgy	10.67
3. Electronic and Information Tech.	18.90
4. Chemical	14.17
Agriculture, forestry and aquatic processing Industries	8.64
Textile & Garment and Leather & Shoes	14.14
Construction material Industries	11.58
Electricity, gas and supply water	13.78
Other Industry	8.07

Potential of the industrial resources

Industrial production in 2005 still, maintains a higher growth rate over the yearly plan and of recent years. Industrial output value at 1994 constant prices was estimated to be increasing by 17.2% against the last year, of which state owned enterprises increased by 8.7%, non-state and FDI (Foreign Direct Investment) sector by 20.9% (oil and gas fell by 4.6%, others rose by 28.1%). The following table gives an overview of the structure of the economy:

[45] [Ministry of Industry]

Table: 4-2 The GDP structure from 1994 to 2003, by economic sectors[46]

Economic Sector	1994	1995	2000	2001	2002	2003
Total	100.00	100.00	100.00	100.00	100.00	100.00
State Economy	40.12	40.18	38.53	38.4	38.31	38.00
Collective Economy	10.17	10.06	8.58	8.06	7.98	7.76
Private Economy	3.06	3.12	3.38	3.73	3.93	4.00
Individual Economy	35.86	36.02	32.31	31.84	31.42	33.00
Mixed Economy	4.38	4.32	3.92	4.22	4.45	3.14
Foreign Invested Economy	8.41	6.30	13.30	13.75	13.90	14.10

Production of main industrial products like pure coal, processed seafood, tinned milk, chemical fertilizer, floor tiles, rolled steel, electric cables, machine tools, assembled automobiles and electricity increased rapidly in 2004. Production of some items raised at a range of 10-15% against last year: ready-made garments, paper and paper boards, cement, assembled motorbikes, beer. Besides that, output of some products decreased in 2004: crude oil; liquidized gas; sugar; molasses; assembled television sets; bicycles.

Table: 4-3 Main industrial products in Vietnam[47]

Industrial sector	Unit	2000	2001	2002	2003	2004 (prel.)
Insecticides	ton	20948	23921	33617	40949	44277
Chemical fertilizer	1000 ton	1210	1270	1158	1294	1453
Soap	1000 ton	276	326	361	377	460
Cement	1000 ton	13298	16073	21121	24127	25329
Tile sheet	1000 m^2	21391	43522	51130	55630	56000
Steel	1000 ton	1583	1914	2503	2954	2929

In many sectors small and medium sized enterprises play an important role. The following table gives some data for the industries covered in this report.

[46] [Statistical Yearbook Vietnam 2004]

[47] [Statistical Yearbook Vietnam 2004]

Table: 4-4 Number of enterprises as of 31 dec. 2003, by number of employees in Vietnam[48]

	Total	**By size of employees (person)**								
		<5	5-9	10-49	50-199	200-299	300-499	500-999	1000-4999	>5000
Manufacture of chemicals and chemical products	759	46	129	314	173	32	32	25	8	
Manufacture of other non-metallic mineral products	1385	25	142	572	382	76	92	66	30	
Manufacture of metal	267	4	26	132	76	12	9	4	3	1
Manufacture of metal products	1573	70	314	839	260	33	26	22	9	
Construction	9717	514	1615	4768	1924	261	277	239	115	4
Sale, maintenance and repair of motor vehicles and motorcycles	5360	2090	1997	1113	128	10	11	9	2	

4.2. Waste Generation

There is no classification of hazardous waste in Vietnam. The major part is not treated or treated in a very simple and insufficient way or put in a municipal landfill. In general, there is a distinction between two main groups: industrial hazardous waste and health care waste. [UNEP 2001, Vietnam].

Statistical data of 4 big cities Ha Noi, Hai Phong, Da Nang and Ho Chi Minh City show, that 15-26% of the municipal waste are of industrial waste and 35-41% are of hazardous wastes. The „Centre for Research- Investment Consult for Rural Development“ estimates the amount of industrial hazardous waste in Vietnam as 2,574 tons/day in the year 1999. This means a constant increase from 1997 (1,930 tons/day) and 1998 (2,200 tons/day). [UNEP 2001, Vietnam]. Table: 4-5 shows generation of hazardous waste for selected important industries cities, and selected industrial sectors. It shows that Light industry generates an important amount of hazardous waste (56,261 tons/year). Furthermore, mechanical and chemical industries produce 20,469 tons/year and 17,941 tons/year of hazardous waste. Total of industrial hazardous waste for these regions is 109,468 tons/year. For the whole Vietnam, the total is given (by this source with 939,510 tons/year).

48 [Statistical Yearbook Vietnam 2004]

Table: 4-5 Industrial hazardous waste in Vietnam in tons/year in 1998[49]

City	Electrical/ Electronic industry	Mechanical industry	Chemical industry	Light industry	Food processing	Others	Total
Ha Noi	1,801	5,005	7,333	2,242	87	1,640	18,108
Hai Phong	58	558	3,300	270	51	420	4,657
Quang Ninh	-	15	-	-	-	-	15
Da Nang	-	1,622	73	32	36	170	1,933
Quang Nam	-	1,554	-	-	10	219	1,783
Quang Ngai	-	-	-	10	36	40	86
Ho Chi Minh City	27	7,506	5,571	25,002	2,026	6,040	46,172
Dong Nai	50	3,330	1,029	28,614	200	1,661	34,884
Ba Ria - Vung Tau	-	879	635	91	128	97	1830
Total	1,936	20,469	17,941	56,261	2,574	10,287	109,468

Reasons for the huge hazardous waste production are rather due to the outdated technology that is widely used and stems often from Soviet times or is cheap technology from China. Besides, an inefficient use of raw materials also causes a lot of hazardous waste.

70% of industries use technologies that are 20 years or older and only a very small part of factories uses waste treatment [Palladino, 2001]. The lack of capital prevents investment in modern waste treatment plants and improvement of technologies. There are laws that prohibit the import of outdated technologies that do not meet environmental standards, but nevertheless the industry buys partly second-hand technology from abroad. So, it is estimated that about 50% of industrial supply is second-hand. Only, 20% of companies modernised their technology [Palladino, 2001].

With the economic growth, waste from households, industries, commercial enterprises, and hospitals is expected to increase rapidly over the next decade.

According to the information from Solid Waste Management Office in Ho Chi Minh City, every day Ho Chi Minh City produce 5,000-5,200 tons solid urban waste, 700-1,200 tons construction solid, 1,000 tons of industrial waste in which 120-150 tons are hazardous waste, 7-9 tons of health care waste. Mr. Le Trung Tuan Anh, Vice Head of HCM Solid Waste Management Office said: “ Urban Solid waste increase 10-15 % per year, it makes budget for treating and handling waste increasing per year" [VN Express 2005]. The following table gives an overview of waste generation in Vietnam. Because of rapid economic growth this numbers are, likely, not to be up to date.

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49 [UNEP 2001, Vietnam]

Table: 4-6 Solid waste generation in Vietnam[50]

Municipal solid waste generation (tons/year) Urban Rural	12,800,000 6,400,000 6,400,000
Industrial waste Hazardous waste generation by industries (ton/year) Non- hazardous waste generation by industries (ton/year)	2,638,000 128,000 2,510,000
Hazardous healthcare waste generation (ton/year)	21,000
Hazardous waste from agriculture (ton/year)	8,600
Amount of stockpiled agricultural chemical (ton)	37,000
Municipal waste generation (kg/pers./day) National Urban areas Rural areas	 0.4 0.7 0.3
Number of solid waste disposal facilities· Dumps and poorly operated landfills· Sanitary landfills	 74 17
Capacity for hazardous healthcare waste treatment (% of total)	50%

Waste collection in cities is improving, but is limited in rural and poor areas. In urban areas an average of 71% of the waste is collected, while in rural areas collection rates are typically less than 20%.

4.3. Environment protection policies regarding to un-precedented economic growth

4.3.1. Environmental management instruments in Vietnam

Regulatory instruments

The first draft of the Law on Environmental Protection (LEP) was written in 1991 as a result of a government project which was supported by IUCN (The International Union for the Conservation of Nature and Natural Resources) Law Centre in Bonn (Germany). The LEP was submitted to the National Assembly by the National Environment Agency (NEA), adopted on 27 December 1993, and was enacted in January 1994 by Decision 29L/CTN of the President of State. The LEP has 7 chapters and 55 articles. The Law gives the general provision and describes measures to prevent and remedy environmental pollution and degradation. It describes the responsibilities and duties with regard to the environmental management of MOSTE, at central level and of the People's Committees at provincial level. The LEP calls for international collaboration and makes provisions for implementation and for

[50] Vietnam Environment Monitor 2004-solid waste

dealing with violation of the law. Other environmental legal initiatives include government decrees, ordinances, interministerial circulars, guidelines and other by-law documents.

Other policy documents have continuously been developed as one of the priorities. For example, the NEA has reviewed the draft of National Conservation Strategy (1985) and has prepared the proposal for a new National Conservation Strategy. In 1990, the National Plan for Environment and Sustainable Development (NPESD) was prepared and this plan was approved in 1991. The Plan was to provide the gradual development of a comprehensive framework for environmental planning and management and to propose specific actions to address priority areas. Four years later, Vietnam prepared a draft National Environmental Action Plan (NEAP) which was build on the NPESD. The NEAP addresses the growing industrial development and urbanisation in the country. Vietnam ratified the Convention on Biodiversity in 1993. After that, the Biodiversity Action Plan for Vietnam was approved by the Government in December 1995. On the international side, Vietnam is among the countries in the region which have ratified the largest number of international environmental treaties. However, the implementation of these international treaties needs further improvement and better coordination.

A set of national environmental standards and indicators has gradually been developed. To date there are 35 standards on water, 20 on air, 11 on soil, and 4 on noise. Effluent standards and the implementation of ISO 14000 are being prepared. These standards are to be applied nationwide and to serve as a national guideline for the National Monitoring System. Today, the system consists of 13 stations, including 1 station for ground environment and 6 integrated environmental monitoring stations. These 7 stations are in charge of collecting data in every 3 months and report to NEA, which is responsible for the preparation of the annual State of Environment Report to be submitted to the National Assembly. Others stations are: for the far sea (1), soil quality (2), acid rain (1), toxic and radioactive chemicals (1), and environmental analyses lab (1). There is a provision to establish 4 more specific stations and 10 provincial stations to be included in the national system.

With regard to activities in EIA (Energy Information Administration), the Government manages to promulgate legal EIA requirements for new projects and environmental audit for the old plants which were established before the LEP. Furthermore, NEA has prepared a number of sectoral EIA guidelines and a guideline for waste management and pollution control, partly with an assistance from the Asian Development Bank (ADB). Further development of guidelines and methods for pollution control and inspection, as well as improvement of EIA reviewing procedure are needed.

Economic instruments

The Government authority for environmental management, NEA, is committed to promoting market-based instruments parallel to the traditional administrative ones.

During the last decade, the Government has been providing grants for a large number of R&D projects, education and awareness raising programs. Several environment-oriented taxation programs have recently been considered for application (e.g. tax reduction for import and/or installation of clean technology, taxes on forest and mineral resources etc.), while the many subsidies on chemical fertilisers and pesticides have been removed.

There are several specific funds which have some similar features with an environmental fund, such as funds for reforestation, proposed funds for coal mining and oil spill contingency. NEA is now moving towards the establishment of a National Reserve Fund and is also preparing itself to be ready for guiding sectoral and provincial environmental funds.

The question of setting up, collecting, and using environmental fees and charges is still under discussion as there are many difficult technical issues which need to be resolved.

NEA and most of provincial Departments of Science, Technology and Environment (DOSTEs) have achieved first results in imposing penalties on violations against environmental law and regulations. Since April 1996, after the Government Decree 26/CP on environmental fines was enacted, NEA and DOSTEs have imposed fines amounting to about USD 50,000 throughout the country.

The problem of defining property rights as an incentive for long-term and sustainable use of the environment and natural resources still needs more attention and further development.

The need for introduction of economic instruments is reflected in the LEP, which requires, that, organisations using the environment "contribute financially to environmental protection". In order to achieve this task, three criteria have been proposed to the government for choosing economic instruments, namely, selection of priority polluting industries, compatibility with regulatory instruments, and institutional capacity and administrative feasibility.

Communicative instruments

Raising public awareness and improving the quality of environmental education and training have long been among the highest priorities of the Government. Nevertheless, this should be designed and implemented in a more efficient way than it is now. Public participation and the involvement of NGOs are not active enough to carry out the supervising and monitoring functions on behalf of the society.

Although the mass media has, recently, been successful in providing the public with a lot of useful environmental information, the problem of wider dissemination and free exchange of information is still a crucial problem to be addressed. Today, a national environmental information system in the form of an electronic network, which has the provision for connection with the Internet and UNEPNet, is being developed intensively.

The mechanism of voluntary agreements with the involvement of NGOs, the victims and the polluters is a new concept to Vietnam and needs to be introduced.

4.3.2. Environmental Policy making in Vietnam

The Institutional Framework for environmental management in Vietnam

A special report of UNDP "Incorporating Environmental Considerations into Investment Decision-making in Vietnam" (UNDP, 1995) clearly describes the existing institutional framework in the country, including the linkages between national, provincial, and local governments. The authority for national environmental management is the Ministry of Science, Technology and Environment (MOSTE) through its operational unit as the National Environment Agency (NEA). The mandate of NEA is as follows:

- Studying and formulating policies, strategies, bills and legislative documents on environmental protection and sustainable development for the government to consider and approve. Inspecting the implementation of laws and regulations on environmental protection
- Taking environmental protection measures in order to maintain a good environmental state
- Appraising and assessing the environmental impacts of projects
- Controlling pollutants; managing domestic, industrial, agricultural and other wastes
- Setting up and managing the base monitoring system for the whole country
- Organising and guiding public activities on environmental protection, participating in education and training, and enhancing the environmental awareness of the general public

Within Governmental ministries are Departments of Science, Technology and Environment (DOSTE) or a similar designation (DST), which are responsible for environmental affairs.

Each of the 61 Provincial People Committees also has a DOSTE, which is responsible for local level management of the environment.

Although the administrative structure for environmental management is in place, there is still a need for a clearer definition of responsibilities and division of roles.

Specific features of the Environmental Policy making process

Today, Vietnam faces many environmental problems which it has in common with other developing countries. However, it also experiences some advantages as well as disadvantages arising from its political situation as a socialist country. Some of the common problems are as follows:

- Weak administrative and institutional capacities
- Poor regulatory enforcement, and a highly centralised system
- Lack of financial resources to support a suitable and sufficient monitoring system

- Enormous growth rate of industrialisation and capital accumulation with economic incentives for private firms to invest in integrated process technologies
- Urgent need to check the problems of resource utilisation and sanitary services with an unprecedented population growth

On one hand, socialism has an advantage, related to the lack of certain private property rights as regards to natural resources (e.g. land, mineral resources, water, forest), that makes implementing regulations easier. Another advantage may be the government's power to prevent the production of various products, which would cause pollution though hazardous wastes. On the other hand, there are some disadvantages seen as "incentives to pollute". They may include the following:

- Most raw materials have been treated as free or open access goods
- Absence of private ownership leads to the absence of protecting various resources
- Pollution control generally appears to be non-productive, while, the existing administrative system lets local government officials to judge almost entirely by how much they are able to increase their region's economic growth. Hence, they are sometimes likely to ignore polluters.

Another obstacle may be seen in the country's legislative framework and regulatory enforcement. The Law on Environmental Protection, which was enacted in 1994, and a number of other laws, government decrees and regulations provide a fairly extensive legal framework for environmental protection. However, this is not applied in a coherent way due to the lack of appropriate knowledge and environmental standards, coordination and consistency in implementing the various legal provisions. This is partly a consequence of the fact that qualified staff and the necessary facilities and equipment are in short supply. To some extent, the problem can be solved by increasing public participation in policy-making, monitoring and assessment. Such participation has been of crucial importance in a market-oriented economy, but is still far from effective in Vietnam. In addition, lack of information makes it difficult not only for government officials to take decisions, but also for the public to support the government's environmental efforts.

Nevertheless, given these constraints, the government is faced with the challenge to revise a large number of national environmental standards. It is most likely to apply as many standards as possible from ISO 14000. It is equally important, that, environmental policy makers will have to develop new regulations and various institutional arrangements to ensure the enforcement accordingly. On the economic front, a major concern for Vietnamese policy makers is that the transition to the Asian Free Trade Area (AFTA) does not disrupt Vietnam's economic growth nor its industrialisation and modernisation process.

An example of making policies with regard to the economic instruments for environmental management in Vietnam

As mentioned above, the transition to a market-based economy and the expansion of the private sector are good conditions for applying economic instruments towards environmental management. The first efforts have taken place in introducing the concept to government officials at central and local levels through a number of awareness raising activities and training courses. A UNDP funded project entitled "Strengthening National Capacities to Integrate the Environment into Investment Decision" has, also, as one of its objectives to explore the use of economic instruments to achieve sustainable development and environmental goals.

The government has issued some decrees and resolutions regarding environmental taxation, fines and fees, for example:

- Resolution of the Council of Ministers No.6/HDBT "Detailed Guidelines for the Decree on Taxation on Natural Resources" (7 January 1991)
- Resolution of the Government No.85/CP on Treatment for Administrative Violations in Management and Protection of Water Resources (22 November 1993)
- Interministerial Circular No.27/TTLB on Rules for Levy and Management Fees and Other Expenses for Biological Protection and Control (30 March 1994)
- Government Decree No. 26/CP on "Administrative Fines for Violations Against Environmental Laws" (26 April 1996).

The problem is that money collected from taxes, fines and fees has not yet been used directly as an investment in the environment, although the Government Decree No. 175/CP on "Guidelines for Implementation of the Law on Environmental Protection" stipulates the establishment of a "National Reserve Fund" for environmental improvement and disaster mitigation. The Ministry of Science, Technology and Environment (MOSTE) and the Ministry of Finance is in charge of formulating guidelines on the collection and utilisation of fee revenues through the Fund. However, a draft set of guidelines prepared by MOSTE is still under discussion.

More specifically, a draft Government Resolution concerning Guidance on Financing and Management in Environmental Protection Activities has been under development since 1995.

Great attention of government environmental management staff, researchers and academic staff is also given to other economic instruments such as tradeable permits, deposit-refund schemes and recycling incentives, performance bonds, governmental grants and special rate credits etc. However, the achievement of these instruments would need not only theoretical interpretation and understanding, but also the government's readiness to change its institutional and legal framework accordingly.

4.3.3. Follow-up activities and the road ahead

To respond to the changing regional and local environment, the government will continue its economic reform, improve effectiveness of its policy-making process, particularly towards the environmental policy making, to meet the requirements of environmentally sound economic development. As mentioned above, the Vietnamese economy today is mixed one, having some elements of both a free market and a centrally planned base. The rules and regulations are still different from other countries in the region practising market economy. For this reason, instruments of direct environmental regulation should be developed in the first stage. These should, then, be adjusted by economic instruments of environmental management.

One of the first priorities is to require the government to formulate its policy and regulations in accordance with international standards. National environmental standards should have as many elements as possible of the ISO 14000. The application of the ISO 14000 series should be made on a voluntary and third party verifiable basis in order to shift the "command-and-control" approach from governmental environmental authorities to the self-responsibility of producers.

Vietnam should continue its labour management reforms. It should increase investment in human capital as it is crucial in promoting efficiency of the domestic economic sector and the absorptive capability of local firms to foreign technology and management skills.

Although Vietnam has already launched a number of initiatives to ensure protection of property rights, there is a need to promote well-defined administrative procedures to make firms and individuals feel secure from violation of their property rights. It is clear that business must also play an important role in meeting the challenge of sustainable development. Thus, a Vietnam Business Council for Sustainable Development, the establishment of which has been proposed to the government, would be an important tool for building a partnership among corporate investors, the government, international aid agencies, and other concerned entities to achieve long-term benefits of Vietnam's economy and environment. The government therefore will need to consult closely with the private sector. The environmental policy making process is also expected to move along this line.

A number of environmental policies should be developed and/or revised. These may include further detailed guidelines for environmental impact assessment, guidelines for environmental auditing, inspection and enforcement, a national regulation on waste management, better management regulation for sustainable use of natural resources, and the improvement of the national system of protected areas.

4.3.4. Environmental issues relating to industrial sectors

Fast economic growth together with the already mentioned issues cause several environmental problems. Some of them, relevant to industries covered by this report are the following:

Insecticide production

- Pollution caused by waste water
- Insecticide residues
- Sludge from waste water treatment
- Hexa or hexa-containing residue made with hexa-chlorocyclohexaane or hexachlorobenzene
- Residue from the use of insecticides

Chemical fertilizer and Soap production

- Pollution caused by Waste water
- Microclimate factors (Temperature, humidity, speed of wind)
- Physical factors (light, noise, dust)
- Sludge from waste water treatment

Cement production

- Cement dust
- Noise
- Waste water
- Sludge from waste water treatment

Tile sheet production

- Asbestos dust
- Noise
- Waste water
- Sludge from waste water treatment

Steel production

- Waste water
- Sludge from waste water treatment
- Dust, NO_2, SO_2, THC (Tetrahydrocannabinol)
- Microclimate factors (Temperature, Noise)

Machining and Vehicle repair

- Metal Chip, oil, noise, dust, paint, waste water, sludge from waste water treatment

Cast iron production

- Cupola oven dust
- Waste water
- Sludge from waste water treatment
- Temperature
- Noise

4.4. Economic development and industrial indicators for Mekong delta

Introduction to economic structure of Mekong delta

The Mekong delta consists of 12 provinces and one City under the Central Government: Long An, Dong Thap, An Giang, Tien Giang, Ben Tre, Vinh Long, Tra Vinh, Hau Giang, Soc Trang, Kien Giang, Bac Lieu, Ca Mau and Cantho City. The Mekong Delta area is 39,554 km^2 (12% of the total country area). With a small area, the Mekong delta produced 47.9% the total food provisions of the country including 50% rice and 60% fruits production, quantity and value of fish and shrimp exportation takes 70% of whole branch in Vietnam.

At present, besides the potentiality of agriculture, fishery and service, the development of industry is an imperative need concerned with leaderships of the Government and provinces. The industrial development of the Mekong Delta is an important contribution for the success of the industrialisation and modernisation strategy in Vietnam. The industry of the Mekong Delta in the period 2006-2010 must have a valuable progress to take part in the development of economic structure of the region. This is true especially for Cantho City as a young city that is taking an important role for transferring sciences and technology in the Mekong Delta.

In the recent years, the industrial field in the Mekong Delta has a remarkable advance. Many industrial and export processing zones have been constructed. The application of new equipments and technologies has contributed to the development of the country. However, there is, still, a lack of knowledge and high-qualified human resource. Moreover, education level of people here is, still low, therefore, awareness concerning an environmental pollution is one of the problems the local authorities have to solve in order to protect living environment. The expansion of high-qualified human resource becomes a great challenge for the Mekong Delta in the development period, in particular, the industrial section. In the near future, the industrial zones will be constructed at the suburban areas of the provinces, such as: My Tho, Vinh Long, Tra Vinh, and Tien Giang.

In Cantho province, which has a favourable conditions of infrastructure and traffic, two industrial zones have been established:

- Tra Noc industrial zone (including Cantho processing zone): 10 km away from the city center, next to the 91st national road.
- Hung Phu industrial zone: In the South of Hau River, near the river port that can receive the 10.000 tones vessel.

In the both industrial zones, the main products are food, aquatic products and consumer’s goods. In addition, there are some mechanical enterprises that manufacture the hydro engines of the motorized boats for the regional demands.

In Kien Giang province, the Ba Hon industrial zone with the principal industry in construction materials, food and aquatic processing has also been established.

The population of Mekong Delta is 18 million people in which working human resource is around 10.12 million people period of 2001-2005 and the GDP (current value) of Mekong Delta has continuously increased: in 2001 it was 77,388 milliard VND, in 2004 it was 120,268 milliard VND and in 2005 137,077 milliard VND.

Industrial section develops considerably, especially in the process engineering for agricultural and aquiculture products for exportation and internal demands. Mekong Delta has 111 concentrated industrial zones with a total area of around 24,091ha in which Long An Province with 24 concentrated industrial zones of an area of 8,278ha takes about 35% of total industrial areas in the Mekong Delta. Non-state industrial sector (foreign and private, Ltd company) expand so fast.

In 2005, there are 92,238 enterprises employing 571,000 workers and take thereby 6.1% human force of MD. In the plan of 2006, there will be 95,400 enterprises and 110,000 enterprises for 2010. Industrial production increases 4.5 times in comparison with the year of 1995 and 2.3 times of 2000.

In general, almost all of the industrial zones have not yet centralised waste treatment systems, just only local system for each project, therefore environmental pollution issues have to pay attention.

In the planning, 2006-2010 local authorities have a plan to remove industrial section far from habitant area and create complex waste systems.

The following tables give an overview of regional distribution and to growth of industrial production.

Table: 4-7 Structure of value of industrial production in Vietnam (in %)[51]

Regions	2000	2001	2002	2003	2004	2005
Whole country	100.00	100.00	100.00	100.00	100.00	100.00
1. South East	53.45	52.50	50.91	50.22	49.98	49.57
2. Song Hong River Delta	21.09	21.68	22.77	23.65	23.64	23.81
3. North East	5.81	5.94	5.85	5.77	5.97	5.92
4.North West	0.32	0.3	0.29	0.31	0.32	0.34
5.North Central Coast	3.44	3.49	3.77	3.85	3.72	3.74
6.South Central Coast	4.57	4.70	5.11	5.08	5.30	5.44
7.Central Highlands	0.99	0.92	0.93	0.98	1.00	1.03
8.Mekong River Delta	10.34	10.46	10.37	10.16	10.06	10.15

[51] Source: Cantho Industrial Department

Table: 4-8 Industrial production in the Mekong Delta (1994's fixed cost in Mill VND)[52]

Provinces	2000	2001	2002	2003	2004	2005	Plan 2006
Total	22,827,134	27,182,717	32,056,423	37,645,653	44,066,749	52,519,389	62,276,530
1.Cantho City	3,470,300	4,776,543	4,397,665	5,441,608	6,591,541	8,000,000	9,800,000
2. An Giang	1,513,330	1,705,730	1,913,995	2,320,816	2,712,047	3,170,599	3,639,500
3. Bac lieu	872,697	1,705,730	1,366,858	1,638,252	1,683,339	2,400,000	2,800,000
4.Ben Tre	958,179	1,111,154	1,354,846	1,510,326	5,974,000	6,768,000	7,752,000
5.Ca mau	2,862,896	3,613,897	4,458,184	4,952,618	5,974,000	6,768,000	7,752,000
6.Dong Thap	1,099,875	1,250,200	1,450,830	1,693,118	2,030,600	2,595,000	3,361,000
7.Hau Giang	1,309,183	1,449,297	1,929,125	2,179,792	2,422,138	2,610,000	3,000,000
8.Kien giang	3,586,227	4,078,696	4,651,360	5,365,676	6,226,768	7,437,000	8,700,000
9.Long An	2,689,510	3,112,308	3,947,104	4,638,638	5,507,227	6,660,000	8,231,000
10.Soc Trang	1,757,822	2,282,386	2,661,145	3,298,705	3.908,960	4,328,790	4,853,030
11.Tien Giang	1,177,927	1,332,536	1,536,333	1,956,481	2,126,874	2,590,000	5,220,000
12.Tra Vinh	608,000	739,000	836,000	1,267,000	1,445,000	1,720,000	2,005,000
13.Vinh Long	921,188	1,021,995	1,174,100	1,382,623	1,660,302	2,040,000	2,500,000

Table: 4-9 Structure of industrial sectors in the Mekong Delta (numbers of enterprises)[53]

	2000	2001	2002	2003	2004	2005	2006 Plan	2010 Plan
Total	**82,217**	**84,552**	**86,894**	**88,210**	**89,142**	**92,238**	**95,400**	**110,000**
1. Types of economy sector								
Industrial sector of Central Government	24	24	28	28	30	32	32	34
Local state industrial sector	135	120	119	123	114	102	111	112
Non- State section	82,006	84,350	86,682	87,987	88,912	92,010	95,146	109,645
Foreign sector	52	58	65	72	86	94	111	209
2.Types of industrial sectors								
Mineral production	3,480	3,654	3,682	3,307	3,509	2,791	2,895	2,230
Processing section	78,369	80,511	82,705	84,199	85,078	88,803	91,824	627

[52] Source: Information from Industrial Departments in Mekong Delta, 2005

[53] Source: Information from Industrial Departments in Mekong Delta, 2005

	2000	2001	2002	2003	2004	2005	2006 Plan	2010 Plan
Food and beverage, TAGS	32,410	32,706	33,483	34,084	34,833	36,429	37,401	44,106
Cigarettes Tobacco	5	5	5	5	5	5	5	5
Textile products	3,415	3,740	3,716	3,709	4,398	4,812	5,021	6,027
Garments	8,585	9,218	8,883	9,005	9,137	9,507	9,812	10,784
Leather & processing	317	352	363	253	290	336	366	556
Wood products	15,465	15,230	16,300	15,558	14,515	14,857	15,006	15,928
Paper & papery products	39	47	42	41	41	47	52	90
Printing and publishing	377	398	410	499	463	494	537	733
Chemical and Chemical product	238	299	307	292	378	390	417	618
Rubber & Plastic products	92	114	140	149	145	162	181	300
Mineral products (non-metal)	2,449	2,807	3,095	3,417	3,406	3,589	3,757	4,548
Metal	910	688	768	857	941	984	1,022	1,107
Metallic products	4,690	5,285	5,522	5,978	6,048	6,285	6,385	7,833
Machinery& Equipment	1,900	1,795	1,685	1,749	1,789	1,810	1,888	2,343
Electrical equipment	493	443	421	522	417	431	453	870
Car production	357	418	456	543	516	568	614	819
Other transport equipment	3,448	3,721	3,478	3,556	3,790	3,856	3,952	4,645
Furniture	3,171	3,232	3,616	3,955	3,923	4,185	4,889	5,533
Medical equipment	1	1	1	2	1	1	2	2
Petroleum products	2	4	4	4	4	4	4	4
Radio, television production	2	1	1	1	1	1	1	3
Reproduced products	3	7	9	20	37	50	60	108
Electricity, Water & Gas	368	387	507	704	555	654	681	716
Electricity distribution	4	6	6	7	7	7	8	10
Water distribution	364	381	501	697	548	645	672	705

Table: 4-10 Structure of value of industrial branches in the Mekong Delta (in Mill VND)[54]

	2000	2001	2002	2003	2004	Plan 2005	Plan 2006
Total	22,827,134	27,182,717	32,056,423	37,645,653	44,066,749	52,519,389	62,276,530
1. Types of classical economy							
Industry of Central Government	3,446,924	3,125,029	3,322,387	4,025,420	4,435,365	4,951,838	5,411,200
Local state industry	7,032,947	8,902,818	9,889,548	10,880,513	12,774,027	13,825,352	15,210,400
Non- State sector	8,903,494	10,755,586	13,645,117	16,749,031	20,524,023	25,672,260	31,270,570
Foreign invest	3,443,769	4,399,284	5,199,371	5,990,689	6,333,334	8,069,993	10,384,360
2.Types of sectors							
Mineral production	225,736	272,626	428,517	445,176	407,587	429,613	848,601
Processing section	22,337,557	26,614,294	31,262,882	36,053,853	43,164,135	51,510,144	60,757,236
Food and beverage, TAGS	15,471,591	19,037,503	22,412,425	25,455,349	31,945,733	38,762,294	46,234,199
Chemical products	1,292,931	1,375,901	1,494,474	1,668,000	1,899,283	2,129,771	2,471,085
Cigarettes Tobacco	424,403	555,299	596,672	698,226	720,984	757,500	760,500
Textile products	667,827	755,804	904,542	1,048,001	1,121,747	1,227,566	1,346,717
Garments	343,186	351,864	420,353	529,045	754,015	940,613	1,065,744
Leather & processing	237,390	227,532	282,918	361,163	489,736	580,180	678,243
Wood products	641,955	643,354	682,538	733,013	814,087	946,102	1,035,492
Paper & papery products	95,251	104,174	113,313	171,327	199,015	222,691	259,550
Printing and publishing	80,470	119,892	141,739	199,931	204,945	222,493	268,059
Rubber & Plastic products	139,044	164,082	204,799	298,452	385,473	441,720	534,766
Mineral products (non-metal)	1,174,245	1,107,973	1,554,965	1,460,751	1,580,326	1,846,411	2,182,168
Metal	362,587	404,049	367,076	528,182	364,261	446,600	516,700
Metallic products	253,062	315,168	362,014	524,011	811,975	938,288	1,103,631
Machinery& Equipment	91,201	101,276	181,353	219,103	2,332,388	247,570	285,986
Electrical equipment	523,531	711,961	813,724	738,806	793,027	814,320	901,120
Car production	22,963	27,130	32,622	37,783	39,216	45,004	49,413
Other transport	218,457	256,997	305,162	949,648	315,077	353,450	398,591

[54] Source: Information from Industrial Departments in MD, 2005

	2000	2001	2002	2003	2004	Plan 2005	Plan 2006
equipment							
Furniture	221,656	270,413	297,163	326,888	383,257	466,930	901,120
Medical equipment	19,052	19,739	21,547	23,333	18,520	20,200	22,000
Petroleum products	56,304	63,651	72,891	80,865	88,558	97,000	107,000
Reproduced products	447	532	495	1,109	1,879	2,381	3,370
Electricity, Water & Gas	263,841	295,797	365,384	424,879	495,027	579,632	670,694
Electricity distribution	201,748	221,868	275,953	310,784	373,637	441,780	507,070
Water distribution	62,093	73,929	89,431	114,095	121,390	137,852	163,624

4.5. Introduction to Cantho City

4.5.1. Economic development and industrial indicators

Cantho City is located adjacent to the Mekong River and at the center of the Mekong Delta, where agricultural production is a main economic activity.

Cantho City has 8 districts, with the natural area of 138,.959.99 ha in which Ninh Kieu district 2,922.04 ha; Binh Thuy district 6,877.69 ha; Cai Rang district 6,253,43 ha; O Mon 12,557.26 ha; Phong Dien 11,948.24 ha; Co Do district: 40,256.41 ha; Thốt Nốt district: 17,110.08 ha; Vinh Thanh: 41,034.84 ha. It has a population of 1,127,765 pers., of which 75% in rural and 25% in urban areas.

Agricultural production is, still, the main source of income of people in a large part of the city, especially in its sub-urban.

In Tra Noc ward, located in the North of the city, an industrial zone of 150 ha was established and will be expanded to 300 ha. Hung Phu industrial zone, in South Cantho, is being planned. After completion, these two zones will cover a total area of 1,000 ha.

Cantho is situated at the hub of navigation in the region, especially the national road number 1 that passes through Cantho City and facilitates connection with many provinces in the MD. Cantho City has three harbours:

- Cantho port plays a very important role in transportation of agricultural production from the region to the markets in Ho Chi Minh city and to international market with area of 60.000m^2, can receive vessel with a capacity of 10,000 tons.
- Tra Noc port with an area of 16ha having three stores with a receptivity of around 40,000 tons, turnover through this port is estimated to be 200,000 tons/year.

- Cai Cui port is going on to build-up to receive vessels of 10,000-20,000 tons, turnover through this port is estimated to be 4.2 million tons/year.

As in plan, International Cantho Air Port will be finished in 2008; it is a good condition for Cantho City to develop quickly on social economy, science and technology, culture in the future.

Nowadays, with the strategy of the Vietnamese government in order to increase value of agricultural products, processing industry as well as other industries, considerably investment in the Mekong Delta is done. Especially, Cantho City is a city under central government and it is a centre of the MD for transferring science and technology as the government demands.

Cantho City has two concentrated industrial zones and two centres of industrial& handicraft area:

a) Tra Noc industrial zone, with an area of 300 ha, including Tranoc I (135 ha), Tranoc II (165ha) that is 2 km away from Cantho air port and about 3 km away from Cantho port.

b) Hung Phu industrial zone, with an area of 975 ha: It is in the South of Hau River, near the Cai Cui port

c) Industrial & handicraft Thot Not centre with 22.5 ha in the first phase and 31.5 ha in the second phase.

d) Industrial & handicraft Cai Son Hang Bang centre with area of 38,2 ha.

Cantho will increases industrial area until 2010 to 25 m^2/pers, and according to the plan in 2010 population of Cantho City will be around 1.4-1.5 million. Therefore Cantho City needs 3,500-4,000 ha for the industrial sector.

Until 2015 Cantho City will develop eight new industrial zones with an area of 3,050 ha and high-tech industrial zone with an area of 2,510 ha. The total industrial area at this moment will be 8,000 ha, if this plan is successful, Cantho City will become an industrial City before 2020.

With the quick rate of development of Cantho City on industry and urbanization, environment issues are the problems that local authorities should focus to solve them now.

Table: 4-11 Number of industrial establishments in area by ownership[55]

	2000	2001	2002	2003	2004
1. Domestic economic sector	4,316	4,607	4,723	5,074	5,346
State	26	25	23	22	21
Non State	4,290	4,582	4,700	5,052	5,325
Foreign invested economic sector	12	12	12	11	11

[55] [Cantho 2004]

Table: 4-12 Gross domestic product in area (At current price in Mill VND)[56]

Year	Total	Agricultural, Forestry and fishing		Industry and construction		Service	
		Central	Local	Central	Local	Central	Local
2000	5,966,985	3,156	1,334,047	398,326	1,459,299	548,947	2,223,120
2001	6,376.295	2,836	1,353,015	390,299	1,680,527	637,246	2,312,372
2002	7,884,375	3,714	1,878,335	456,396	2,107,295	660,456	2,778,179
2003	9,408,615	3,976	2,009,448	536,654	2,724,112	894,679	3,239,746

Table: 4-13 Number of industrial establishments in area by kind of industrial activities[57]

	2000	**2001**	**2002**	**2003**	**2004**
Mining (stone and other mining)	**3**	**3**	**3**	**2**	**2**
Manufacturing	**4,323**	**4,614**	**4,730**	**5,081**	**5,352**
Food and beverage	1,316	1,455	1,381	1,540	1,647
Cigarettes and tobacco	1	1	1	1	1
Textile product	5	8	10	10	28
Garments	716	993	866	917	991
Leather tanning & processing	35	42	36	38	65
Wood and wood products	1,132	904	1,133	1,195	1,206
Paper & paper products	9	15	17	18	14
Printing, copy and publishing	30	55	47	56	53
Chemicals	21	56	54	56	116
Rubber and Plastic	16	20	31	34	29
Non-metallic products	107	120	141	151	113
Metal	1	1	1	1	8
Metallic products	290	325	385	408	438
Machinery and equipment	226	174	157	166	171
Assembling &repair motor vehicles	28	27	12	14	18
Furniture’s	313	332	342	353	372
Reproduced goods	-	-	-	-	3

[56] [Cantho 2004]

[57] [Cantho 2004]

Table: 4-14 Some main industrial products in Cantho relate to the research[58]

	2000	2001	2002	2003	2004
Oxy (1000m^3)	1,237	1,439	1,806	2,020	1,927
Acetylene (1000m^3)	36	31	18	29	28
Insecticides (Tons)	2,374	2,687	3,117	3,622	4,434
Chemical fertilizer NPK (tons)	73,870	68,824	69,856	81,932	102,718
Washing soap and washing powder (tons)	357	2,402	6,314	7,467	7,791
Tile sheets fibro cement (1000m^2)	485	719	1,266	3,560	1,129
Cement (tons)	386,000	516,000	1,012,000	776,000	730,560
Hand farming implement (1000 pieces)	183	205	214	175	766
Threshing body (pieces)	338	579	389	422	211
Steel (tons)	77,000	86,000	74,000	72,535	63,840

Table: 4-15 Number of enterprises as of 31 Dec.2003 by size of employees in Cantho City[59]

Total	<5	5-9	10-49	50-199	200-299	300-499	500-999	1000-4999
1,277	286	425	426	91	13	16	10	10

Waste generation in Cantho

According to report of Cantho URENCO, the company collected and transported: total solid waste in year 2005 is 119,788.03 tons, average is 328.18 tons/day.

4.6. Ideas of local policy makers in Cantho City

Current situation

- Actually, the hazardous industrial waste treatment systems are, still, poor and they are not efficient.
- Almost all industrial wastes are collected and treated with household waste.
- Health Care Waste is collected separately and an incinerator used to burn it.
- Around 60% of enterprises have not waste treatment systems in Tranoc Industrial zone - Cantho City, and, each day the river receives more than 5,000 m^3 of waste water that have not been treated.

58 [Cantho 2004]

59 [Statistical Yearbook 2004]

- Almost all industrial zones in the Mekong Delta are located near the river but as the waste treatment systems are not yet efficient, it causes pollution problems for the rivers.
- Moreover, aquaculture is also a source of water pollution in the Mekong River.
- Not only the industrial zones, almost all of the hospitals in Cantho city also do not have a water treatment system. This situation should be improved.

Measurements and policies of local authorities of Cantho City

Carry out an investigation on hazardous waste (quantity and their characteristics) in the whole Mekong Delta (Mr. Le Quang Minh, Chef of Environment Management Office of Cantho City).

Besides the solid and liquid hazardous waste, sludge is also a problem to Cantho City.

For environment protection of Cantho City, Mr. Nguyen Thanh Son, Vice Chairman of Cantho City demands responsible people to evaluate the level of environmental pollution of each enterprise and give the time to solve this situation.

In order to create a central waste treatment system there are two possibilities: to convince the enterprises in the Industrial zones to invest or call for investment from outside (foreign or another company).

For new industrial zones, a central waste treatment system has to be installed at the beginning of the construction.

Refuse the projects with outdated technology that causes an environmental pollution.

Through the SACODI project, the local policy makers on environment management of Cantho City would like to cooperate closely with Cantho University and with the foreign experts and other companies.

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4.7.2. Relevant Vietnamese Laws

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- Decision No.2575/1999/QD-BYT (1999) by the Ministry of Public Health on **promulgation of management of medical waste**.
- Directive No 29/1998/CT-TTg by the Prime Minister on strengthening **the management of pesticide uses and persistent organic pollutants**.
- **Law on Environmental Protection**
- Decree of the Government No 175-CP on 18 Nov. I994 **"Implementation of the Law on Environmental Protection**"
- Resolution of the PMinister No 415-TTg on 10 Aug. 1994 "**Regulation on organisational structure and activities of the inspection for fisheries resources**"
- Directive of the PMinister No 200-TTg on 29 Apr. 1994 "**Supply of clean water and sanitation in rural areas**"
- Inter-ministerial Circular of State Planning Committee - MOSTE No 155-TTLB on 11 Apr. 1994 "**Provisional Guideline for environmental planning**"
- Resolution of the Minister for Science Technology and Environment No 1220-QD/MTg on 22 Oct. 1994 "**Improvement of equipment supply for the environmental monitoring stations and laboratories which have a mandate of designing an Environmental Monitoring System**"
- Resolution of the Minister for Science, Technology and Environment No 1806-QD/MTg on 31 Dec. 1994 "**Structure and Mandate of the Reviewing Panel for Environmental Impact Assessment reports and Environmental License**"
- Resolution of the Minister for Agriculture and Food Industry No 252-QD/NN/BVTV on 17 April I995 "**Authorisation for the Official and Amended Register to include some pesticides into the list of pesticides for use and limited use in agriculture in Vietnam**"
- Circular of MOSTE No 1420-MTg on 16 Nov. 1994 "**Guideline of EIA for existing enterprises**"
- Circular of MOSIE No 715-MTg on 3 April l995 "**Guideline for reporting and reviewing EIA for direct foreign Investment projects**"
- Circular of MOSTE No 1485-MTg on 12 Dec. I994 "**Guideline for the structure, Mandate and Scope of Activities of Environmental Inspection**"
- Circular of MOSTE 3370-MTg on 22 December 1995 "**Guideline for treatment of oil spill accidents**"
- Government Decree 26/CP on 26 April 1996 "**Regulation on the punishment of administrative Violation of Environmental Protection Law**"

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5. Policy making

5.1. Framework for Decision making

The first section of this chapter will talk about general aspects of decision and policy making with a focus on environmental issues. General economic, social and educational principles will be introduced in the following pages. The following section 5.2 will then, go more in detail about application of policy making on hazardous waste.

5.1.1. General aspects of decision making

Politics and decision making should be based on comprehensible arguments. So, some structure in developing of pros and cons to a project and in specifying details of implementation are helpful. There are different approaches for policy and decision making. This section shows three of them.

Facets of decision making

Authorities and even private entrepreneurs have to observe a lot of aspects within their decisions. Any regulation or project will affect business, society not only on a local but also on a national level and also, often the environment. All effects are entangled somehow. The following checklist gives an overview of the most important aspects in developing management plans for environmental issues and especially, waste and hazardous waste. Based on this list, most important effects of implementing policy or projects can be identified. In applying this list to a concrete project or policy, it can be seen, if there exist some wanted or unwanted side effects and, whether, the whole project is reasonable. An application of this list gives some basic information about the positive and negative effects of a project.

- **Economic aspects** (from a business or financial view)
  Any project or policy must be paid somehow by someone. So, the direct costs of collection, treatment and disposal of waste, for example, must be covered somehow. Workers have to be paid and investment is necessary. This can be done through two channels, direct payment of waste generators through waste fees or taxes or direct and indirect subsidies from the society (it means in fact, the taxpayer). Subsidies can be channelled through the government or through communities.
  Theoretically, it is best to cover all expenses by the waste generators (the so called "polluter pays principle"), practically, it is sometimes not possible because the polluter can not be identified or the polluter can circumvent the waste charge. So, often, some compromise is necessary.

- **Economic and efficiency aspects** (from a view of the whole economy and society)

  Untreated hazardous waste causes costs through pollution to the society, e.g. additional medical costs (for further explanation see paragraph on external effects on page 153). These indirect costs should be considered and the goal should be to reduce or internalise them. This helps to increase the efficiency of the whole economic system. Especially, the long run effects are important because, they are often overseen, ignored and for many reasons, not considered appropriately by the market forces.

- **Technical feasibility**

  Any regulation should be technically feasible. Otherwise, the implementation will fail. Not every time best available technology is feasible, because, it is not available or only available at prohibitive costs. Often, maintenance of best available technology can not be secured in the long run. The use of local available technologies and local available knowledge can be often recommended because, a reliance on non-local technology causes usually, high costs, needs lot of communication and travel and leads often, to delays in project implementation and maintenance.

- **Understandability**

  Regulation should be understood from all affected persons and institutions. Theoretically optimal solutions are often, not practically applicable. So, sometimes, compromises e.g. in setting waste fees are necessary. Too complicated regulations may be ignored or implementation will go wrong and will be inefficient because, nobody understands it. This will lead to an inefficiency and not meeting the goals of the regulation.

- **Ecological sustainability**

  Ecological effects are often very complicated, because, often, there is besides the direct impact also, an indirect ecological impact. So, e.g. collection of waste causes transport costs in form of monetary costs as well as environmental costs as noise or energy consumption. Any landfill consumes precious land. Thermal treatment may cause air pollution. So, the issue of ecological sustainability raises often the question to find the best environmental solution. One example, is the consideration of thermal treatment versus landfill.

- **Juridical**

  A regulation must be consistent with all laws and should try to adopt future laws. Especially, the consideration of future changes in the legal system (that includes also international agreements) is necessary because of the long investment period for waste treatment options. Especially, for large and capital intensive investment, a reliable legal system is necessary. Otherwise, business can not be involved and there is the possibility of wasted and misallocated money and a long term inefficiency.

- **Social**

  Waste economy employs often people in an informal sector (waste pickers). So, a change in the waste collection system can have considerable effects on this informal sector. So, questions arise like: What is done with the waste now? Who profits from this waste? Who uses it? Are there effects on employment (informal and formal sectors). Is there an acceptance of the change in the system? Are there ethical or cultural problems Or issues derive from traditions (e.g. with Indian castes)? What is about the political acceptance? Furthermore, the introduction of a high waste fee may have adverse economic effects (at least in the short run and especially with abrupt changes).

  The consideration of social effects is necessary because, otherwise, protest may arise or the regulation will fail as it will be undermined or ignored. A democratic system needs the approval of the population.

- **Control**

  It must be possible to control the implemented system. In the waste sector often, exists the possibility to transport the waste (illegally) to another place, dump it illegally or dilute it (especially with waste water) so that, the pollution or the polluter can not be identified. Control must be feasible and cost efficient to the regulator and as well as to the business. To safeguard an efficient and true control, it is very important to make unannounced checks by an independent body.

Stakeholders

The stakeholder approach enables to understand support and opposition of people or groups to a certain project or change in regulation and thereby its social and political sustainability and support. Any economic activity or change of it, affects a lot of stakeholders who are directly or indirectly involved and who may, hamper or support a project or regulation.

Stakeholders could be the operator of a waste collection system, a treatment or segregation plant, affected entrepreneurs, employees, residents in the neighbourhood of a waste treatment site or a polluting industry, local government and authorities or non-profit-organisations. It is advantageous to regard every stakeholder, her demands and her stake in a project or regulation. This helps, to satisfy them sufficiently and so as to prevent potential protests, improve social effects and strengthen short and long run support. A careful consideration of all stakeholders ensures the longevity and sustainability of a project and smoothens the political process.

Even people who are not directly involved but, through a contract may be affected, and hamper or even thwart the project through passive or active protests. This applies especially, to the neighbourhood of a waste treatment plant.

Cost benefit analysis

Policy makers should make their decisions based upon the full knowledge of all advantages and disadvantages of their policy or projects. Benefits and costs of different alternatives should be known to find the best one. Cost-Benefit-Analysis is a tool that helps to decide between different alternatives for an issue. Ideally, all information should be collected so that, it is possible to quantify the impacts of different alternatives.[60] For a public project, it is often not so easy to specify all costs and benefits as it is for private projects who just have to calculate their income and their expenses to find out if a project promises for a profit.

To make a comparison of costs and benefits of a public project possible, all available data have to be transformed into one uniform level. Usually, a monetary value is taken. Monetary costs for investment and running facilities are available. On the other hand, it is difficult to specify monetary values of environmental pollution. But, this is possible by asking the people for their willingness to pay for a cleaner environment.[61] Another option is to specify the damage of the environment in monetary terms. They can be expressed e.g. by additional medical costs borne or, by the cost borne towards water treatment to obtain drinking water. With monetary valuation of different alternatives, a comparison of them is easy. So, it is possible to compare the benefits of waste collection with the additional costs of waste collection. By making a sensitivity analysis, the stability of the results can be checked and. Furthermore, it is possible to see the changes of costs and benefits by changing auxiliary conditions like sources of finance or use of different technologies.

But, most often, it is not possible to quantify all data in a reasonable manner. Especially, quantification of environmental costs is not easy and there are ongoing debates about the value of a human life. So, at least, it should be tried to specify all available qualitative data. Then, decisions have to be taken on this base, allowing for some error. The advantage of a cost-benefit analysis, even, when it is not based on perfectly quantified data, is its transparency and, furthermore, it is a good base for a rational discussion.

For complete details of cost-benefit analysis check the literature.[62] For details in applying cost benefit analysis in waste management see e.g. [European Commission 1997], [European Commission 2000] or for an application in PVC waste treatment [Kristensen 2004].

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[60] Alternatives can be simply "Do nothing" versus "Collection of hazardous waste" or e.g. different treatment options of hazardous waste: incineration" versus dumping on a landfill.

[61] It is also possible to determine the willingness to pay by indirect means. E.g. the sum people pay to move from a polluted area to an unpolluted area or the amount of money they spend for remediation of pollution.

[62] There is a huge bunch of literature about cost-benefit-analysis. Just to mention two books: [Hanley and Spash 1997] or [Fuguitt and Wilcox 1999].

5.1.2. Policy principles of environmental policy

5.1.2.1. Environmental policy

Hazardous waste as a part of environmental policy

Hazardous waste policy is a part of waste policy. Therefore, it is not possible to separate hazardous waste management and policy issues completely from a more general approach to waste management. So, most of the principles mentioned here and the approaches apply in almost the same manner to the management of other kinds of waste as well. Differences and specialities arise especially in application of technical processes and procedures. This is, because of the properties of hazardous materials (e.g. toxic or corrosive). Hazardous waste causes often immediate or direct danger to humans, the environment or other materials. Therefore, a proper handling of hazardous waste from source in all steps of its generation and handling, is more important than, with other waste, to reduce the immediate dangers. So, direct dangers make hazardous waste policy even, trickier than other waste policies and this may lead to a stricter policy. Furthermore, the properties of hazardous waste lead to a more comprehensive approach than a simple waste management. Danger prevention is much more inherent in hazardous waste management than in other waste or environmental issue management.

From a technical point of view, hazardous waste management needs some very special approaches but it is important to view hazardous waste management every time as part of a general waste management approach. This is, in turn, part of an environmental policy in a broader sense. So, this guidelines will tell first something about general aspects of environmental and waste policy and in later sections, more technical and hazardous waste specific issues will be addressed.

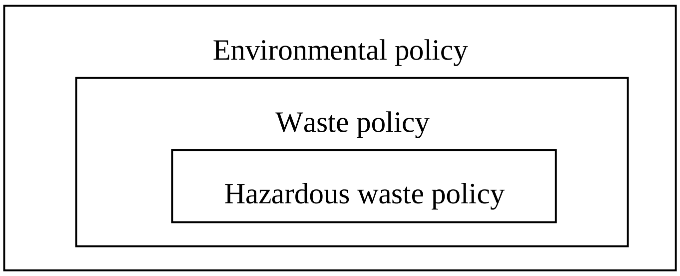


Figure: 5-1 Hazardous waste policy as part of a general policy approach

The need for integrated approaches

An integrated thinking is necessary in dealing with hazardous waste streams. Any improper method of treatment or disposal of hazardous waste, can cause serious impairment of human health or irreversible damage of environment. Hazardous waste, as any other waste, is finally disposed somehow on land, in water or air. Interrelations have to be considered. For instance, burning of hazardous waste reduces the amount of disposed waste, but it may cause air pollution and the ash can be hazardous as well and may need careful disposal. Treatment of wastewater reduces the impact on water bodies, bu, as the result, there will be dangerous sludge. This sludge must be treated and disposed. If the disposal is not done properly, hazardous components can leach into the groundwater. The effect of the original water treatment will be diminished. Stringent policies which, focus just on one issue without considering the overall environmental effect, may produce unacceptable results for human health, the environment or the economy and the society.

Aspects of environmental policy

Environmental policy is not just a policy, improving environmental standards. It contains, different aspects. Some of the most relevant are the following:

- **Human health:** Any environmental policy should improve living conditions with the aim to safeguard human health.
- **Environmental soundness:** The environment should be kept in a state that it can be used by the society for all necessary purposes, like agriculture, water supply or, other social and economic activities.
- **Sustainability:** Activities that influence the environment should be done in such a way, that, they help to support also, the future generations.
- **Economic efficiency:** Environmental policy should support economically efficient solutions, otherwise, their political sustainability is not safeguarded.

All these aspects belong together. The importance of human health and environmental soundness are obvious. Sustainability is a very controversial issue, because, it is very difficult to measure it and a stringent and coherent concept does not exist yet. Nevertheless, it is obvious that any responsible policy should take care of the following generations from environmental, social and economic aspects. This means, . the avoidance of uncontrolled dumpsites that may bring considerable, uncontrollable and unpredictable dangers to the future generations.

As the economy and economic incentives are the most important steering instruments, section 5.1.2.2 will shed some light on environmental and economic issues, explain the idea of economic instruments and will give an introduction to some most important environmental and economic concepts.

Political instruments[63]

Environmental regulation can be distinguished in different groups. As the following list shows, environmental regulation can be done by many different ways, not only command and control policy or direct bans and regulation.

[63] For further details see also [Schemann 1996], [Luken 1990] or [Siebert 1995].

1. **Bans and command and control policy**
   This is the common way to environmental regulation. The advantage is clarity and the direct effect. Especially, for hazardous materials and waste there exists a lot of bans and commands in every country as well, at the international level. Because of the need of danger prevention in hazardous waste policy, direct and precise policy like bans and control is often needed. The disadvantage of this policy is the economic inefficiency that can be found very often.

2. **Liability law**
   The use of this instrument depends upon the development and the structure of the juridical system. So, in the US it is extensively used. Theoretically, this instrument can be very efficient. Practically, there are often problems: e.g. the weak party can not fight against a powerful party or company (esp. in terms of finance, or knowledge) or even in clear cases, compensation can not be paid by a bankrupt company. Nevertheless, the threat of liability sues should enforce the business to improve hazardous waste handling at least, to a commonly accepted level. An application of liability law should lead to a risk reducing strategy by the companies, to avoid the payment of compensation.

3. **Taxation of resource or material use**
   This is a very efficient means to correct environmental issues. Especially, taxation of energy in many countries, is quite common. Taxation of hazardous materials (e.g. lead) would be a possible solution to diminish some problems. But, it is not common now, even though, there are ideas about it.

4. **Better information**
   Even though, the so called “soft measures” like information and education, often do not show direct measurable effects, they are very important and needed to improve environmental situation. They complement other environmental instruments.[64] The lack of knowledge found, at business, in the workers or in the population, is very common. Often, some little support of competence building bringing a big improvement in the society and the environment.

5. **Subsidies**
   Subsidies can help to improve the current situation without additional costs for the business. As an advantage, with subsidies many environmental goals can be reached very quickly and easily. Nevertheless, there are monetary and economical costs[65] for the society so that this instrument should be used only for quick relief of extreme situations, as a complement to other environmental instruments or as a temporary measure.

[64] See e.g. [Stehling 1999].

[65] It means, subsidies causes often economic inefficiencies and windfall gains.

6. **Governmental economic activity**

   Some kinds of market failure are difficult to correct. Especially problematic are very small markets that do not give scope for several companies and therefore, enough competition. Another market failure is the need of very high investment that will pay back only after a very long time. Private companies may avoid this investment. In that case, it can be a very simple solution for the government or community to act by themselves (even though government run companies may have a lower economic efficiency than private run companies). This kind of activities can be found often in waste collection. In an extension it can be complemented for e.g. by recycling activities.

7. **Voluntary agreements**

   The basic idea of voluntary agreements is that, business knows better what can be done, than some authorities. The problem thereby is the lack of economic incentives, so that voluntary agreements often will not work properly. So, they may be better combined with an economic incentives. But, they are useful as a kind of soft instrument because, they increase identification with environmental issues.

8. **Quantity restrictions in connection with tradeable permits**

   This environmental policy instrument is now more in use (e.g. CO_2 tradeable permits as a result of the Kyoto protocol). The advantage of this instrument is, that it is possible to determine the environmental effect exactly. The disadvantage are quite high administrative costs and a rather complicated system. In using waste as fuel and thereby to reduce CO_2 tradeable permits can be in future of interest for waste [Eckardt at al 2004]. But, for hazardous waste this instrument seems to be not practicable.

A special application of environmental politics to hazardous waste is explained more in detail in section 5.2.

5.1.2.2. Economic framework of environmental policy

The need for “real prices”

Why is it necessary to develop extensive environmental regulation in a market based economy? Why can the market not solve the problems by itself?

Besides, reasons like danger avoidance and risk control, there are also, economic reasons. A simple reason for the need of environmental regulation in economics is, that, a market based economy needs a working demand and supply of goods and thereby, positive prices come into existence. Otherwise, no production will be possible. But for waste there exists usually, no demand and therefore, no market and no positive price. Usually, waste will bypass the market economy. This means, in general, there will be too much waste generated with too high hazardous material compound, because the generator has not to bear any costs. Therefore, there is the need for some additional regulation that overcomes these economic shortcomings by introducing some kind of price or costs for the waste generator. Costs for waste will lead to lesser generation of waste or to a higher recycling quota. So, a price for waste will lead to a social and economically acceptable level of waste generation. It shows further, that, for valuable waste (e.g. some electronic waste), i.e. waste that has a price, a market exist and there is no urgent need for state interference to reduce the amount of waste (Nevertheless, regulation may be needed to avoid dangers for the environment or for humans in recycling firms.)

External costs

External costs, also sometimes called Externalities or external effects arises when activities from an individual or a company have an impact on another group and this impact is not fully accounted. This impact can be e.g. noise, air, water or soil pollution. This means, some effects and with this some costs of an activity have to be borne by someone else who is not directly involved in this activity and do not profit from it. No proper compensation is paid by the polluter. Environmental problems are usually closely linked with external effects. Because the polluter do not have to pay the true costs for his activity, there will be a gap between the costs of an activity from business perspective of the polluter and from the perspective of the whole economy.

One example is the production of paper. It needs a lot of water that will be spoilt during the production process. People around the plant will suffer because they can not use the water and agriculture will be harmed. They have to bear non-monetary (e.g. health problems) and monetary costs (e.g. income loss). This costs should be added to price of paper of this plant.

It is the task of the government to find solutions to internalise these external effects and so give environmentally sensitive activities a real price. This internalisation can be done by different ways e.g. by the enforcement of a water treatment plant or with taxes on polluting activities or subsidies for environmental friendly activities. [see also Cantner 2000a]

Economic effects of environmental policy

Environmental protection activities are usually costly (Even though they may save costs in the long run, e.g. through lesser material and resource costs). Therefore, environmental protection activities are often neglected. Especially, under the threat of global competition any additional costs are regarded as negative to business and thereby to the economy. It is feared that strict environmental regulation may cost some jobs, because factories have to close or to reduce their production activity. But, of course environmental protection is necessary because damage of human health or the environment causes external costs to the society (e.g. health costs, loss in agriculture), that easily can be higher than the economic benefit of a certain activity. Stricter environmental protection reduces this external costs.

Besides this, environmental protection activities create new business, new jobs and lead to the introduction of new technologies (e.g. through recycling activities) and this may spur innovation. Environmental protection industry will emerge, new sectors and services will be created. So, there will be some indirect economic stimulation effect. These positive effects of environmental policy are often overseen and underestimated. To estimate the overall economic effects, it is also important to consider not only short run effects, but also long run outcome of any environmental protection activity. Environmental impacts and thereby also economic costs from improper disposal of hazardous waste emerge often only after a long time. For instance, the effect of a landfill from which toxic materials leach to the groundwater may appear many years after disposal of the materials. But, then it is too late as the damage can not be reversed. Costly water treatment may be required, agriculture is impaired or impossible and health of people living in the surroundings is negatively affected.

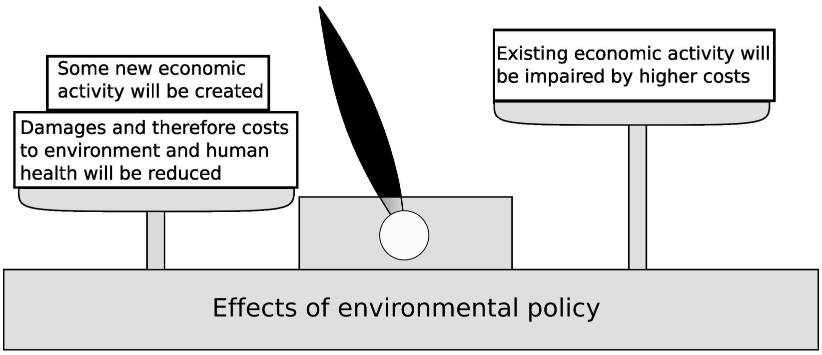


Figure: 5-2 Economic Effects of environmental policy

So, any environmental regulation and environmental protection activity must be balanced and consider all positive and negative short and long run effects. Excessive stringent environmental policy may impact economic activity, but, on the other hand, from a lax policy only some factories will benefit, but the whole society has to bear a huge burden in the form of direct and indirect economic losses.

Efficient waste pricing[66]

Efficient targeting of environmental instruments means the economic actors, reflect in their actions social costs, and not just private costs from product's birth to product's death. With generated waste, this is often not the case, because, waste causes usually external costs. Efficient pricing means, that marginal costs are equal to marginal benefits, it means, an additional economic activity should generate as much benefit as it costs (to the society). Marginal private costs are easily observable. They can be taken from the books. But marginal external costs are not so easy visible. Marginal social costs are the sum of marginal private and marginal external costs. Efficient environmental pricing tries to

[66] For further discussion see e.g. [Porter 2004].

make marginal private and marginal social costs equal. A company, in contrast, will only equate its (private) marginal costs with its (private) marginal benefit (or in business terms profit). For an illustration see Figure: 5-3 that shows a schematic approach (ignoring for other costs than for waste).

So, in case of the public financed waste collection system there are marginal costs of collection. Every item of waste causes costs to the society but no marginal costs to the generator because she has not to pay for it. Such a system is economically not efficient. Waste generation is (indirectly) subsidised and therefore it is "too cheap" and thereby too much waste will be generated. A higher price for waste generation will lead through higher private cost to less waste and therefore less social costs (external costs are lower). So, waste generation should be taxed or levied with a fee to reduce the gap between social and private costs.

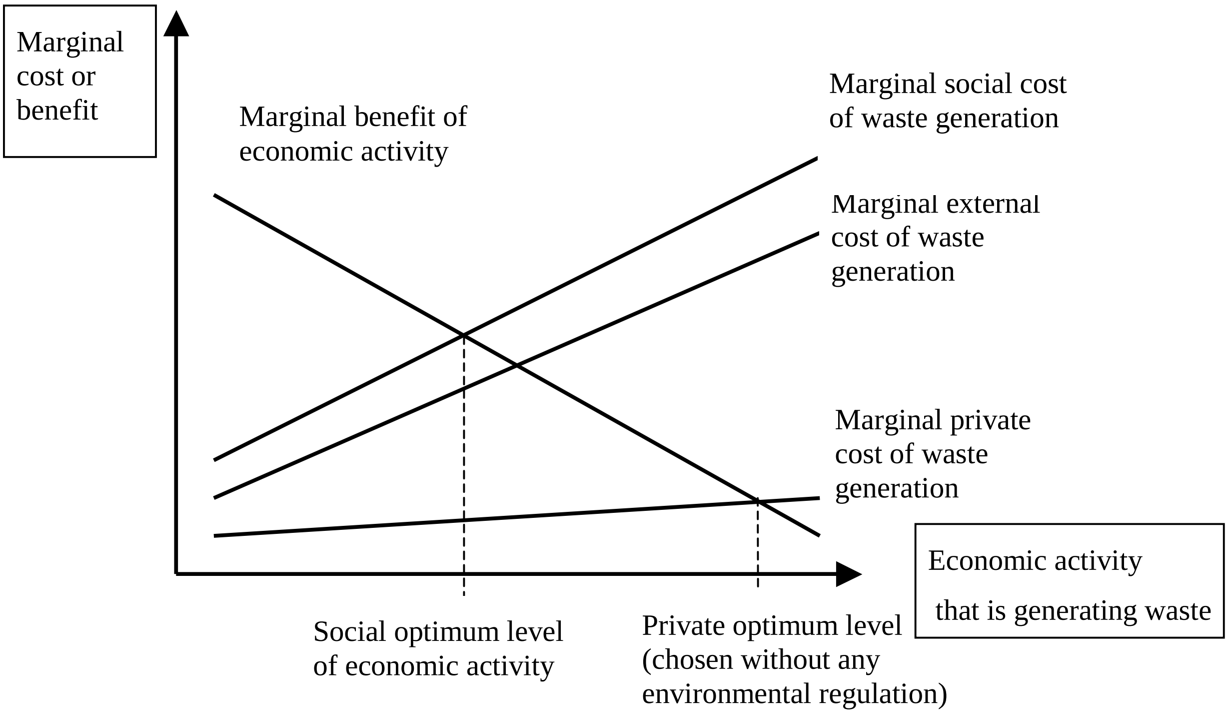


Figure: 5-3 Marginal costs and benefits

Besides direct control approaches, an economic influence on the behaviour of waste generators is possible. The simplest and the most used way is to demand a waste charge. It makes waste more expensive and generation should be reduced. The main issue with this approach is the possibility to circumvent it by illegal or legal means. So, in most cases the better alternative is to demand an advanced disposal fee, a fee the producer has to pay as soon as he sells his product in the market. It will make the product slightly more expensive. From the advanced disposal fee it is possible to pay the collection and disposal of waste.[67] When recycling for the product is feasible, then, there exists a third possibility: a deposit and refund system. A deposit and refund system on vehicle batteries is for e.g. introduced in several countries [Sigman 2004]. More details about a deposit-refund system can be found on page 164.

Polluter pays principle

This principle, also called prime responsibility means the cost of waste should be borne by the generator of waste. If costs of waste are correctly charged to the party having the prime responsibility, the party will try to find solutions for waste reduction and cheaper alternatives to conventional waste disposal. The idea is, to give an incentive system towards an environmentally and economically sound waste disposal systems. This principle serves best to avoid external costs. As an advantage, it may lead to a comprehensive responsibility of the polluter who will consider also long run costs of his production activity. A disadvantage emerges as soon as there are avoidance possibilities like, the “export” of waste to some other, cheaper place.

A positive example of the polluter pays principle is the European Electronic Waste Ordinance [Waste Electrical and Electronic Equipment - WEEE]. Any producer of electronic equipment, like computers, has to take it back after the end of its lifecycle. They can not charge the consumer for this. So, the consumer can easily give his old electronic device back and the producer has to bear the costs for treatment of electronic waste. So, any producer has the incentive to reduce the amount of electronic waste. A reduction of waste will save his costs because he is responsible for the costly waste treatment and disposal.

Voluntary agreements

As already mentioned, voluntary agreements are often problematic, because of the lack economic incentives, but, on the other hand, they help to increase environmental awareness. As an advantage they avoid pressurising the business directly. To give them a chance of success the following points should be considered:[68]

- **Force from governmental side**: The government should threaten to implement tougher actions when a voluntary agreement do not show any results. This is some kind of economic incentive to implement a voluntary agreement.

[67] This system is introduced in EU for cars already since a longer time and recently for electronic waste. See [ELV] and [WEEE].

[68] See also [Burger 2002].

- **Public pressure**: Especially for firms who are in direct contact with consumers, public relations are very important. So, public pressure is an incentive because firms can loose reputation and this may lead to financial losses.
- **Market structure**: The number of participants in the market should not be too large. Within small markets, transaction and control costs are lower and the risk of the free rider problem is lower.
- **Market phase**: Young markets with new products are often, heterogenic. Voluntary agreements are more difficult to accomplish than in more homogeneous markets.
- **Rate of industrial organisation**: Within a good organised industry, a voluntary agreements is easier to implement.
- **Cost of implementation**: With equally distributed costs among the companies an accomplishment is easier.
- **International competition**: In export oriented industry, costs (but also benefits) of a voluntary agreement have to be seen in an international context.
- **Clear goal**: A voluntary agreement should be more than “business as usual” Otherwise, it is useless. But, especially, because of the free-rider problem voluntary agreements tend to be too soft ant therefore, not efficient.

5.1.3. The role of education and training

It is widely recognized and acknowledged that the largest gap between policy statements and real changes on the ground is implementation. The objectives, targets and aims may be clearly identified, but how is the transition made from declared ambition to actual functioning operation? The most progressive governments, industries and companies throughout the world recognize that two of the most cost effective and high impact activities in support of implementation are those of education and training.

For the purposes of this project, education may be defined as the process of teaching and learning that includes instruction in the concepts, theories and principles of the subject discipline. In the context of SACODI, training is interpreted as the presentation of systematic instruction aimed, specifically, at developing skills, gaining experience and applying professional or operational practice. Without being too pedantic, SACODI recognizes that there are discrete differences between the two processes, though they are often integrated in some of the most effective schemes of study and instruction.

Who needs education?

The short answer is that we all do. Without being facetious, it is fair to say that all members of society need to learn more about the crucial phases of the life cycle of hazardous waste. Politicians who make policy, regulators who prescribe regulatory frameworks, operational managers who oversee industrial operations, local communities that, both contribute to, and suffer from, the impacts of such waste, and individuals themselves who as consumers demand an ever-widening range of products – all have a vested interest in learning more. It would be to mutual advantage for all stakeholders and interested parties to learn more about this critically important, global environmental challenge.

However, in the context of SACODI where the focus is clearly on regional and local initiatives (albeit often within a national or international framework), the target audiences for education and training are: (i), Local authority and community representatives, and selected operational managers, and (ii), Operational staff and students (the latter being potential operatives and managers of the future).

Education and training programmes have the potential to bring value-added status to R&D projects such as SACODI because they can:

- Act as a catalyst for further action
- Help raise awareness of key issues
- Assist continuity of activities and the adoption of best practices
- Contribute cost-effective opportunities for implementation of waste schemes
- Bring the importance of the concepts, tools and methodologies to a wider audience
- Encourage the development of local or internal capacity and competence to continue and enhance further the achievements and objectives of the project
- Be an active demonstration of commitment and progress where evidence of performance is important for funding and support
- Recruit support and resources to sustain the activity for the future

5.2. Hazardous waste policy

This section will talk about hazardous waste specific aspects of policy making. Some arguments will be based on the previous section but they will be extended on technical aspects of hazardous waste.

5.2.1. The hierarchy of waste management

The following hierarchy should underlie all waste related activities from communities to private business. Following this hierarchy helps to develop a sustainable development in environmental as well as in economical terms.[69]

[69] For an application to the German law see e.g. [Schimanek 1997].

1. Reduction and avoidance of waste

This is first and most important point in the strategy for waste management. This strategy is most preferable and a base for sustainable development. It can be done by altering of production technology or sometimes, even by an other product design. Any change of production technology should seek to reduce amount and hazardousness of waste. Furthermore, waste reduction is also possible through manufacturing of longer lasting products, quality improvement of products, design of reusable products or design of easy to repair products [Linscheid 1998, p 25]. The goal of waste reduction through introduction of less waste generating products, has even a repercussion on consumer behaviour who may have to change their consumption pattern.

Waste reduction has the big advantage, that it helps to reduce input of raw materials or energy and to reduce waste disposal costs. These savings have a direct positive economic effect on business and a long run positive effect on the whole society. So, waste reduction can lead to a win-win situation it means environmental damage can be reduced and at the same time costs are lower. It is because of the great importance of the reduction of waste generation, this strategy should also play an important role in any environmental regulation and appliance of regulation. The authorities should promote this strategy as much as possible. E.g. the German recycling management regulation (Kreislaufwirtschaftsgesetz) explicitly mentioned a priority of reduction and avoidance to a treatment of waste. Waste minimisation should be central strategy in waste management.[70] For the nevertheless remaining waste, the following hierarchical steps should be considered:

2. Re-use

In some cases it is possible to re-use materials. Usually, it is also an economically beneficial solution. Application of re-use depends upon the properties of the material and the costs to make the material again available in terms of energy costs, cleaning, transportation etc. Re-use involves usually some costs to clean the waste or to transport the waste to another user, but it helps also to reduce disposal costs and costs for raw materials. On site re-use could be e.g. reuse of cleaning material.

3. Recovery (recycling)

Recovery is usually distinguished into material recycling and into the less preferable option, energy recycling.

Material recycling: For some materials, recycling or recovery from waste is technically possible. If it is practically feasible may depend upon different factors. On one side, there must be a market for the recycled materials. So, availability and price of raw materials and quality of the recycled material are important. On the other side, recycling involves costs for proper collection which avoid mixing,

[70] For details see e.g. [Childers 1998]

transportation and recycling. Sometimes, it causes even environmental pollution, other waste and energy consumption so that the overall environmental balance is not positive. Theoretically, the potential for recycling is high, practically it is constrained through many economical and environmental factors. Politics can support recycling e.g. by the introduction of a tax on virgin materials or similar incentives.

Energy recycling: Incineration of waste can bring some small environmental benefit. But for hazardous waste the potential is, rather low. Incineration of hazardous material is not every time possible and in case, it is possible the energy gain is usually rather small because of the low calorific value. Toxicity and often highly corrosive nature of the waste and therefore, the flue gases require precautionary measures. Properties of hazardous waste requires some special equipment and advanced technologies for incineration. Therefore, often high investment costs are necessary. Besides a possible small energy gain incineration has the advantage to reduce the overall amount of hazardous material. So, disposal will be easier and cheaper. Energy recycling depends upon many factors like calorific value of the waste, technical and economical constraints to operate an incinerator.

Figure: 5-4 gives an overview to waste reduction options.

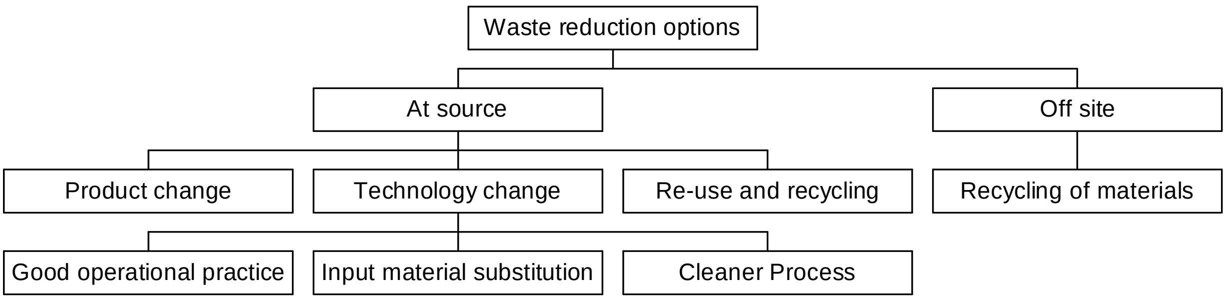


Figure: 5-4 Waste reduction options

4. Disposal

This is the least preferred option for waste treatment. Sometimes, it is unavoidable for technical or economic reasons. The aim should be to find technical solutions, that reduce the dangers which go out from disposal. Therefore, often treatment of waste is necessary.

5.2.2. Integrated waste management

The previous section has shown that waste management integrate different approaches. There is no simple single best solution. Depending upon the special substance and situation, waste handling must be organised in an appropriate way. Sometimes, waste can be avoided in a simple way. Then it is necessary to set incentives properly. Sometimes, recycling is possible and recommendable. In that case, incentives through raw material pricing must be set und some support may be necessary to develop a cheap and easy recycling technology. Nevertheless, sometimes only disposal of material is possible. Then, it is necessary to find the best choice for collection so that a high percentage can be collected and an optimal choice for treatment or disposal can be found.

As hazardous waste forms only a small fraction of all kinds of waste, integrated waste management includes also other waste such as household waste and less hazardous industrial waste. As the following figure shows, a central element of integrated waste management is the collection and sorting of waste. This is the base for any further treatment. An another non-negligible part of an integrated waste management is transport. Transport in itself, needs energy and pollutes the environment, it involves costs and especially for hazardous waste it is connected with dangers e.g. of accidents. Therefore, a transport optimisation is needed that reduces negative impacts and risks of it. The following figure shows most important parts of waste management. It refers to the chapters where more technical details are explained.

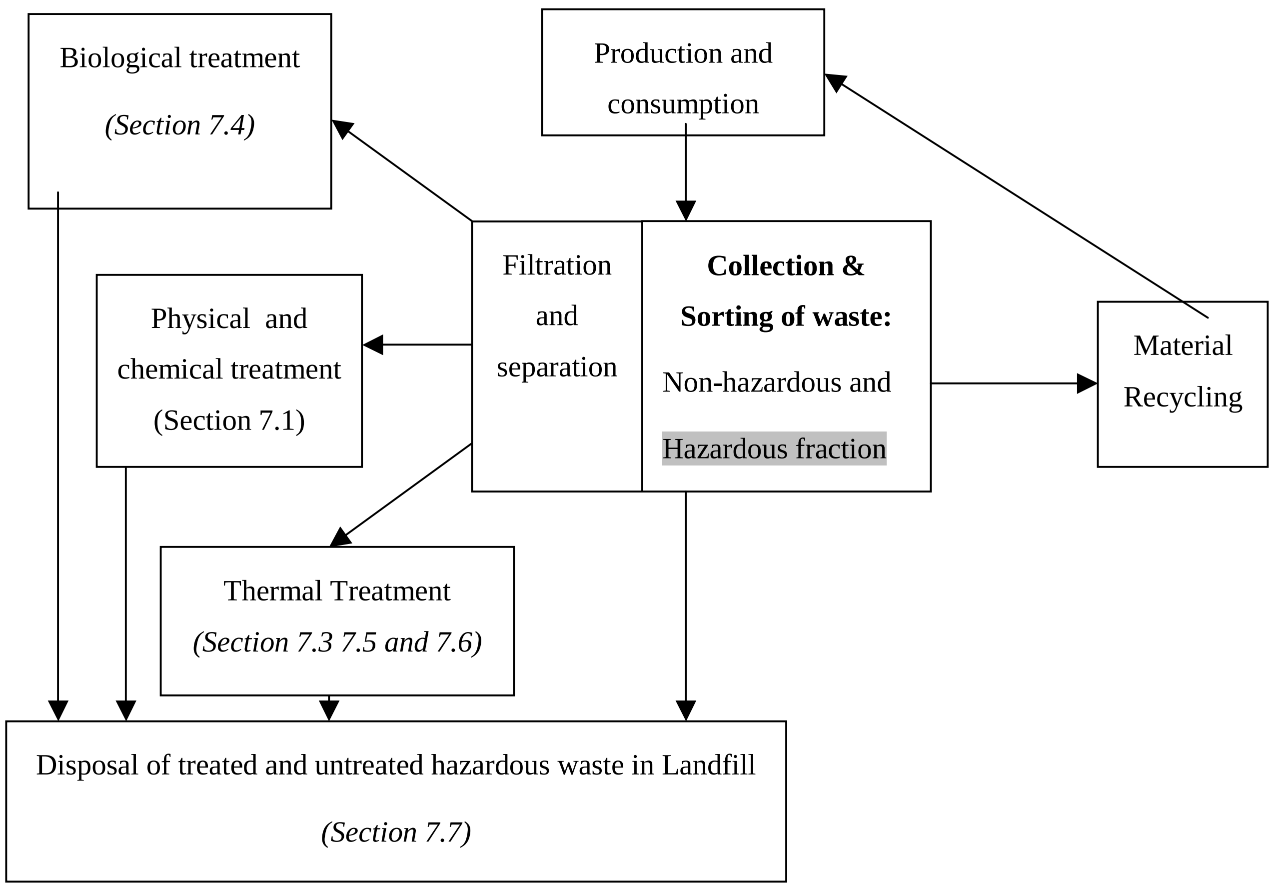


Figure: 5-5 Integrated waste management

5.2.3. Incentives, economic and social effects

5.2.3.1. Different aspects of an economic system

The following section will talk about general legal, economical and financial aspects of regulation and waste related project implementation.

General requirements for a legal system

A comprehensive legal system is needed for proper treatment of hazardous waste. Depending upon the structure of the administrative and legal system, regulations for hazardous waste can be more on a local level or more centralised. So, the legal system gives authorities more or less scope for decisions. Some legal requirements can be found even on international level. E.g. for any export and import of hazardous waste in most countries the Basel Convention is relevant.

Any legal system should be not too detailed in technical aspects, to give authorities and firms the required scope to act and to find individual solutions fitting to the particular situation. This is also necessary to adapt regulations easily to the state-of-the-art. Regulation should find the balance between the needed strictness and an openness, enabling quick reaction and continuous improvement.

Best regulation on hazardous substances includes every stage of production and consumption, beginning with extraction of the raw material up to final disposal of the product. This “life cycle” approach avoids leakages in the system and a possible contradiction of single regulations for every stage of the life time of product. Only this “life cycle” approach leads to optimal environmental protection and protection of human health. A “life cycle” approach is also a good base for long run solutions.

Incentives

Economic activities are driven mainly by incentives. This means in turn, by setting of proper incentives it is possible to influence economic activities. This applies also for any hazardous waste related issues. Incentives should be set in such a manner, that the amount of hazardous waste and dangers going out from hazardous materials to the environment and to human health are reduced. Basically there are two kinds of incentives: negative and positive.

- Negative incentives are bans, strict regulations, restrictions or constraints. Any violation of a law will be punished. In environmental and especially hazardous waste issues, strict regulation is necessary and it forms, in most countries, the base for the environmental regulation system. Negative incentives work only, if there are possibilities to control them. Negative incentives define clearly the scope of what to do what not to do.
- Positive incentives in economy are mostly monetary incentives like tax reductions, subsidies or bonus systems. Positive incentives operate mainly through price setting. Positive incentives are often preferable, also for psychological reasons. Usually, they give a broader choice of options. So they are more open to innovation and to new solutions. But, economic incentives and rewards are not always applicable due to monetary constraints.

Optimal waste fees

Waste fees can be based on different reasons:

- **Financing** of waste collection, treatment and disposal
- Allocation **efficiency** (internalisation of external effects)
- **Political goals** (e.g. waste reduction, less resource use)

Of course, usually all three reasons are somehow entangled. This is also, because an exact calculation and specification of these goals is not really possible for different reasons:

Financing of waste treatment and disposal can be very tricky, because, often it is not possible to determine the exact cost of waste treatment. Especially problematic are fixed costs, costs that emerge independently from the amount of waste. They can have the adverse effect, that with less generated waste the price per unit of waste will increase. Another problematic effect arises with disposal of waste. Because long run effects and long run costs are unknown, it is not possible to calculate exact full costs for a landfill [Linscheid 1998, p 44]. Landfills are a risk that can not be calculated. Even the exact composition of waste is often not known but for an exact pricing it may be needed.

Furthermore, exactly taken, costs of waste administration, control and information belongs to overall waste treatment and disposal cost. They have to be borne by the government but they origin from the generation of waste. It shows, that it is not easy to determine the exact costs of waste treatment and disposal. Any calculation will leave out some aspects and it may happen that some costs of waste disposal have to be borne by the society.
A difficult question arises also with costs emerging from contaminated sites as uncontrolled old landfills. Who has to bear this costs? The society (the taxpayer) or the current waste generators? So it is possible to argue that even the costs emerging from old improperly treated waste should be borne by current waste generators. Regarding allocation efficiency, it may be better than to let the taxpayer carry them.

The goal of allocation **efficiency** and internalisation of external effects are described already in detail. As an issue, practically it is difficult to determine an efficient price, even an estimation is not easy.

Political goals are very important, because a cost covering or efficient price is often not exactly determinable. So, waste prices are also more or less political prices. Fees determine also behaviour of consumers and producers. Hence, it is possible to reach long term waste reduction goals with waste fees.

The opportunity of illegal dumping may influence also the waste fees [see Linscheid 1998 p61]. To avoid illegal dumping it may be necessary to reduce waste fees to give incentives for legal waste collection. The reduction of fees can be cheaper to the society than the costs that emerge from illegal dumping. But, because this does not correspond to the polluter pays principle and does not give an economically efficient result, it should be avoided whenever possible. As an alternative, stricter controls are necessary that reduce illegal dumping. Sometimes too low waste prices can be accepted as an intermediate solution until a better legislation and control system is implemented.[71]

Better alternatives are deposit systems or an extended producer responsibility. With such systems no incentive exists anymore for illegal dumping and the polluter has to pay the price for waste disposal. No avoidance activities are possible. Because such systems need at least a nation wide system, this changes are only possible on a high political level. [For further details see also Hecht 2000]

Deposit-refund system

A deposit refund system is a very efficient way to decrease amount of waste. It incorporates different principles. The producer will be responsible for its product. So he will try to minimise waste costs because this will minimise his costs and he has to bear the costs for disposal. For the consumer or user of a product there exists a high incentive to return the old worn out product to get the deposit back. So, a deposit-refund system has even stronger economic incentives than just a producer responsibility that allows a consumer to return the used product or the waste free of charge. A small disadvantage of a deposit system are higher transaction costs, because retailer and distributors have to be involved into the system. Furthermore, a deposit system should be introduced nationwide. Common are deposit systems for containers and e.g. in some countries for lead batteries of cars.

Waste taxing

Taxing environmental damaging activities is an efficient way to internalise external effects, to achieve an efficient allocation and to diminish negative environmental impact. Taxation can be done in different ways:

Taxing of virgin materials: This is a useful tool for materials that have a negative impact regardless of there chemical status (e.g. heavy metals). It will help to reduce input of dangerous materials and it will encourage recycling. So, several years ago the US considered to introduce such a tax [Environment reporter 1991]. But it will work only with a nationwide application.

Taxing or demanding a fee of environmental damaging output (e.g. wastewater, waste): This is a quite common means to reduce the amount of waste. So, a fee can be found very often as well as a special tax (e.g. waste tax as in Norway or landfill tax as in GB (for details see [Davies and Doble 2004], [Martinsen T. and Vassnes E. 2004] or [EU/OECD 2006]. Both fees and taxes have a similar economic (and environmental) effect. Differences occur mainly on a legal or administrative side.

[71] For further discussion see also [Porter 2004 p 131]. The size of the influence of waste fees on illegal disposal is however not clearly statistically proofed. For a bibliography on this issue see [EPA 2006].

Fees and taxes

Fees serve mostly cost covering of necessary actions. So, a waste fee should cover costs for collection, segregation, transport, treatment and disposal. A fee can be demanded by public as well as by a private company who does the job of waste collection, treatment and disposal.

A fee has to be paid for a certain service (e.g. disposal of waste). Taxes, on the other hand are paid not for a certain service. They have either a financing goal or have the aim to influence the behaviour of the taxed person or company (this is especially applicable for environmental taxes).

But, this theoretically clear distinction is practically often not so clear, because fees are often “political fees”. As mentioned, usually it is not possible to compute an exact price for a service. Furthermore, fees will change similarly the behaviour of an individual. So, even fees have an economic effect like taxes.

Liability law and risk management

Liability is an important issue in environmental economics. Because pollution for example through hazardous waste lead to short, as well as long run dangers, the generator of dangerous pollution is in risk of liability suits. This depends of course upon the liability law and its implementation in a certain country. So, a strict enforcement of liability law should lead to more environmental protection (at least up to the common accepted level).

Similar to liability law is the importance of public relations. In countries like US or European countries public campaigns against polluting industries can have a considerable effect on companies. A strong liability law may enforce companies to sign an insurance contract. Then, the insurance company will exert pressure to improve certain especially dangerous situations. Furthermore, the handling of hazardous materials will reflect in the insurance premium. A sound environmental management will lead to lower insurance premiums. So there emerges an economic incentive.

Liability and public relation is a part of risk management of companies. This is, also, because poor environmental performance cause often accidents with great damage or fatalities and thereby cause high costs to companies. Especially important is the risk of fire. But, also the risk of health problems of employees or neighbours of the plant should be considered. Environmental pollution creates an economical risk to a company. Therefore the compliance of environmental law is also necessary for a long-term economic success. In some extreme cases, especially when accidents due to lax environmental standards occur, even a criminal suit to the responsible persons is possible. So, it should be in the interest of a company and of responsible persons to reduce environmental dangers.

For a company, an environmental risk analysis is recommended. Society and the company will profit from it. Therefore, a support of risk evaluation and minimisation by authorities will be very helpful. This risk evaluation should contain the following steps:

- Evaluation of the current situation:
    - Information about used and generated hazardous substances
      Attention: Even small amounts of certain substances can cause big troubles
    - Check of the characteristics of theses substances
    - Check of the current pathway of these materials (done by an input-output analysis), including a control of the amount of the materials. This will also show where substances may get lost.
- Development of necessary changes and improvements for
    - Labelling of all potential dangerous substances
    - Storage
    - Transport: within as well as to and from a plant
    - Handling during all steps of production
- Assignment of responsibilities to certain persons. Personal responsibility increases proper and careful handling

Optimal size of a waste treatment plant

Because many actions depend upon the financial background, investment is an important issue in waste management. This is true especially to the determination of the size of a waste collection system, treatment plant or landfill. The size determines the investment and thereby to a large extent the costs. Furthermore, it may influence even further politics through “sunk costs”.

Advance technologies like a good thermal treatment needs often high investment costs, whereby operating costs are comparatively low. So, planning of dimension of a treatment plant is very complicated and should regard also possible future changes in legal system, economic development, consumer behaviour, production technology. This planning should regard the lifetime of a plant.

Too small treatment plants lead to high operating costs and to a permanent need to extend the system further. Too big treatment plants on the other hand, lead to an inefficient use of the treatment plant (or may even cause technical problems as it occurs in thermal treatment plants with too low load). This leads to higher operating costs and to the adverse effect that waste is needed to improve efficiency of the treatment plant. So, waste reduction goals may be failed and resources will be spoilt or waste will be imported [for further details see also Cantner 2000].

5.2.3.2. Assessment of a collection and disposal systems

As mentioned, any change in regulation or introduction of a new system for waste handling affects different groups of people. So, for any collection or disposal system an assessment of its positive and negative effects is needed. As in section 5.1.1 already showed in more general terms, there are different approaches to estimate effects. Regarding waste management, some of the most important issues that should be clarified are:

Environmental friendliness

To this belong different aspects as:

- Energy use during collection and treatment. Especially transport is critical, because it consumes much energy and creates negative environmental effects. In optimising transport, there is a huge environmental potential.
- Material use: Especially for recycling activities, additional materials are necessary that cause additional environmental costs.
- Land use: Especially landfills are problematic because they consume much land directly and indirectly (adjacent land owners are affected) e.g. by bad smell or noise. In densely populated areas this is a real problem.
- Form and amount of waste of dumped waste: Under the aspect of sustainability, any dumped waste should be inert.[72]

Socio-economic effects

Socio-economic effects are important regarding support or resistance for or against certain changes or projects. To this belongs:

- Jobs: In every economy, job creation or destruction is more and more important. Extensive hazardous waste regulation usually can help to create jobs. Especially recycling activities are job creating. Of great importance are waste-pickers. They may loose their poor livelihood through an improved waste management system. To avoid social tensions they should be employed in a new waste handling system.
- Economic effects of waste fees. High waste fees may hamper economic activity or may lead to unwanted avoidance activities like waste export or illegal dumping. So, it may be necessary to set waste fees under the optimal or required level (at least temporarily) to have a chance to enforce them and to reach some acceptance.

[72] Inert means chemical stability. Inert waste will not chemically react and thereby create new substances.

- Economic effects of recycling activities: Recycling has usually a positive stimulation effect on economic activities. By encouraging recycling activities, it is possible not only to reduce the consumption of resources, it may also create employment, thereby leading to the development of new technologies, to innovation and new firms. [EPA 1995, EPA 1997]
- Acceptance by the public: Acceptance is a very complicated issue (see also section 5.2.4.2) that is not every time rationally handled by affected persons. It may be influenced by moral and ethical views (so the caste system in India could be relevant) but can be influenced also by political correctness. Acceptance is one of the most critical points, because waste management depends much upon compliance.

5.2.4. Strategies of hazardous waste management

5.2.4.1. Development of a hazardous waste management plan[73]

A waste or hazardous waste management plan helps to identify short and long run goals, to develop strategies and start actions. It can be developed on a factory level as well on the community level. The following headwords give main aspects of forming a waste management plan for a community. They can serve as a framework for elaborating a locally adopted plan. When it uses a feedback mechanism and an continuous improvement mechanism, a management plan is especially useful in achieving goals in the long run. Thereby, it may help to develop an integrated and sustainable waste management system.

Goal, Targets, Needs, Objectives

A broad target, a general goal gives a framework. So, a possible visions can be:

- To avoid irreversible damage to the environment
- To minimise the adverse effects of hazardous waste management in general,
- Use hazardous waste as resource, as far as possible

Based on a general vision and with background information, more specialized goals can be developed. These special goals should account for special local needs. So, these local goals can be a concrete visible progress, like cleaner water bodies, removal of an uncontrolled dumpsite, creation of job opportunities.

Based on this information, it is possible to develop a set of targets. Targets should be somehow measurable and verifiable. So, a target can be: to collect a certain amount of used batteries within a

[73] For further details and application see e.g. [DETR 2000], [City Council Christchurch 2003] or [Washington Department of Ecology 2004].

certain time. Or, better would be a reduction target e.g. the reduction of dumped waste by a certain percentage or to reach a certain water quality.

To develop a system of targets, background information as national goals and strategies or the estimated economic development are needed.

Principles

The definition of principles helps to develop a sensible waste management plan that correspond to general applicable rules to local customs, that can be accepted by the public, is feasible and sustainable. This list is not exhaustive.

- **Education:** The goal of education is to increase public concern and to create the necessary technical knowledge.
- **Cost effectiveness,** and affordability: This is the base for economical sustainability
- **Transparency** to the public, open reporting: It has a twofold effect: on the one hand, it helps to increase awareness and on the other hand, it creates social sustainability of the waste management process.
- **Polluter pays principle:** This is the main principle to discourage waste generation. But of course, the waste management plan may also contain subsidies or other economic incentives, if necessary.
- **Control of cultural impact**: Even though this may be less important for hazardous waste, culture plays an important role. To culture belongs the use of certain materials or reuse and recycling activities. A simple example is agriculture. The use of pesticides is not only based on scientific principles, it is also some kind of custom. To reduce the impact of pesticide use (and thereby also the impact of pesticide production), this culture has to be influenced.

Strategies

Based on general and concrete, local goals and the underlying principles, it is possible to develop strategies. Again, there is a not-exhaustive list of strategies for a waste management plan:

- **Proper segregation** of different kinds of waste: creation of incentives for segregation, introduction of rules and supporting initiatives for segregation
- Development of a system of **incentives and disincentives** for waste minimisation. To this belong especially economic incentives but also strict rules.
- Development of a **partnership** between the local council and the business: A partnership helps to use the know-how of business. It can increase confidence of business into the system and it can increase efficiency of technical implementation.

- Funding of **new technologies** and technical developments: Subsidies for advanced technologies may be needed and this can increase the speed of implementation of a proper waste management

- **Engage the community** Promotion of a better understanding of waste issues, involvement of the public secures long run success.

Actions

Based on the long term targets, the principles and the strategies, concrete actions can be developed. The following list gives an idea about feasible actions. But, it is possible to take more ideas from this guidelines :

- Identification of waste, information gathering and data collection as a base for systematic action

- Monitoring and feedback to provide relevant data to business and on the other hand, collection of data from business to community to increase know-how

- Training and orientation programme to increase expert knowledge

- Information campaigns, advocacy and lobbying: To promotion of waste and hazardous waste related issues, that are beyond the control of local authorities and to increase awareness.

- Enhance the local rules and other legal mechanism including city planning with the aim to reduce waste

- Improvement of the collection system with the support of the local community

- Improvement of treatment and disposal either, by direct economic activity of the local community or, by the inclusion of private business.

5.2.4.2. The siting of a hazardous waste facility (the NIMBY syndrome)

The so called NIMBY (not in my backyard) syndrome is a common problem for nearly all authorities who have to plan a facility that may be inconvenient or perceived as negative for the adjacent owners. It can be a waste incineration plant, a biogas plant or a landfill. The neighbourhood will be apprehensive of bad smell, danger of fire or, something else. Nobody wants to have a dirty facility in her neighbourhood. But, the society needs it. Hence, there is no simple answer. There are only different approaches to ease the problem.

In planning of such “dirty facilities” it is nearly unavoidable to have conflicts. It needs probably a long negotiating process to find a final solution. The main problem is the risk perception. Often, this risk perception do not fit in to the real risk. The perceived risk is often, much higher and does not correspond to experiences. Therefore, a cost benefit approach may be limited, because concerned persons are not receptive to rational arguments (For details see also [Portney 1991]).

So consider the following approaches:

Risk perception

As mentioned risk *perception* is a key issue, not the *real risk*. So, a first step should be:

Evaluation of perceived risks:

It is very important in the evaluation of a facility site to find out the perceived risks. There are different perceived risks and reasons for opposition: Probably, three main groups can be identified:

1. Fundamental opposition because of rejection of the technology or because of religious or sociological reasons
2. Fear of health and safety risks
3. Economic reasons: e.g. fear of loss of value of one's own property

All these perceptions have to be taken seriously. Based on an evaluation, actions to reduce opposition can be taken. But, be aware that all measures may have only a limited effect. But, without measures to reduce opposition and fear of risk, long run success of a "dirty" facility may be limited.

Fundamental opposition is a difficult problem. In short run, probably not much can be done. In the long run, a larger involvement of citizen can be useful (see improved participation process).

Fear of health and safety risks is very common and easily understandable. Risk perception should be the base to find **measures to reduce this risks**. To this belongs measures like, strict following of regulation, regular inspection (probably even voluntarily), publishing of environmental data (so that there can easily be seen that there is no risk or only a very low risk), special safety measures that improve current situation (e.g. installation of fire brigade that can help also the neighbourhood and thereby improve there safety situation). Introduction of a **strict risk management**. All these measures help also the hazardous waste facility to reduce long run risks, and therefore, also business risks.

Some specific fears of economic losses can be reduced by direct **financial compensation**. More general economic fears can probably be reduced by economic benefits like a hazardous waste treatment plant brings to a community: jobs, tax generation, improved infrastructure.

A general promising approach is **risk substitution**. This means, to draw a linkage between perceived new risks through a hazardous waste treatment plant and already existing risks (e.g. through bad hazardous waste treatment). New risks should be connected with reduced existing risks. This shows the advantages and the advances a waste treatment plant brings to the people.

Improved participation process

Long run involvement of citizen is highly recommendable. This may help to reduce some opposition and it ensures long run sustainability of a project. This is especially important because hazardous waste issues rely on participation (especially to collect the hazardous materials). One part of long run involvement is education. It helps people to understand hazardous waste issues better, but it may also increase perception of risk. Siting of hazardous waste facilities shows the dilemma of democracy. Involvement of public is necessary to improve long term success but, it makes people also more critical.

So, any participation process is a very difficult task, but citizen's participation seems absolutely necessary for the process, as it is to be seen as legitimate to gain long run success. The following figure is a scheme for a possible way to design a participation process:

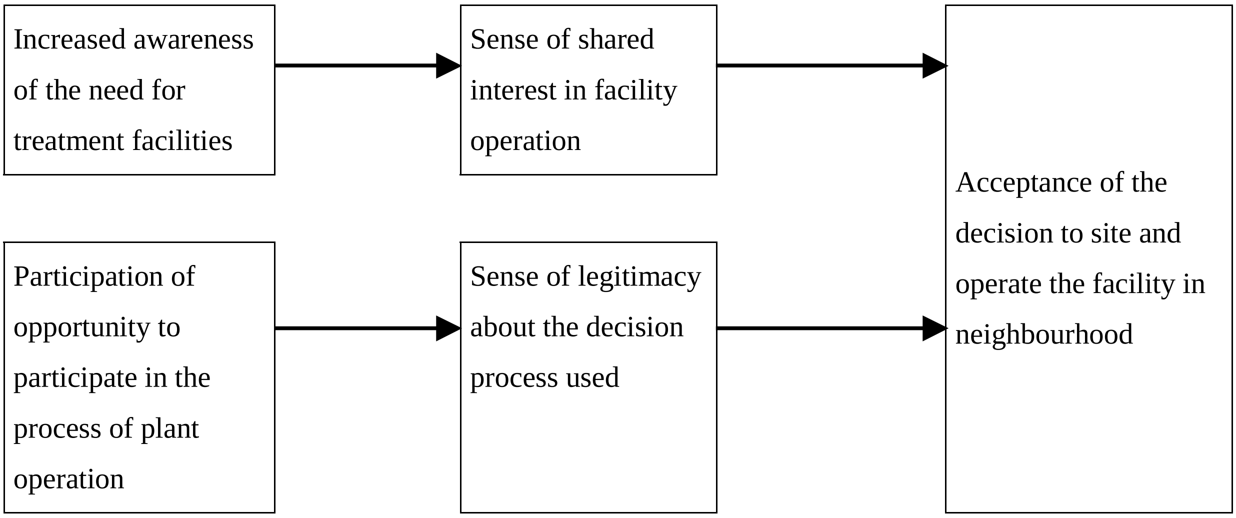


Figure: 5-6 Participation of citizen in a siting process[74]

5.2.4.3. Case study: Collection and Recycling in Dresden (Germany)

Dresden is a town with about 500, 000 inhabitants. As the law requires the municipal waste collection system is well established. But in such a big city besides the household waste a lot of hazardous waste is generated by households or small enterprises. So the task is to collect as much as possible of hazardous materials and to separate them from other materials to make treatment or recycling easier.

As a result, the disposal of small amounts of hazardous material is free of charge. So there is no economic barrier for the citizen to deliver them. There are several places within the city where people can bring there old electronics, paint leftovers and other dangerous materials. Furthermore, there is a mobile collection of hazardous substances that waits every day on a different street in the city. Every half a year, all households are informed about the places and time when they can get rid of their hazardous materials. So, illegal dumping is mostly avoided. Only lazy people may dump their hazardous waste in an inappropriate way.

[74] See [Portney 1991 p 55]

Figure: 5-7 Mobile hazardous waste collection truck

Who pays for it? Because of this sophisticated collection system the materials are quite well sorted. This helps to reduce further treatment and disposal costs. Furthermore, it is possible to recycle some of the materials. It brings some money. The second source of money is the waste fee, all inhabitants of the city have to pay for their household waste. Besides this, the recycling system brings a lot of jobs to mentally disabled people who do disassembling and sorting jobs. By provision of jobs, the city saves money for social welfare of these people.

Figure: 5-8 Different containers for separated waste

5.2.5. Influence of communities and authorities

Communities and local authorities can influence waste and hazardous waste policy by different means directly and indirectly. On a local level there are exist often more options than expected.

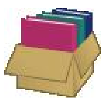
- **Procurement policy** of communities: Communities or other public institutions have a considerable demand for goods and services. Thereby, they can influence local economy. So, they can impose certain conditions like environmental friendliness on their orders.

- **Information access:** Local institutions can support firms as well as households with information about waste handling. The closure of the information gap can improve situation considerably. To this information belongs the general support for waste handling as this guidelines do , as well as special local information nobody else can give.
  To increase trustworthiness of the information centre, it should be an entity separated from administration and the control body.

- **Publicity**: Through media like press, TV or advertisements that the local authorities can publish their goals and involve the citizens. Public relations are an integrative part of any policy.

- **Communal investment**: In case of market failure and the lack of political instruments to correct them, a community can invest itself in necessary waste treatment plants. It is common in the case of municipal dumping site. In construction of this site, the municipality can set and improve environmental standards. But, a community can also go further for e.g. by installing a recycling factory. Own investment creates the possibility to overcome market failures and to set standards themselves. Of course, there are limits caused by costs of waste treatment.
  Municipal investment may be also necessary because of a long pay back period of complex and big waste treatment projects. Payback time in business is often rather short. So, a project even when it is profitable in the long run, may not be started by the private business as it may not promise short run profits.

5.3. References and Links



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6. Collection of hazardous waste

The following chapter will describe some aspects of collection of hazardous waste. Especially, technical together with safety issues will be depicted more in detail. Some more details about handling and safety at work can be found in the second part of the handbook. Here, the more general aspects of segregation, transport and labelling are explained. This chapter will be closed with some remarks on incentives for waste collection.

6.1. Technical aspects

6.1.1. Separation and segregation

As already mentioned in the previous chapter, there are different reasons for the importance of separation and if needed, segregation of hazardous waste:

1. Hazardous waste separated from other non-hazardous material makes further treatment and disposal easier and cheaper because there is no complex mixture or waste. After separation the non-hazardous material can be treated by less costly methods and the amount of hazardous material is reduced so, smaller treatment facilities are sufficient. Typical example for this, is the pre-treatment of contaminated water. After separation of hazardous material the wastewater can be treated as any other wastewater. The remaining toxic sludge has only a small volume compare to the original waste.
2. After separation, reuse of waste components my be possible This can be done e.g. with solvents or oil. After purification from waste components, the liquid can be reused for some time. So, separated waste helps to increase recycling quota and this may reduce costs.

This shows, that it is very important not to mix different kinds of waste. Treatment of mixed waste is much more difficult, dangerous and expensive. Collection of sorted waste means reduced costs, because no further segregation is necessary. In other words, waste segregation starts in the factory, in the production process. It should be avoided to put any other kind of waste into one container. Instead different containers for different kinds of waste must be used.

If waste is already mixed, segregation of different substances is often, necessary to simplify further treatment. Some of the possible technical procedures for segregation of different substances are described in section 7.1.

6.1.2. Transport and storage

There are many special means of transport. So, for e.g. in multi-chamber collection-transporters, the substances can be transported separately. For collection of liquid and paste-like substances, vacuum collection systems are used. In every case, the waste should not be mixed during the transport. Especially, high concern is needed for unstable chemicals as peroxides or picric acid.

Regular training for the personnel is essential. This applies especially, to emergency training. Furthermore, responsibilities for storage areas or transports should be designated properly to certain persons. This avoids a leak of information and dangers caused by incomplete and scattered information.

Rinse water is contaminated and cause a great danger to the ground water. So it should not be discharged into the ground and it's use should be minimised e.g. by re-application. Empty bottles and containers contain often dangerous leftovers. They can not be reused for other materials than the original substances.

Transport has to be done in appropriate containers that correspond to the chemical and physical characteristics of the hazardous materials. This is important to avoid accidents and in case of accidents to reduce effects of it.

Containers for toxic or caustic substances

For transportation of toxic or caustic substances, appropriate container material has to be used (Figure: 6-1). Other non appropriate materials will not last for long time and the containers will leak after some time and accidents are possible.

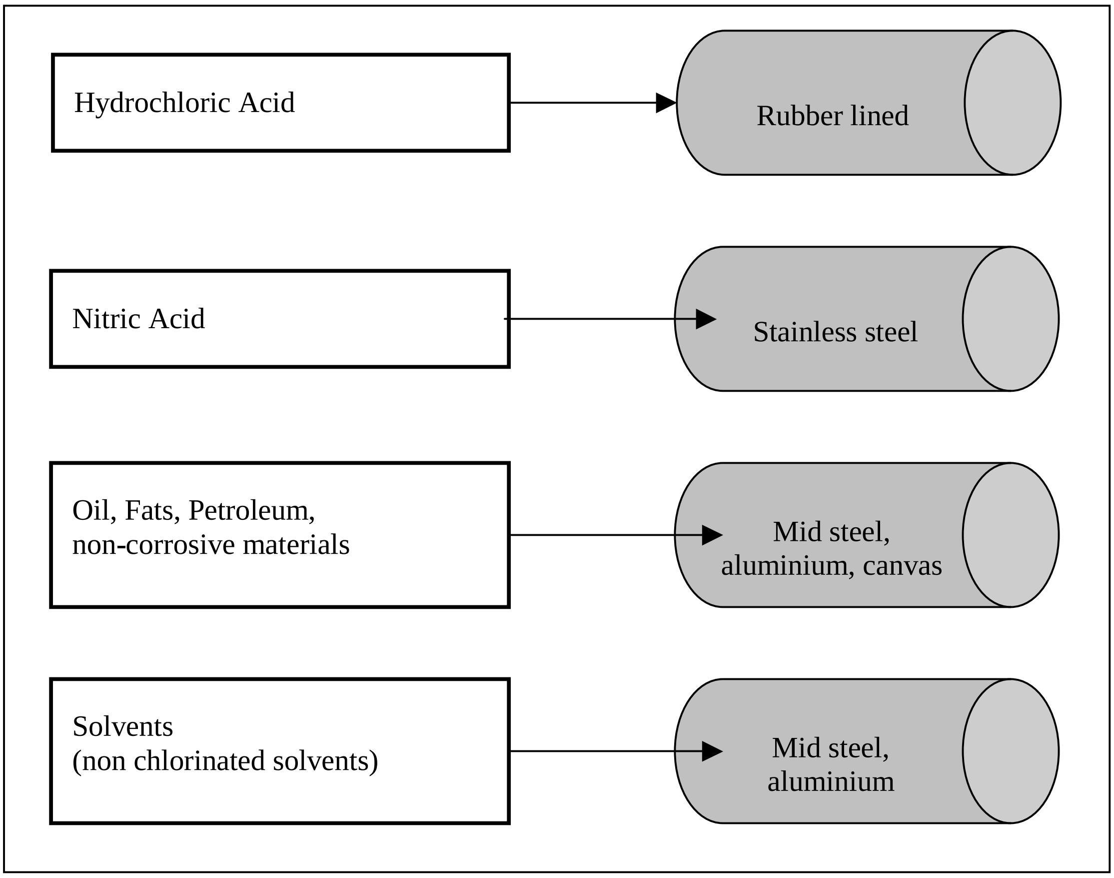


Figure: 6-1 Tank materials

Container for solid or pasty wastes

There are many container systems usable. Especially, for solid wastes, mostly, open sedimentation basins (sometimes with covers) are used. Very small volumes should be collected in cubic tanks with a volume less than 1000 litres. These systems are often piled up. In case of collecting fly ash or filter dust, bags made of polypropylene are used and disposed together with the waste. The following picture shows a filling system for fly ash.

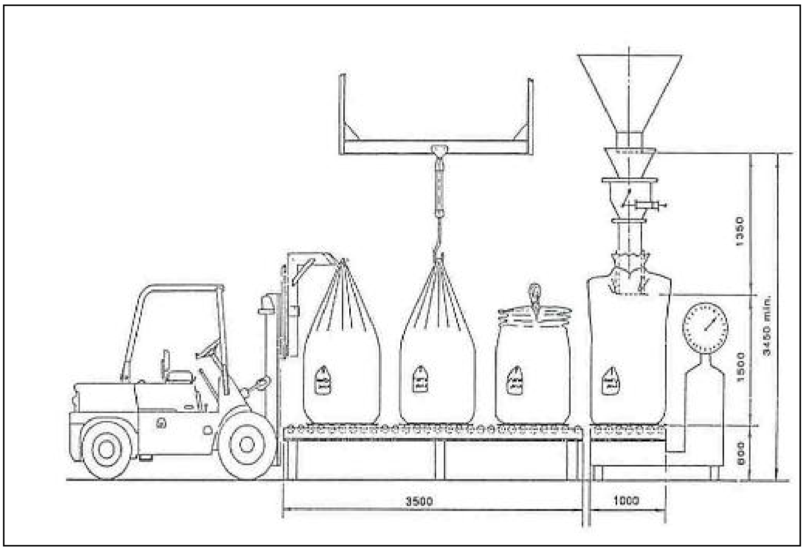


Figure: 6-2 Filling system for flue gas[75]

Like liquid substances, also, solid waste (e.g. contaminated sand from foundries) can be collected by vacuum-collecting systems. Advantages of such systems are the possibility of collecting waste, which has been stored in pits or basins.

Transport

Some common aspects about the transportation and storage of hazardous materials are the following. The first step for securely transport of harmful chemicals and hazardous waste is the training of drivers, loaders and handlers. In every case, the driver should:

- keep a certificate about origin, destination and characteristic of transported substances,
- stop the engine during loading-process,
- set the brake during loading- process,
- drive moderately,
- Take account of climatic circumstances.
- not take alcohol and drugs, or smoke,

[75] [Bilitewski at al. 2000]

- use personal safety equipment,
- have first aid equipment,
- Be trained for steps after accidents and leaks.

Besides this, a strict labelling and suitable vehicle are to be used (see section 6.1.3). Details about road transport can be usually found in national road transport regulation. But, even on the area of a plant where this road transport regulation may not apply, it is very important to follow strict security measures.

Collection points and temporary storage areas

Depending on the type of hazardous waste, the substances can be collected directly from the waste producer or with the help of independent carriers. Often, waste has to be collected in special storage areas before its transport. If similar wastes accumulate, the costs can be minimized and the logistic optimized. Appropriate storage requires careful design of the storage area.

Before a treatment or a disposal, hazardous wastes can be pre-treated in thermal treatment plants or plants for a chemical-physical treatment. The task is to separate and recycle resources from hazardous waste. The scheme of processes that can be done in such a collection point is shown in Figure: 6-3.

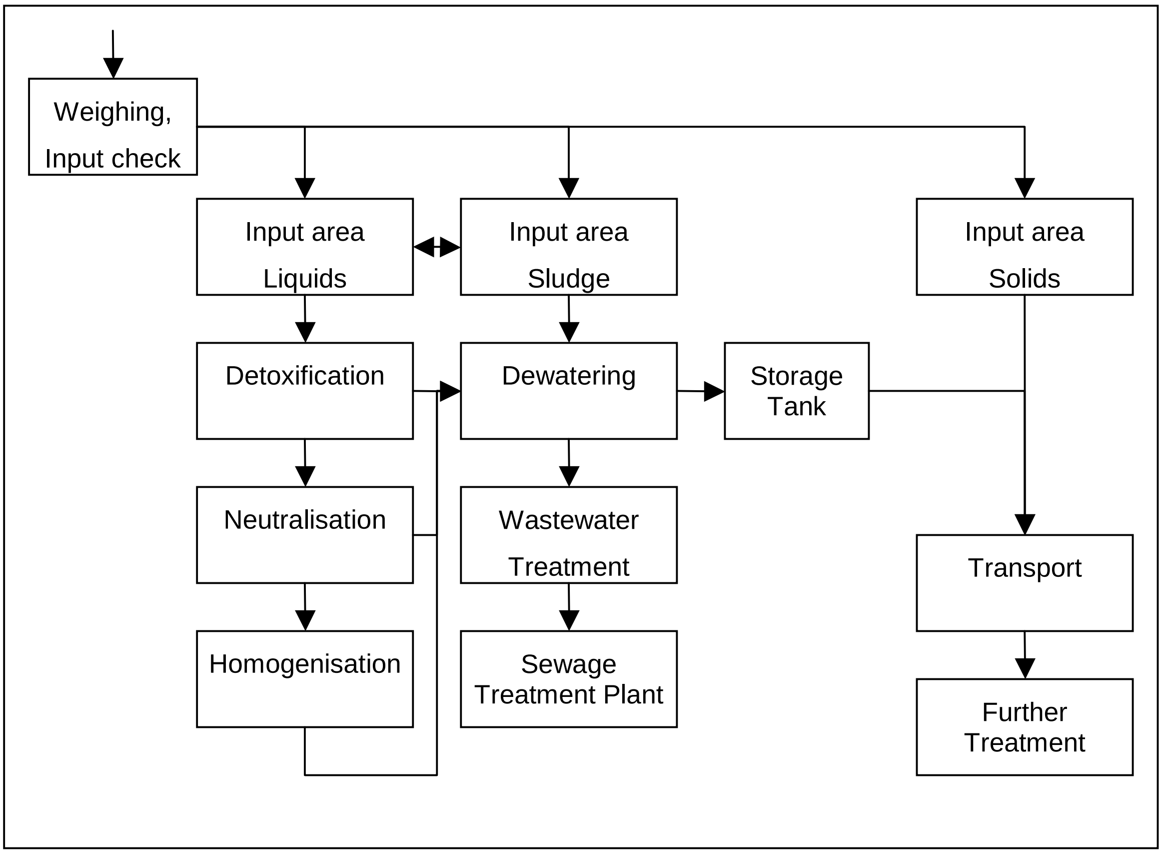


Figure: 6-3 Scheme of sorting in a collection point

Besides the treatment, it is very important to analyse and label all waste streams to prevent risks for the environment and people. From the collection, the substances are brought to plants for further treatment or disposal. Generally, a collection point should be divided into the following parts:

- Area for a possible mixing of substances,
- Area for mixing different before transport in further treatment plant or landfill,
- Plants for the separation of emulsions,
- Plants for detoxification, drainage and neutralizing

For the collection points special requirements are there to consider. Areas for filling and storage should be roofed over, in order to prevent a mixing of chemicals and rain. The floor must be impermeable for water, acids and other harmful liquids. Besides a cement layer, the following protection layers can be used:

- Layers made of metals,
- Multi-component layer systems,
- Plastic-based layers

Figure: 6-4 shows a room of storage for small amounts of hazardous materials in drums and containers. The floor is made of steel. The air is exhausted. there is a fire extinguisher. Under the shelves are catchment tanks. The walls and the door are fire resistant. The sorting of different containers in a shelf has to be done carefully, so that, a leakage in a upper container will never damage the lower container or even cause a chemical reaction with it. All containers are closed.

Figure: 6-4 Storage room for hazardous materials

A checklist for hazardous waste storage areas:[76]

1. Is the hazardous waste storage area free of spills and leaks?
   The hazardous waste storage area includes the area directly adjacent to and associated with the storage location. Immediately clean up any spilled materials in hazardous waste storage areas.
2. Are all hazardous waste containers designated for liquid storage in appropriate secondary containment and stored properly?
   To ensure regulatory compliance and prevent an uncontrolled release, secondary containment trays must be able to hold all liquid waste in the event of breakage. Do not place too many containers in one tray. Do not stack bottles in containment trays.
3. Are the hazardous waste containers and secondary containment free of spills or contamination?
   There should be no visible signs of contamination on tops or sides of waste. Wipe down or clean containers and containment as necessary.
4. Are incompatible wastes segregated?
   Segregate wastes into different secondary containment based on hazard class (corrosive acid, corrosive base, flammable, oxidizer, etc.).
5. Are containers and secondary containment easily accessed?
   You must be able to see and access hazardous waste containers in order to inspect or clean up a spill. You should not have to move secondary containment trays or waste containers to visually inspect or access containers.
6. Are all containers sealed with proper fitting lids?
   Check the lids carefully for a good fit.
7. Are all waste containers kept capped or sealed except when adding hazardous waste?
   Keep waste containers closed and sealed when not adding waste. Waste containers should never be left open when no one is in the work area, say, during a break or overnight.
8. Are all containers and lids made of a material compatible to the chemical waste contents?
9. Are all chemical waste containers stored in a safe location?
   Do not store waste in high traffic areas where breakage could occur. Do not store waste near any heat source (ovens, refrigerators, appliances, etc.). Keep waste in a secured and supervised work area. When no one is present, the work shop door should be kept locked.
10. Is the container size appropriate for the rate of waste accumulation?
    Use an appropriate size waste and avoid large containers that take a long time to fill. Fill waste containers to maximum 95% capacity in order to allow headspace for changes in temperature.

[76] See [UCSC 2003].

6.1.3. Labelling

All waste containers must be tagged, labelled and dated as soon as waste collection begins in that container. Labelling of waste containers is very important. Proper labelling avoids contamination and mixture of waste and it reduces dangers which may emanate from waste. What are the reasons for that?

- This helps further processing e.g. decision about landfill or thermal treatment, because properties of waste are known at every stage of collection and transport.
- It makes handling easier, because properties of waste are known and appropriate safety measures can be taken care of.
- In case of an accident, it is necessary to know exactly, the dangers from the material, so it is possible to react in an appropriate way and to avoid additional dangers.

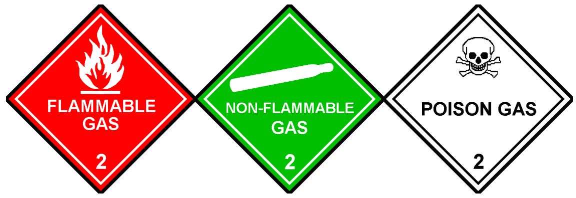
During storage, transport and disposal hazardous compounds must be properly labelled. In the case of hazardous materials, such as raw chemicals the label must always contain the following information:

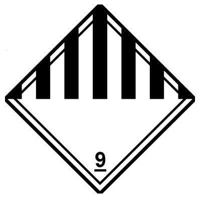
- Specific chemical name,
- Specific trade name,
- Protective equipment
- Special hazard warnings.

Commonly used labels based on the internationally used classification of hazardous waste are summarized in the following table:

Table: 6-1 United Nations Classification System for hazardous materials

Class 1	**Explosives**	
1.1	Explosives with a mass explosion hazard	
1.2	Explosives with a projection hazard	
1.3	Explosives with predominantly a fire hazard	
1.4	Explosives with no significant blast hazard	
1.5	Very insensitive explosives	
1.6	Extremely insensitive explosives	

Class 2	**Gases**	
2.1	Flammable gases	
2.2	Non-flammable, non-toxic gases	
2.3	Poisonous gases	
Class 3	**Flammable Liquids**	
3.1	Flash point below –18°C	
3.2	Flash point between –18°C and 23°C	
3.3	Flash point between 23°C and 61°C	
Class 4	**Flammable solids; Spontaneously combustible materials; and Dangerous when wet materials/Water-reactive substances**	
4.1	Flammable solids	
4.2	Spontaneously combustible materials	
4.3	Materials that are dangerous when wet	
Class 5	**Oxidizers and Organic Peroxides**	
5.1	Oxidizers	
5.2	Organic peroxides	
Class 6	**Toxic substances and Infectious substances**	
6.1	Poisonous materials	
6.2	Infectious materials	
Class 7	**Radioactive Materials**	

Class 8	**Corrosives**	
Class 9	**Miscellaneous hazardous materials**	

Beside this classification system, there is also a collection of labels indicating special dangers. These signs contain basic information about certain dangers.

Explosive

Materials that can explode owing to friction, sparks, fire, movements, beats or other ignition source. Handle with extreme care. Some materials should be checked frequently for signs of deterioration and aging. These signs include "sweating" of a container, bulging, crystal formation around the cap, etc. Deteriorating explosive materials are potentially more dangerous to handle than new explosives.

Oxidising chemical

Materials that spontaneously evolve oxygen or other oxidizing substances at room temperature or with slight heating, or that promote combustion. Together with combustible materials there is a danger of fire or explosion. Oxidizing materials can speed up the development of a fire and make it more intense, cause substances that do not normally burn readily in air to burn rapidly, cause combustible materials to burn spontaneously without the presence of obvious ignition sources. Examples are nitric acid, chromic acid or peroxide. Handle with care and keep it away from flammable chemicals!

Flammable

Flammable materials are (flagged by the sign **F**) are liquids that have a flashing point below 21° C and, that are not extremely flammable. Solids that can be inflamed through a short contact of an ignition source and continue to burn. Flammable is also material that develops together with water or wet air, extremely flammable gases, material that can be heated by themselves at normal temperature without additional energy and burns finally. Examples are many solvents or dust of many material in a high air concentration.

Extremely flammable

Material are extremely flammable and are flagged by the symbol **F+** when they are liquids, and that have a flashing point below 0° C and a boiling point below 35°C or ignitable gases at normal temperature and pressure.

Toxic or Poisonous

Toxic materials harm humans who touch, breath or swallow it. Material's toxicity depends, usually, on the dose. But, even very small doses can be dangerous especially, after long term or repeated exposure. Symbols discern two classes: **T** toxic and **T+** very toxic. One example for poisonous hazardous materials are heavy metals that are found in many metal residues or pesticides.

Irritant or Harmful

This sign marks material that causes danger to health. The sign **Xn** denotes harmful material. The sign **Xi** denotes material that is irritant to the skin to eyes or the respiratory system. Many substances can be irritant or harmful. It can happen even through a degreasing effect to the skin. Even, in households harmful substances like, cleaning agents can be found.

Corrosive

Corrosives are materials that can attack and chemically destroy exposed body tissues. Corrosives can also cause damage or even, can destroy other materials like metals. They cause damage as soon as they come into contact with the skin, eyes, or other materials. Most corrosives are either acids or bases. Everyone, who, works with corrosives must be aware of the hazards and how to work safely with them. So, the skin must be protected. Storage and transport of corrosive materials has to be done in special containers. Examples are common acids like hydrochloric acid, sulphuric acid, nitric acid, chromic acid, acetic acid or hydrofluoric acid and bases like ammonium hydroxide, caustic potash or caustic soda. Dangers depend upon the concentration of the substance. Corrosive substances in low concentration are irritant.

Environmental hazard

Hazardous materials endanger, often the environment. This danger can be direct or through long exposure to harmful substances. Concentration plays also an important role in determining the environmental effect of a hazardous substance. But, in a long run even at low concentration, environment can be affected negatively by hazardous waste.

6.2. Incentives

As in chapter 5 mentioned, a proper framework of economic incentives is necessary to obtain reasonable results for hazardous waste collection and separation. In that chapter facts about economic incentives on the micro and macro level are described more in detail. Here, some practical hints about hazardous waste collection are mentioned.

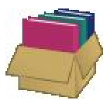
In case that there is no or, only a very weak economic incentive of segregate and collect the waste, handover of waste should be rather simple for concerned firms or persons to smoothen the process. This may reduce illegal dumping and unnecessary mixing of waste. What may be necessary:

- Information about the dangers and the need to segregate and collect the waste
- Information about proper labelling
- Provision of suitable containers for hazardous waste (e.g. by a deposit system for containers)
- Easy handover, e.g. by a mobile hazardous material collection. This can be done either on demand or in fixed periods. (Many cities install this for hazardous waste from households and small workshops.)

A small investment from the side of the firms, where the hazardous materials are generated may help to reduce treatment and disposal costs considerably. In organisation of collection of (hazardous) waste, the basic goal to be kept in mind should be:

Waste should be segregated at source!

6.3. References and Links



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7. Treatment and Disposal of hazardous waste

Treatment of hazardous waste can be done by different means. Physical, chemical, biological or thermal treatment is possible. The final goal of any treatment is the destruction or immobilization of the hazardous substances. One step to this, is the separation of hazardous and non-hazardous materials that is sometimes necessary. This chapter gives an overview of different treatment options and requirements for disposal.

7.1. Physical treatment

Physical treatment processes are widespread as a very basic treatment, especially with the goal of separation of different materials.

7.1.1. Separation by filtration

Filtration is a mechanical process, where a mixture of substances of different phases passes through a filter with different pore size. The greater particles stay beneath the filter and form the so-called filter cake. The fluid phase passes the filter.

There are two possible aims of the filtration:

- The production of clean water out from less loaded sewage deep bed filtration and the cross-flow filtration. [Freeman, 1998]
- The drainage of sludge with 1-30 % solid particles and extraction of pasty or solid waste for dumping. For this filtration, with a mud cake is often used. [Freeman, 1998]

Deep bed filtration

The deep bed filtration (Figure: 7-1) is used only at liquids with less than 100 ppm solid particle concentration [Freeman, 1998]. The solid particles will be held back by the filter medium by physical and chemical processes and the liquid component passes through.

For this type of filtration, filter with granular materials, screen filters and deposable cartridge filters are used.

This process usually, is practiced discontinuously. Continuous processes can be, however, possible as in the case of sand filters. These need, however, more technical complexity. The filter medium should be exchanged depending on degradation of the drain or, after the need to increase the pressure required for the filtration.

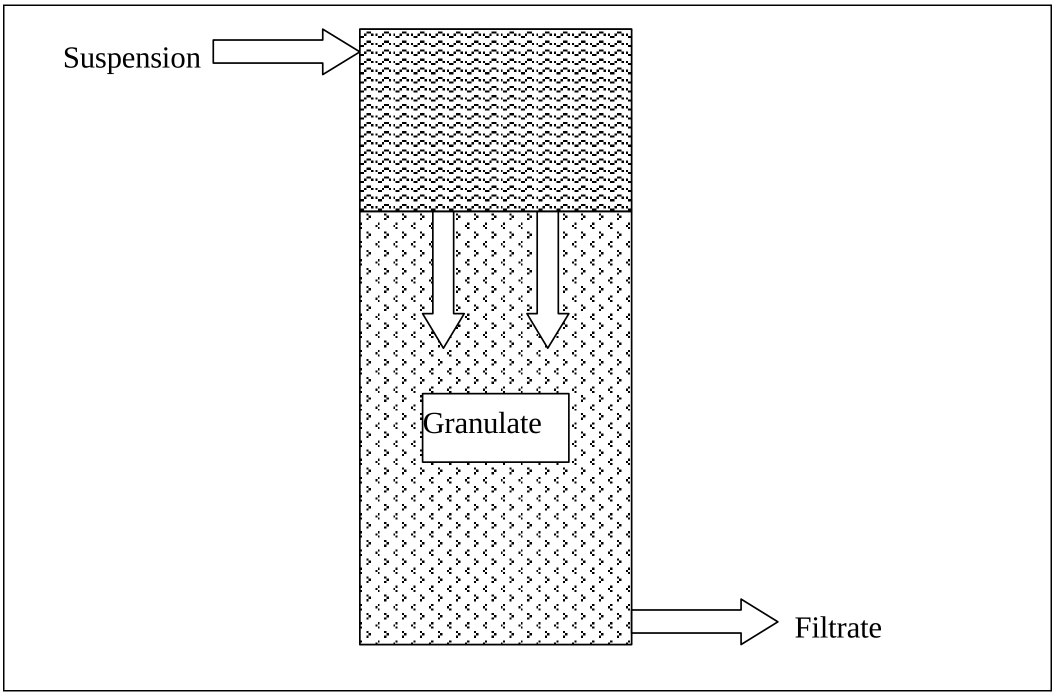

Figure: 7-1 Deep bed filtration

Filtration with a mud cake

As in the case of the deep bed filtration, the liquid passes through the filter medium, while the particles are held back in the filter medium. The difference consists in the formation of a filter cake, through its growing thickness it takes over the role of the filter medium. The filter cake will be cleaned and can be drained by drying or pressing (Figure: 7-2).

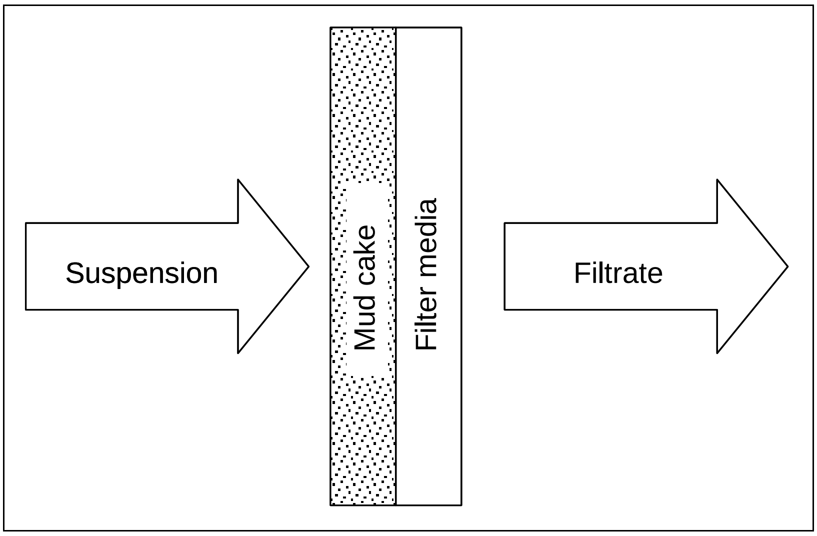

Figure: 7-2 Filtration with a mud cake

Cross-flow filtration

At the cross-flow filtration (Figure: 7-3), the suspension is fed into the filter medium parallel and with a high speed. A turbulent flow which prevents a formation of a filter cake arises from it. The permeate is absorbed vertically, to the flow direction by the filter medium. This method works most effectively with Suspensions with less than 0.5% solid particles [Freeman, 1998].

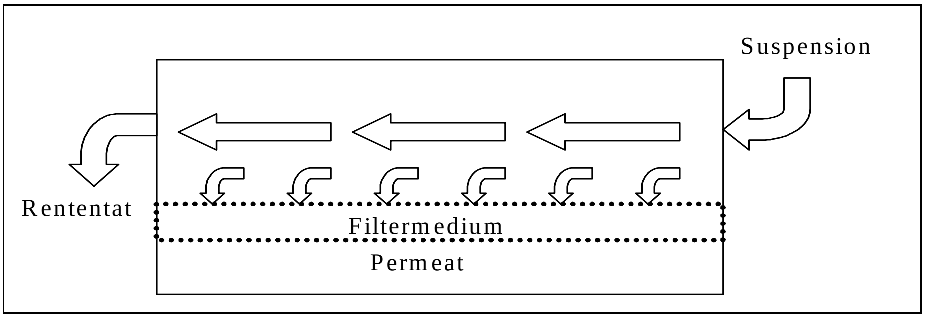

Figure: 7-3 Cross-flow filtration

Granule bed filter

These filters are used for the deep bed filtration of industrial effluents. They consist of a tank with a grid. On the grid, the filter medium is heaped up and the filtrate can flow through it. Depending on number of filter media, simple bed and multiple bed filters are distinguished. After the passage of the suspension the bed must be cleaned. It can be exchanged, reprocessed or flushed back. A continuous process can be implemented by a two way system. While, one filter is cleaned, the second one takes on the filtration [Freeman, 1998].

Screen filter

The screen filter (Figure: 7-4) also, is used with low loaded effluents. It is regarded as the most important and most frequently used in the industry. The operation is rather simple. The Suspension flows through the openings in the can, the particles stay at the pipe. The Cleaning is carried out through a rotation of the can along a fixed scraper. A backward flush of the filtrate it also possible [Freeman, 1998; Mann+Hummel 2000].

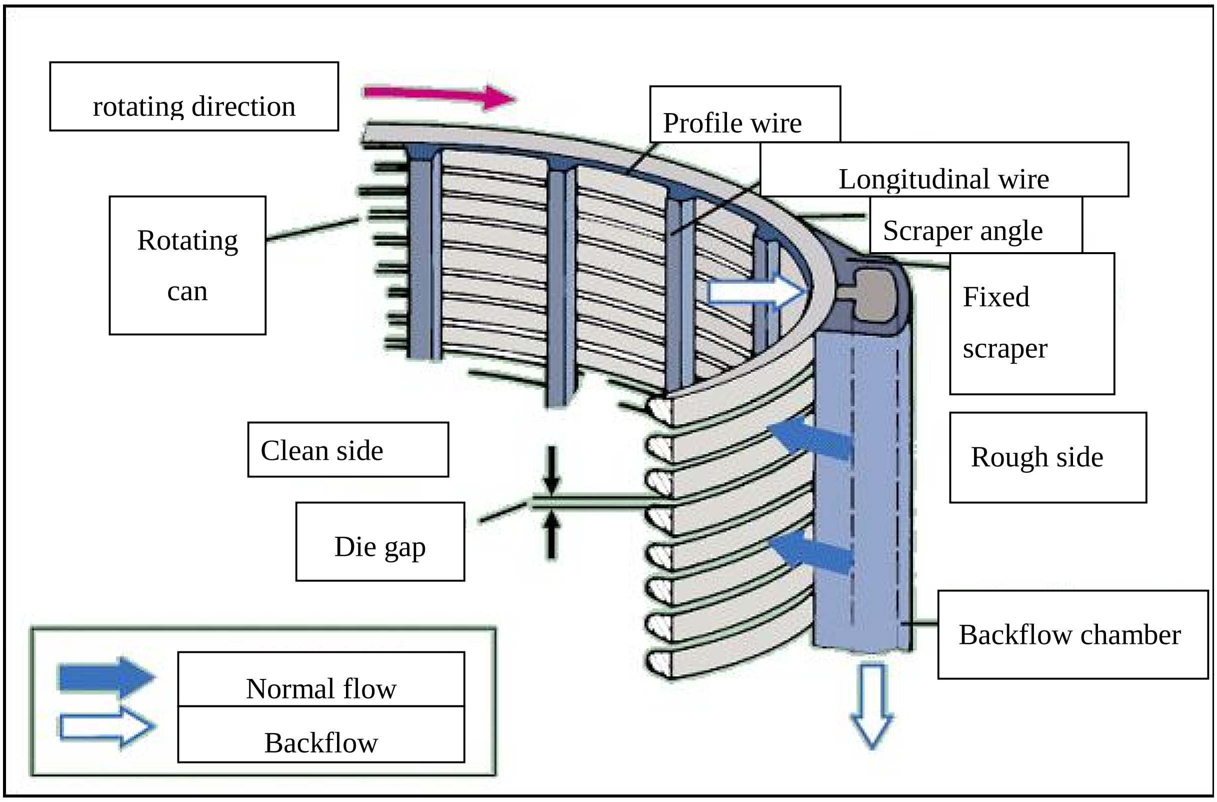

Figure: 7-4 Screen filter[77]

Vacuum drum Filter

This filter serves the drainage of industry sludge. The filter medium is wound around a rotating drum and dives into the Suspension. A vacuum which draws the Suspension into the inner one is in the of the drum. The filtrate (water) is collected in the inner and is transported over a pipe to the outside (Figure: 7-5). The great advantage is the possibility of continuous and maintenance-free operation [Freeman, 1998].

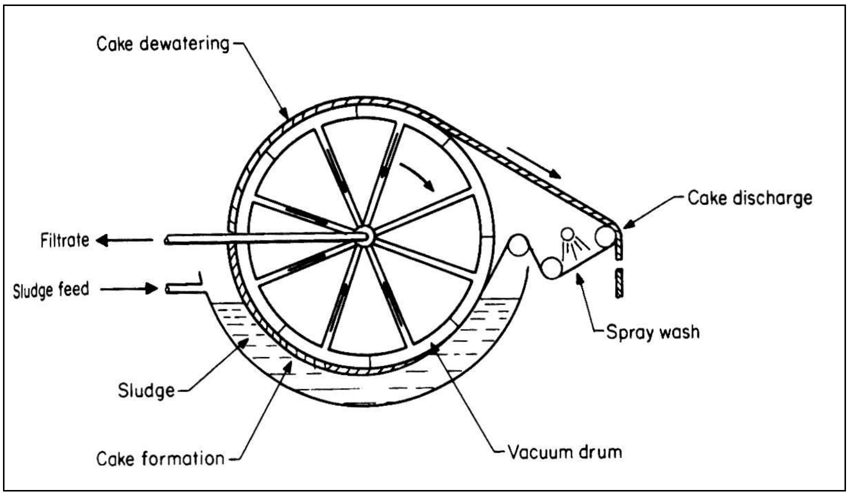

Figure: 7-5 Construction Vacuum Drum Filter[78]

77 [Mann+Hummel 2000]

Coated Vacuum Filter

This filter works with a surface layer from an outside medium on the filter material. This surface layer enables the deposition of great particles by cake formation and small particles by deep bed filtration. During the cleaning with a scraping knife, a part of the surface layer is also removed so that, a renewal of the surface layer is necessary after several cleaning processes. This is the disadvantage of this method. Through the renewal of the surface layer, the filter is not usable for around one hour [Freeman, 1998].

Filter press

Filter presses (Figure: 7-6) are used for the drainage of sludge. The sludge is pumped into horizontally or vertically arranged chambers. On the filter medium in the chambers, a cake will emerge. The chambers will be filled with sludge, until they are filled completely with filter cake. With the help of hydraulic or other mechanical strength, the filter chambers are squeezed together and the rest of the water will be pressed from the cake into the filtrate. After pressing, the filter cake is dried and is removed from the open press. The filter material is washed and the press is locked for next use [Freeman, 1998].

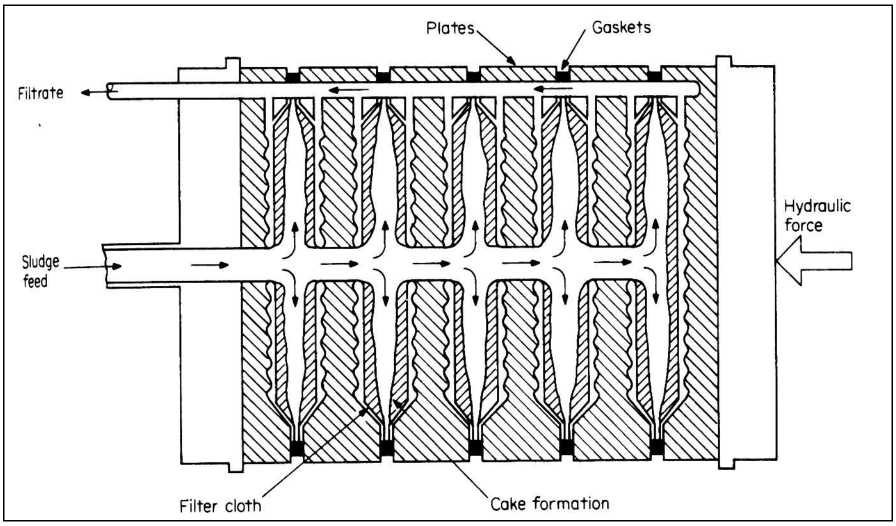

Figure: 7-6 Filter Press[79]

[78] [Freeman 1998]

[79] [Freeman 1998]

7.1.2. Separation by density differences

The separation by density is carried out with the help of the gravity or by the buoyancy of the particles in the material flow. There are three different variants of separation: Flotation, Sedimentation and Centrifugation (Figure: 7-7).

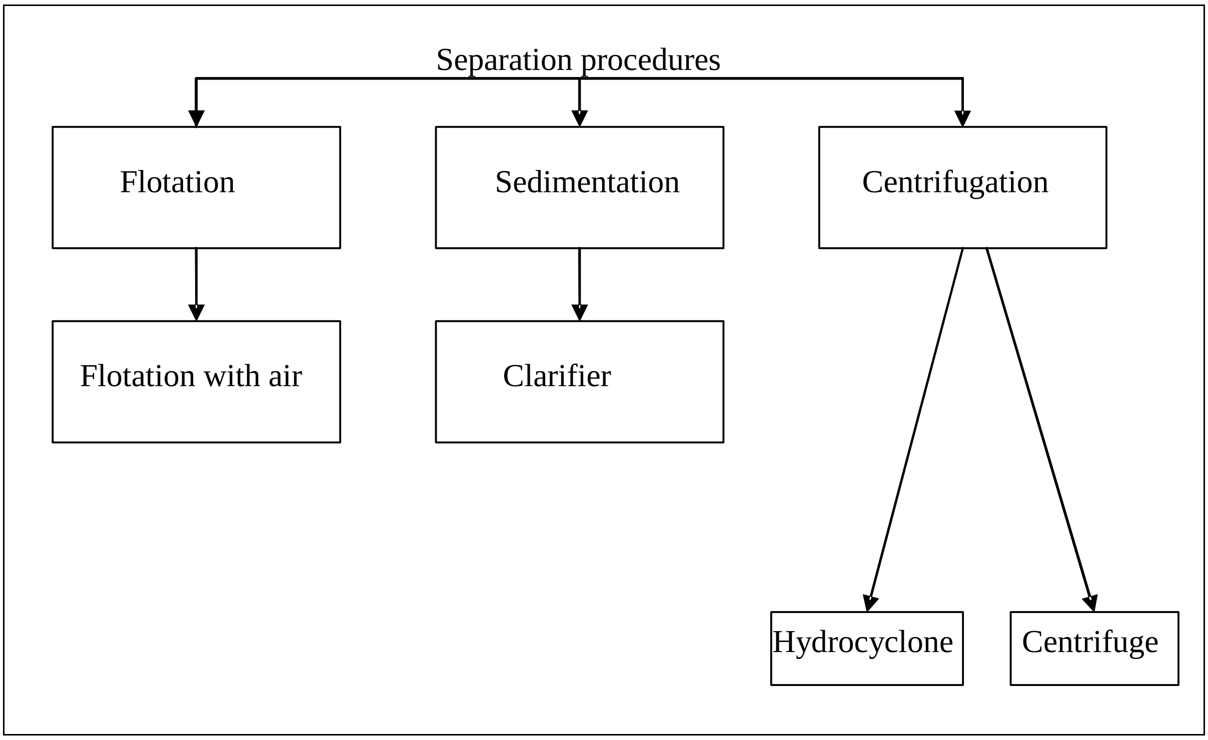

Figure: 7-7 Separation by density differences

Flotation

Flotation is a physical separating process whereby, the substance separation is performed by the insertion of air bubbles. The separation is dependent on the surface characteristics and the force of water attraction of the particles. Particles with low water attraction attach to the air bubbles and will be transported to the surface, where they can be removed.

Sedimentation

The Sedimentation is based on the principle of sinking of particles in a resting or slowly flowing liquid by gravity. The solid fraction accumulates on the bottom of the vessel or basin. This principle is applied in grit chamber or clarifier basins.

Centrifugation

Centrifugation is based on the separation of lightweight and heavy substances by a centrifugal movement. Thereby, it does not matter whether the complete suspension reservoir moves (centrifuge) or only the suspension executes the movement (so-called Hydrocyclone).

7.2. Chemical treatment

They are based on different principles so that, it is possible to treat different kinds of hazardous waste. According to procedural complexity and amount and kind of additives, the treatment is more or less cost-intensive.

7.2.1. Chemical precipitation

The chemical precipitation (Figure: 7-8) is, of special importance for the immobilisation of toxic pollutants like heavy metals. Thereby, the dissolved substances will be transformed into insoluble complexes which can be removed by precipitation from the bottom of the reactor.

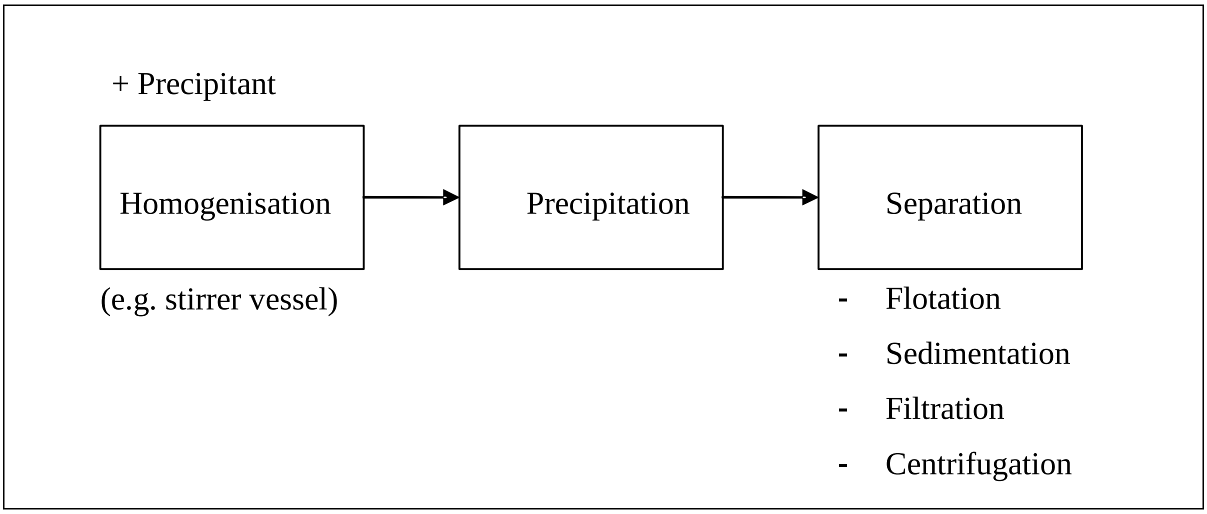

Figure: 7-8 Treatment by chemical precipitation

<u>Hydroxide precipitation</u>

The precipitation with hydroxide ions is made by the use of calcium hydroxide

$$M^{2+} + Ca(OH)_2 \rightarrow M(OH)_2 + Ca^{++}$$

The process depends upon the kind of metal, the conditions for reaction (particularly the pH) and the existence of disturbing substances which prevent reaction. There is a particularity with the precipitation of chrome. It can react only, in the form of chrome III to an insoluble complex. To reduce chrome VI to chrome III, it is necessary to add sulphur and to reduce the ph [Freeman, 1998].

<u>Sulphide precipitation</u>

The precipitation with sulphide ions has an advantage, that, the solubility of metal sulphides is lower than those of the metal hydroxides.

$$M^{2+} + FeS_2 \rightarrow MS + Fe^{++}$$

Another advantage is the not needed pre-treatment of chrome VI for precipitation. A great disadvantage of sulphide is the potential of formation of the toxic hydrogen sulphide. So, it is only conditionally recommended to the use this process [Freeman, 1998].

Carbonate precipitation

With metals like cadmium or lead the precipitation with carbonate ions has to be preferred compared to a precipitation with hydroxide ions since it produces better separable sludge at the same pollutant concentration during operation.

$$Na_2CO_3 + M^{2+} \rightarrow M\ CO_3 + 2Na^{+}$$

However, with metals like zinc or nickel, the use of carbonates is not recommended [Freeman, 1998].

Sodium borohydride precipitation

Unlike the previous processes the metal ion is converted in an insoluble elementary form by the sodium borohydride. This makes this process applicable for the retrieval of valuable metals like lead, mercury, nickel and copper.

$$4M^{2+} + NaBH_3 + 2H_2O \rightarrow NaBH_2 + 4M + 8H^{+}$$

This process works with a pH between 8 and 11 at the most effective [Freeman, 1998].

Cementation

With cementation, dissolved ions of precious metals are displaced by ions of base metals. Precious metals are precipitated and recovered. Particularly, gold, silver and copper are gained by this process [Freeman, 1998].

7.2.2. Solidification und Stabilization

Solidification and Stabilization are processes that, immobilise hazardous substances.[80] Usually, they can be applied without any pre-treatment. An exception is, Chromium VI that has to be transformed to Chromium III.

Solidification

Solidification means, to reduce the water content by adding additives. The water will be bound and the waste gets solid and appropriate for disposal.

[80] This section base mainly on [Freeman, 1998].

Stabilization

Stabilization aims to alter instable chemical compounds through additives into stable chemical compounds. The product is not necessarily, in a solid state because, the water is not bound, only the chemical composition is changed.

Chemical fixation

This process describes the combination of solidification and stabilization. Hazardous sub-stances are converted to non-hazardous and the water content will be reduced to bring the waste into a solid state.

Encapsulation

Through encapsulation of the waste through a containment (e.g. made of polymers or asphalt), the hazardous substances are not let to move out any more. Depending upon the size of the agglomerate, micro- and macro encapsulation is distinguished.

Vitrification

Vitrification is done at high temperatures (ca. 1000°C). thereby, the waste melts and stabilises itself. During that process, incineration of flammable substances and volatilisation of metals and organic compounds is possible.

Sorption

Sorption means the addition of activated coal or clay. Thereby, the free water will be bound on the surface of the additive. This means, there is only an immobilisation of the hazardous substances. Therefore, this procedure is used together with solidification and stabilisation.

7.2.3. Chemical oxidation and reduction

Oxidation of hazardous waste

With chemical oxidation many hazardous substances can be treated. But, the treatment of high concentrated effluents is expensive because of the needed chemicals. Furthermore, for treatment, there are additional processes like incineration or treatment with ozone, needed. It is usable for organic compounds (phenols, benzene, toluene, chloride substances) as well as inorganic compounds (sulfides, ammoniac, cyanide or heavy metals)

Oxidation with Chlorine und Hypochlorite salt

Chlorine dissolves in water and forms a hypochlorite acid. It is cheaper than hypochlorite salts but, it is toxic and therefore, its application needs careful working. Often, chlorine is used for oxidation of cyanides. But, the concentration should not be higher than 1000 mg/l. [Freeman 1998] The reaction takes place in two steps

$$CN^- + H_2O + OCl^- \rightarrow CNCl + 2OH^-$$

$$CNCl + 3OCl^- \rightarrow OCN^- + Cl^- + H_2O$$

For that reaction, a pH-Value of more than 10 is needed [Freeman, 1998]. The resulting cyanate is of low toxicity so that, a further oxidation to carbon and nitrogen is recommended.

$$2OCN^- + H_2O + 3OCl^- \rightarrow CO_2 + +N_2 + 3Cl^- \ 2OH^-$$

For an efficient process, the pH-Value should be reduced to 8.5 [Freeman, 1998].

Oxidation with chlorine dioxide

Chlorine dioxide is an yellow-red and in water, easily soluble gas. At high concentration, there is the risk of explosions.

Oxidation with hydrogen peroxide

Hydrogen peroxide is a inodorous and colourless liquid with strong oxidizing characteristic. The disadvantage is its decay into water and oxygen. Therefore, additives are necessary. Hydrogen peroxide is used for the removal of lead, cyanides, mercaptan (thiol) or amine from effluents [Freeman, 1998].

Oxidation with potassium permanganate

Potassium permanganate ($KMnO_4$) is a stable, black crystalline compound. It is easily soluble in water. The potential for oxidation depends upon the pH-Value of the solution. It is used for the removal of phenols, mercaptan (thiol), unsaturated organic acids, ferrous II, manganese II, sulfides and cyanides. The disadvantages are the manganese salts in the effluent and the relatively high costs [Freeman, 1998].

Oxidation with oxygen

Because of the high safety and the low costs, oxygen is the most used substance for oxidation. But, it has only a low solubility in water. Therefore, organic compounds and many metals are only oxidized with a low efficiency. It can be used well for ferrous II and manganese.

Oxidation with ozone

Ozone is a penetrative smelling gas that has a higher solubility than oxygen. It is a very strong oxidation substance. Thereby, it can remove also, organic substances from waste.

Advanced Oxidation Processes

This process based on the reaction of the waste with short lived hydroxide radicals. They are produced with ozone and hydrogen peroxide. But, the control of this process is, rather complicated because, many factors have to be considered [Freeman, 1998].

7.2.4. Reduction of hazardous waste

Reducing agents are used for the removal of hazardous materials like heavy metals as chromium or copper used. At the same time, a precipitation is possible.

Sulphur dioxide and Sulphite

The potential of reduction of sulphur dioxide is lower than that of sulphite. SO_2 is difficult to handle but much cheaper. Both substances are used mainly for the removal of chromium VI to chromium III, as well as chlorine and manganese.

Reduction with metals

This process is used especially with elementary iron. The metal is oxidized and solved. With the help of iron chromium VI can be reduced. Furthermore, the extraction of copper and silver is possible.

Reduction with ferric sulphate

Ferric sulphate is a common form of ferrous II. It is relatively cheap and therefore used quite often. As a disadvantage, oxygen leads to an oxidization to ferric III, that will precipitate [Freeman, 1998].

Reduction with Sodium dithionite

Sodium dithionite can be used as a reduction agent only, in base solutions. It is used also, for chromium reduction.

Reduction with Hydrazine

Hydrazine is a very powerful but also very toxic reduction agent. It decays during a reaction with water and nitrogen. Therefore, an after treatment is not necessary. But, its costs are high and this process is not very common [Freeman, 1998].

Reduction with Sodium borohydride

Sodium borohydride is a powerful reduction agent, that is stable under base conditions. Under neutral and acid conditions, it decays with the emergence of hydrogen. Furthermore, it is very expensive [Freeman, 1998].

Reduction with hydrogen peroxide

Under base conditions hydrogen peroxide has a weak reducing impact and therefore, it can be used for the reduction of chromium VI to chromium III and for the removal of silver.

7.2.5. Pervaporation

Pervaporation is the separation of hazardous substances from liquids. Like evaporation (Section 7.2.7) it does not degrade the hazardous materials. But, it separates the different materials and allows thereby, further treatment or reuse of some components.

A liquid streams along an impermeable membrane. The volatile components penetrate the membrane due to concentration differences and will be exhausted through low pressure. After that, the gas will be condensed (Figure: 7-9). Thereby, a variety of organic substances as benzene, xylene, toluene, alcohol, methanol, trichloroethane, polyvinyl chloride or chloroform can be separated from effluents [Freeman, 1998].

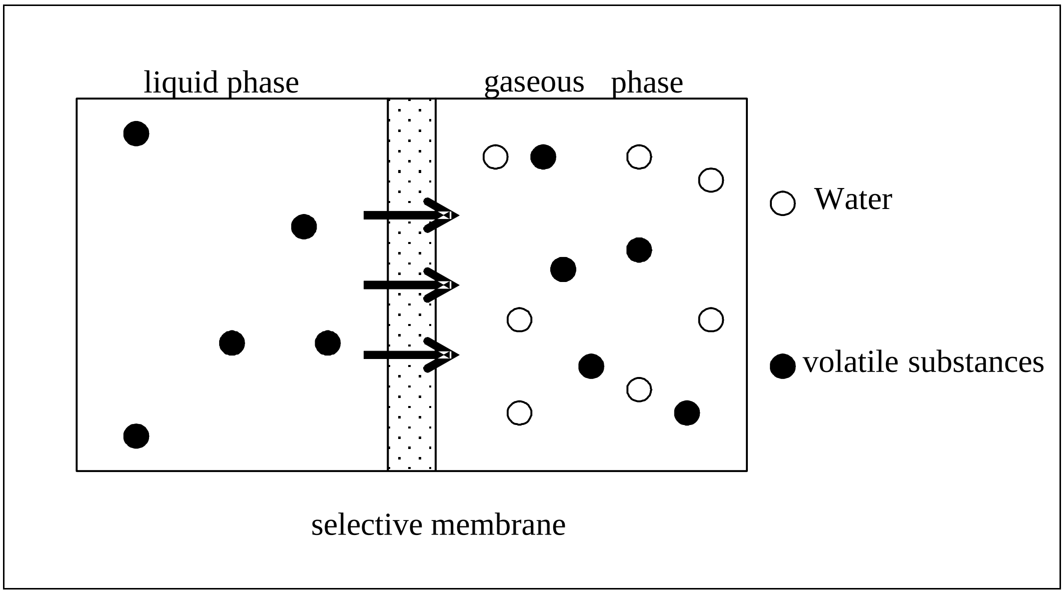

Figure: 7-9 Scheme of pervaporation

7.2.6. Ozone treatment

Ozone treatment of waste is very common in many branches (water, brewery, electronic industry, iron and steel, mining, hospital, textile, paper). For water treatment, it has been used already, since more the 50 years. Now, it is used especially, to remove and decay cyanide, phenol, organic acids, xylene, aldehyde, mercaptan, hydrosulfide, nitrite, iron and manganese. As an advantage, ozone can be yielded directly from the air, no transport is needed. But the process control is quite difficult and there is the need for a high investment [Freeman, 1998].

The ozone generation (Figure: 7-10) is made by a high voltage between two electrodes. Thereby, oxygen will decay to atoms and synthesised to ozone. The Figure shows the complicated process that is very energy intensive.

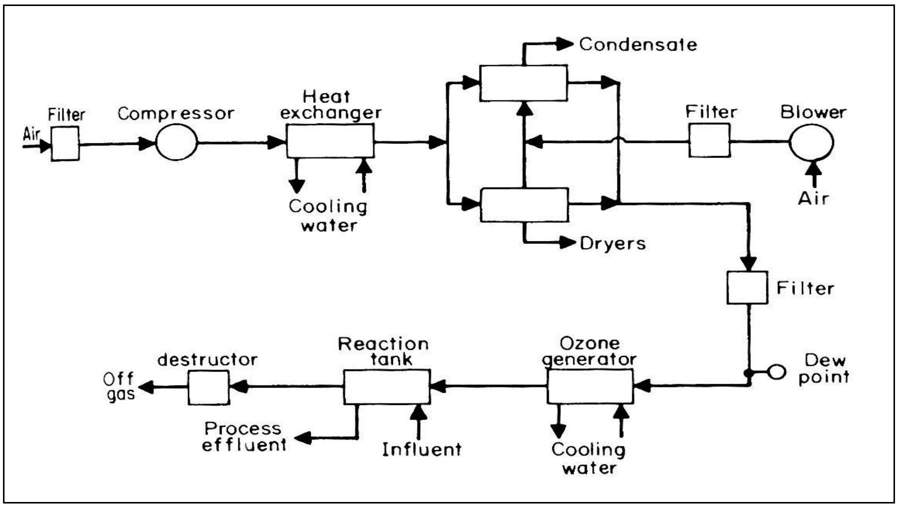

Figure: 7-10 Ozone generation[81]

7.2.7. Evaporation

Evaporation of hazardous substances is done through a quick heating of the substance mixture. It means, the heat must be transmitted as quick as possible and the material stream needs a large surface when it enters the reactor.

Different technologies can be distinguished:

- Rising-Film Evaporator
  The waste stream comes into the reactor on the bottom and will heat during the rise until the boiling point. The vapour will be exhausted at the top.
- Falling-Film Evaporator
  In this system the waste mixture enters the reactor at the top and will be heated during a downward stream. The emerging vapour collects above the liquid phase and will be removed through a valve. The waste mixture will be removed through a pump.
- Forced-Circulation Evaporator
  The waste mixture is pumped from the reactor into an external heater. From there, the heated mixture is returned to the reactor. The vapour can rise and will be exhausted at the top. The remaining material will be continuously removed at the top [Freeman, 1998].

[81] [Freeman p 7.77]

7.2.8. Summary

Not every treatment process is suitable for every kind of waste. A detailed overview about possible application can be found in table.

Table: 7-1 Overview of hazardous waste treatment options

	Hazardous waste												State of aggregation		
Process	Corrosive materials	Cyanide	halogenated solvents	Non halogenated solvents	Chlorinated organic compounds	Other organic materials	Oil residues	Polychlorinated Biphenyl	Water and heavy metal containing wastes	Water and organic material containing waste	Reactive	Contaminated soil	Liquid	Solid	gaseous
Filtration		X	X	X	X	X			X	X			X		X
Chem. Precipitation	X								X				X		
Stabilisation	X	X										X	X	X	
Oxidation/Reduction		X								X			X		
Pervaporation			X	X	X	X				X				X	
Ozone treatment		X		X		X					X		X		X
Evaporation			X	X	X	X	X						X	X	

X = suitable

7.3. Thermal Processes

The following section describes processes for removal of pollutants by thermal energy. The incineration and energy recovery of hazardous waste will be considered more in detail in section 7.5.

Thermal processes have an extensive energy consumption due to the high temperatures needed. Therefore, they are not wide spread. Although, there is often, a possibility of coupling them to a production process, like in the encapsulation in hot asphalt. Like previous processes, thermal processes are based upon different operating principles.

7.3.1. Wet Oxidation

Within wet oxidation (Figure: 7-11), the pollutants which are dissolved in water, are destroyed by mixing with oxygen at higher temperatures.

An optimal treatment of different pollutants is possible by adjusting the temperature range. The oxidation of sulphides takes place at quite low temperatures of about 150–200 °C. Medium temperatures of about 200–280 °C cause the destruction of organic materials and the transformation to biodegradable compounds. Usually, a temperature of about 280–375 °C is needed to completely oxidise the pollutants. The process can be run either continuously or discontinuously [Freeman 1998].

The water, heated by added compressed air, reaches the reactor, where the oxidation proceeds. Two material flows are generated, the exhaust gas flow and the drainage of oxidised pollutants. Volatile substances are discharged from the reactor by the exhaust gas flow, which leads to the necessity of treating the exhaust gas with flue gas scrubbers or active carbon.

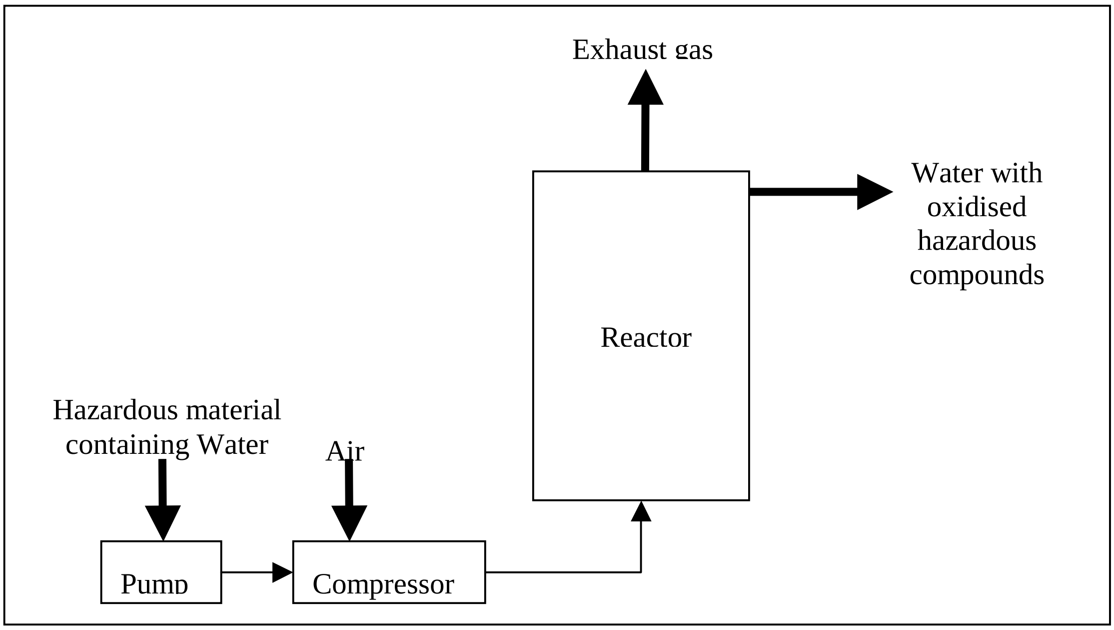

Figure: 7-11 Wet oxidation

7.3.2. Thermal Oxidation

Thermal oxidation (Figure: 7-12) is applied for the treatment of organically charged exhaust gases. Therefore, it can be used for the treatment of exhaust gases from the wet oxidation. The crucial difference to a common burning is the fact, that this process works without flames. The other attributes and reactions are the same, that is why a treatment of the exhaust gases of the oxidation is necessary. The generation of flames is suppressed by a matrix within the reactor. Before entering and passing through the reactor, the exhaust gas is mixed with oxygen. The temperature of the oxidation is adjusted between 870 and 980 °C [Freeman, 1998].

For an optimal reaction, it is necessary to avoid temperature peaks and differences within the reactor. To reach and maintain the temperatures, the exhaust gas can be mixed with high-heating-value fuels. As this process is a form of incineration, environmental damaging gases like sulphur dioxide arise. These gases have to be eliminated from the exhaust gas flow by flue gas scrubbers.

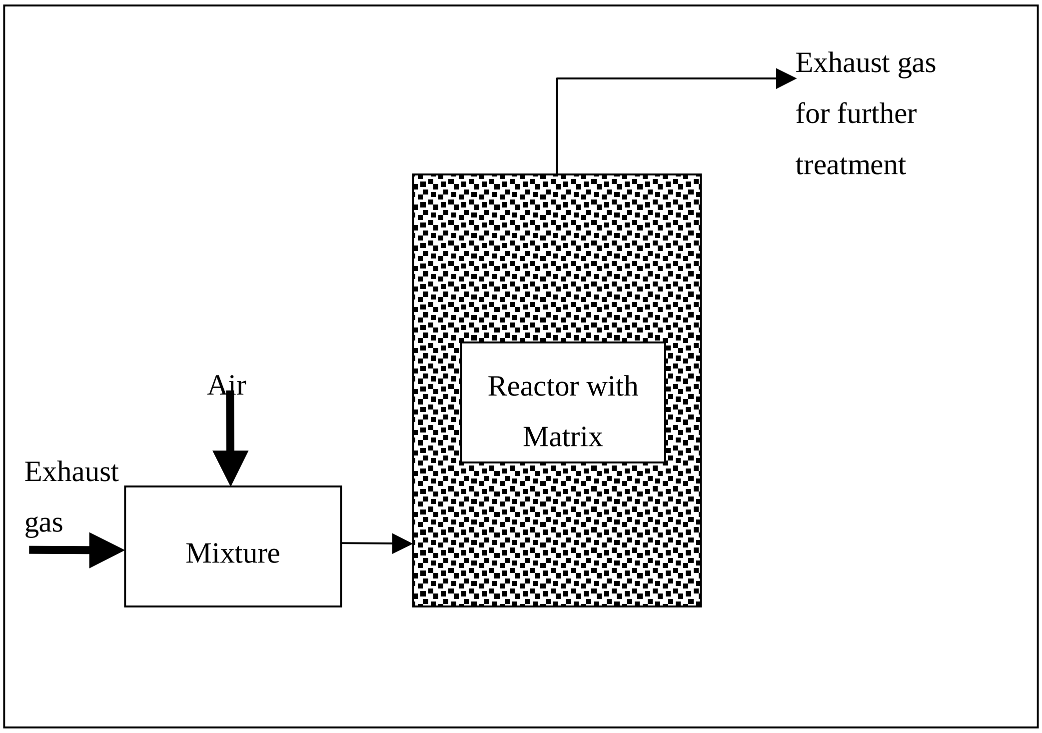

Figure: 7-12 Thermal Oxidation

7.3.3. Admixture to Asphalt

Hazardous wastes can also be treated by solidification and chemical stabilisation. The admixture and encapsulation into asphalt is a long approved process. This asphalt can be used in road construction. It is necessary to use heat for the treatment of asphalt, to bind the pollutants. There are two different kinds of asphalt applicable for encapsulation: hot asphalt-cement and asphalt in emulsion.

Encapsulation with hot Asphalt-Cement

Sludge-like wastes are mixed in a mixer or extruder with hot, melted asphalt. To prevent solidification of asphalt in the extruder, additional heat has to be applied. The water is removed from the waste and the pollutants are immobilised by the warming. After solidification the pollutants are firmly enclosed (Figure: 7-13). Basically, two types of process can be distinguished. Within the Batch-Mix-Process, asphalt and waste are discontinuously added to the mixer. In contrast to that, the Drum-Mix-Process works continuously, due to a constant charge and discharge of the materials [Freeman, 1998].

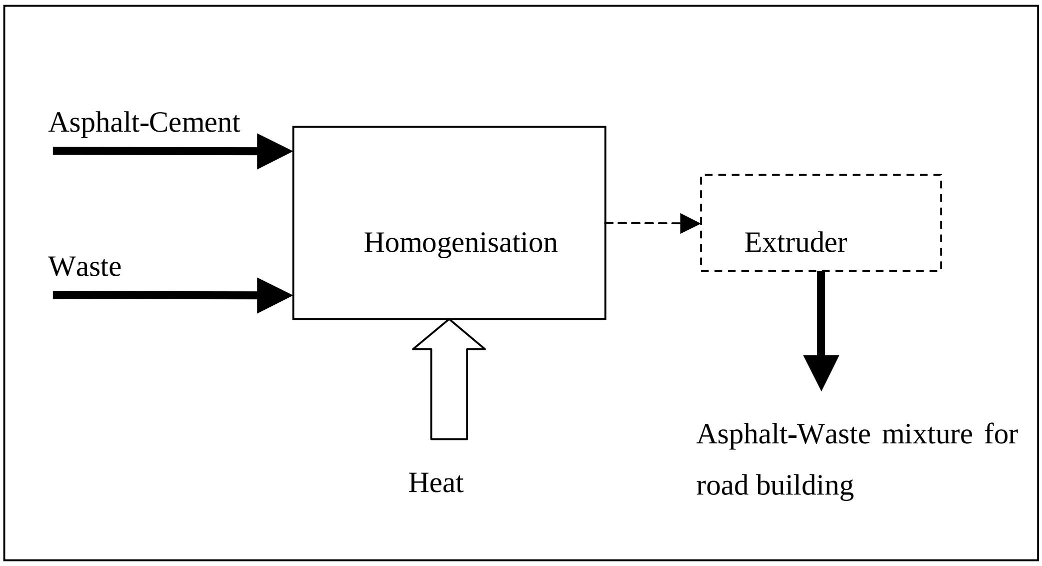

Figure: 7-13 Encapsulation with hot Asphalt-Cement

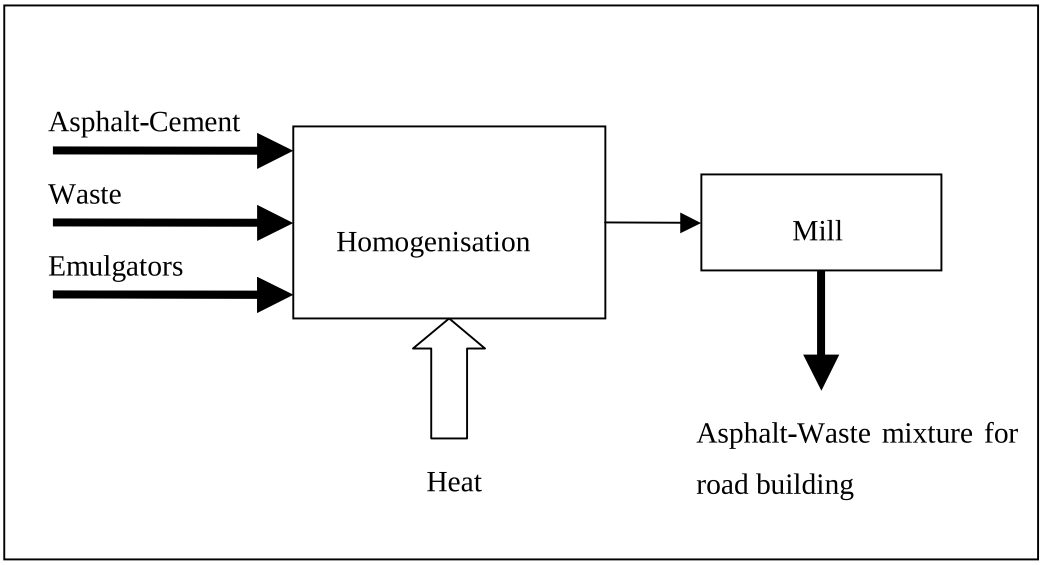

Figure: 7-14 Encapsulation with Asphalt-Emulsion

Encapsulation with Asphalt-Emulsion

Asphalt-emulsion is a mixture of asphalt-cement, water and emulators, which are needed to enable the compound of the materials. This process is similar to encapsulation with pure asphalt-cement, with the distinction, that in addition to waste, water and emulators have to be added. After adding to an emulsion the mixture solidifies and hence, has to be crushed in a mill (Figure: 7-14) [Freeman, 1998].

7.3.4. Vitrification of Hazardous Waste

At the vitrification (Figure: 7-15), the waste is heated up to a temperature above 1000°C to melt it. Mainly, organic compounds and nitrates are decomposed by heating, the waste up. The burnable compounds are burned with the presence of oxygen. Volatile compounds get into the exhaust gas which have to be applied to a special treatment, if necessary. Ash, mineral and low volatile materials are converted to a crystalline product. Thus, the remaining pollutants are immobilised and difficult to be re-released. By melting, the mass is reduced and the pores are closed. This causes a waste-volume reduction of factor two to one hundred depending on the kind of waste [Freeman, 1998].

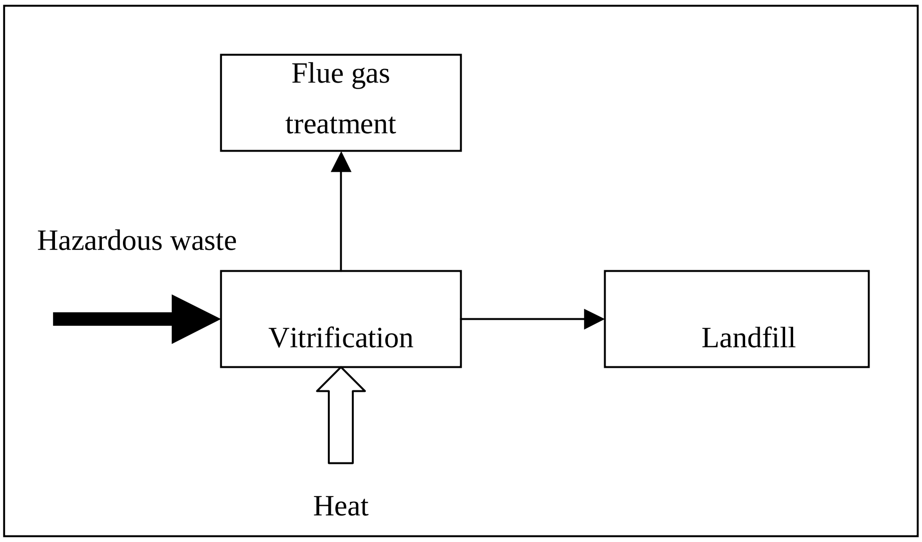

Figure: 7-15 Vitrification of Hazardous Waste

The heating of the waste can be done by different procedural versions:

- microwaves,
- electrodes (utilisation of electric resistance),
- fuels,
- thermal plasma. [Freeman 1998]

Vitrification can take place in reactors or, if electrodes are used, directly in the contaminated soil (hazardous waste landfills) (Figure: 7-16). Therefore, the electrodes are placed in the soil and an electric current is applied. The waste is heated by its conductivity and its electrical resistance. To avoid diversion of pollutants to clean areas, encapsulation, gathering and treatment of the exhaust gases are very important.

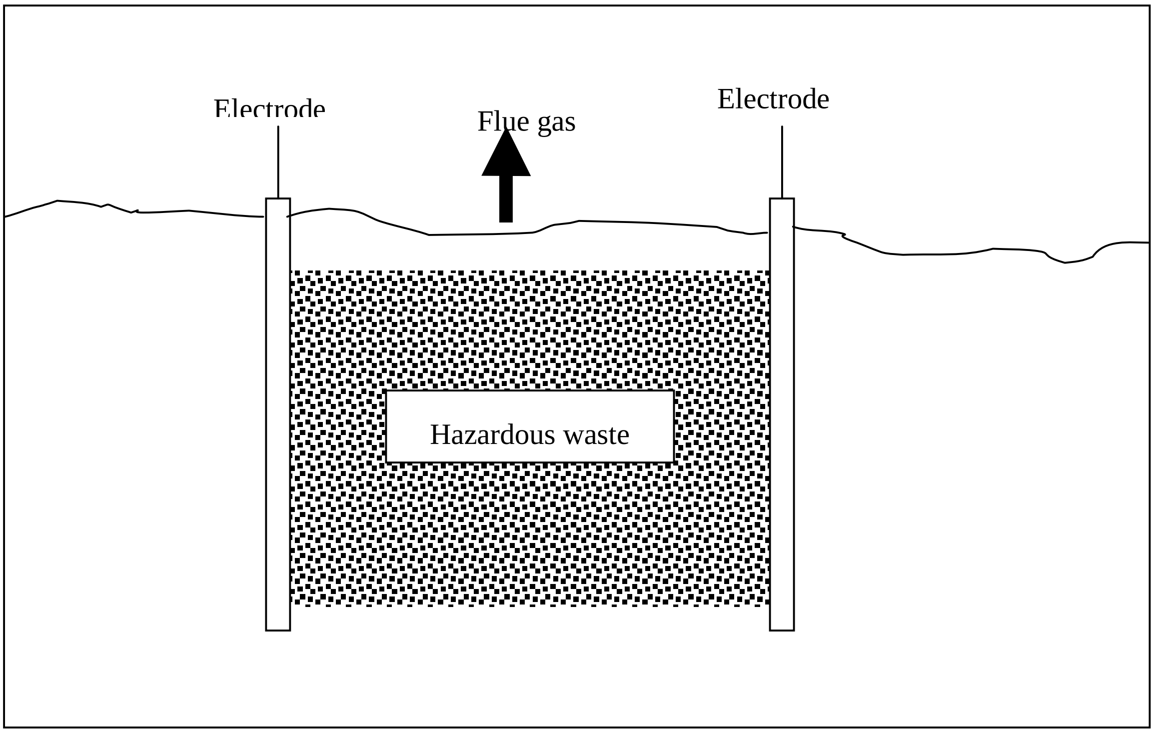

Figure: 7-16 Vitrification directly in the contaminated soil

7.4. Biological Processes

Biological waste treatment has great advantages owing to its easy control of the process and the comparatively low costs. However, the decomposition processes are time-consuming and vulnerable to malfunctions. Also, quick starts and shutdowns are not possible due to the biological processes. Furthermore, only pollutants can be converted by micro-organism which do not contain toxins and include enough energy for survival and reproduction of the micro-organism. It is because of this reason biological treatment is mostly used for elimination of organic pollutants in the waste flow.

7.4.1. Biological Treatment of industrial Sewage Water

Industrial sewage water with organic pollutants can be treated by microbiological degradation. In this process, the charge of pollutants can be destroyed and eliminated from the sewage water by conversion. The treatment of other materials like heavy metals is not effective due to their toxic effects on micro-organism. The conversion to other organic compounds like, methyl-mercury can even increase the hazardousness of the material flow. It is possible to run the process with oxygen (aerobic) and without oxygen (anaerobic).

7.4.1.1. Aerobic Processes

There are two main processes for the aerobic treatment of industrial sewage water:

- elimination of carbon
- elimination of the nutrients nitrate and phosphor

Hydrocarbons, fats and proteins from the organic load are converted to carbon dioxide and water.

$$\text{Organic materials} + O_2 \rightarrow CO_2 + H_2O + \text{Biomass} + \text{Nutrients}$$

The removal of phosphate (Figure: 7-17) works through an anaerobic stage to ferment large organic compounds to smaller compounds that can be easily be decomposed and it leads to the release of phosphor. Within the aerobic stage the phosphor is converted to phosphoric sludge.

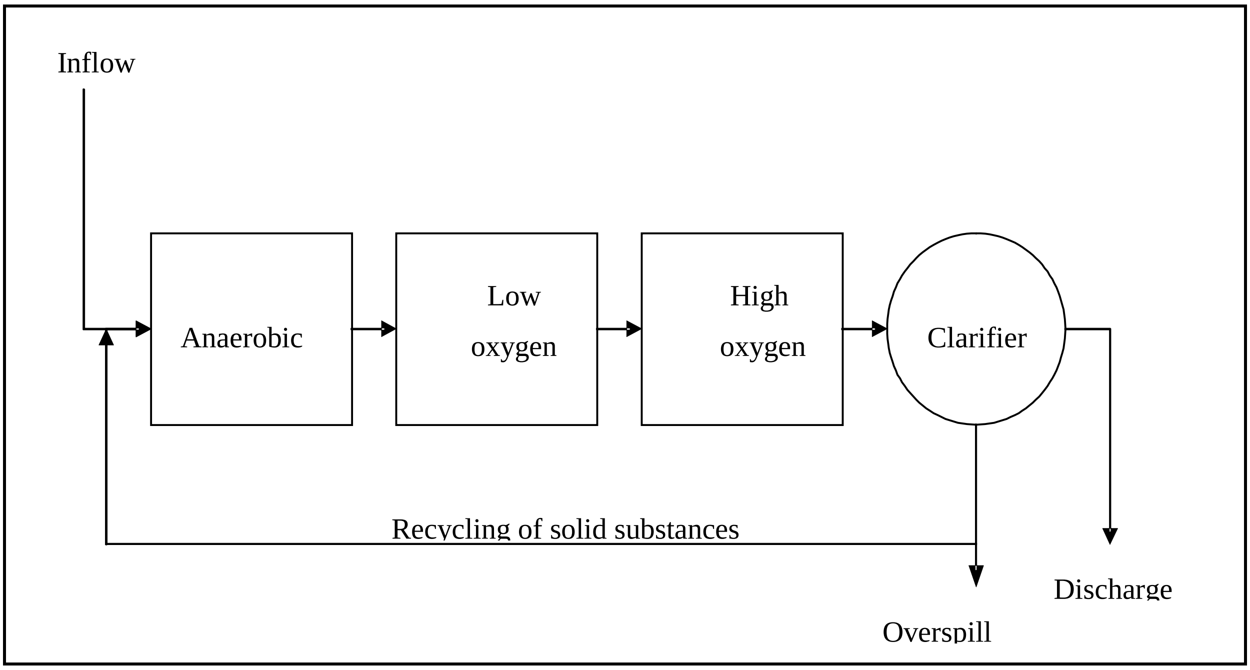

Figure: 7-17 Principle of phosphate decomposition[82]

One special feature of this process is the degradation of ammoniac which is converted to nitric acid by nitrification. The nitrification works under the influence of oxygen and carbon dioxide.

$$NH_3 + O_2 + CO_2 \rightarrow +H_2O + HNO_3 + \text{Biomass}$$

The denitrification (Figure: 7-18) removes the nitrites and releases nitrogen.

$$HNO_3 + \text{Organic materials} \rightarrow CO_2 + H_2O + \text{Biomass} + N_2$$

In general, there are two procedures which can be used: the activated sludge treatment and the percolating filter treatment.

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[82] [Freeman p 9.11]

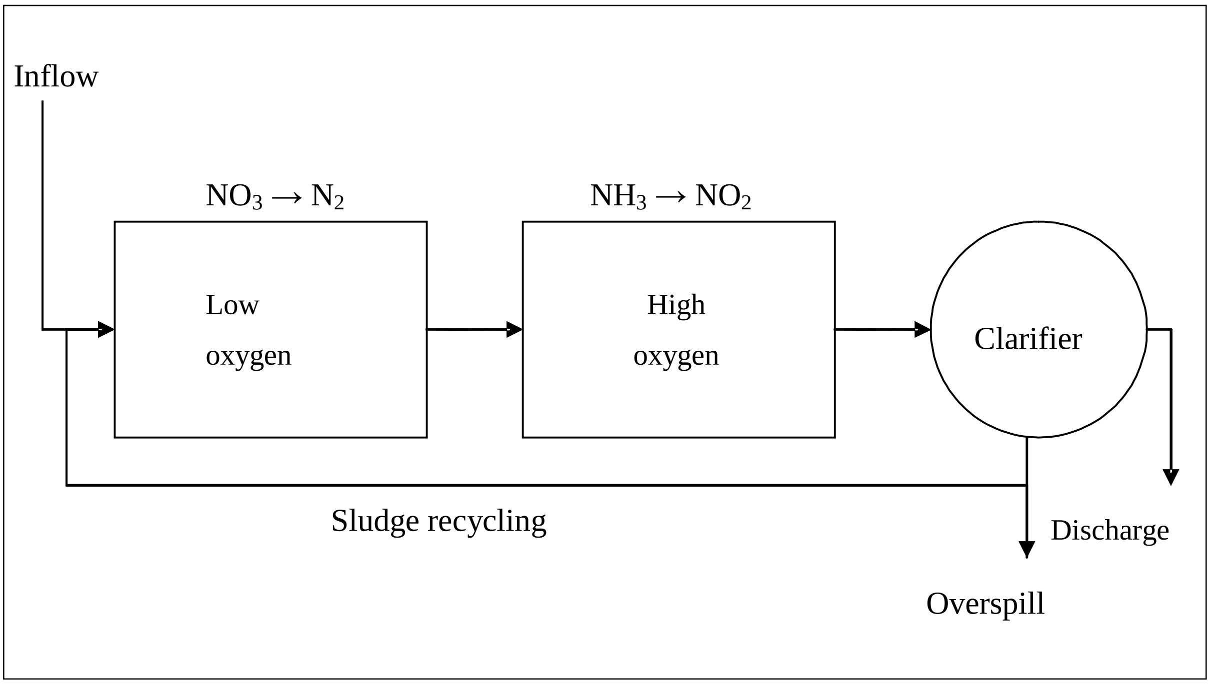

Figure: 7-18 Principle of nitrate decomposition[83]

Activated sludge process

A preliminary sedimentation is recommended. As a result of this process sludge will arise. In addition to this, substances which interfere with the process are eliminated. The pre-cleaned sewage water is led to the tank under addition of air, which is needed for the aerobic degradation process. A biological conversion takes place in the tank and biomass is generated. The sewage water is led to the secondary clarifier and the activated sludge is removed. A part of the sludge is reused to keep the population of micro organism constant. (Figure: 7-19).

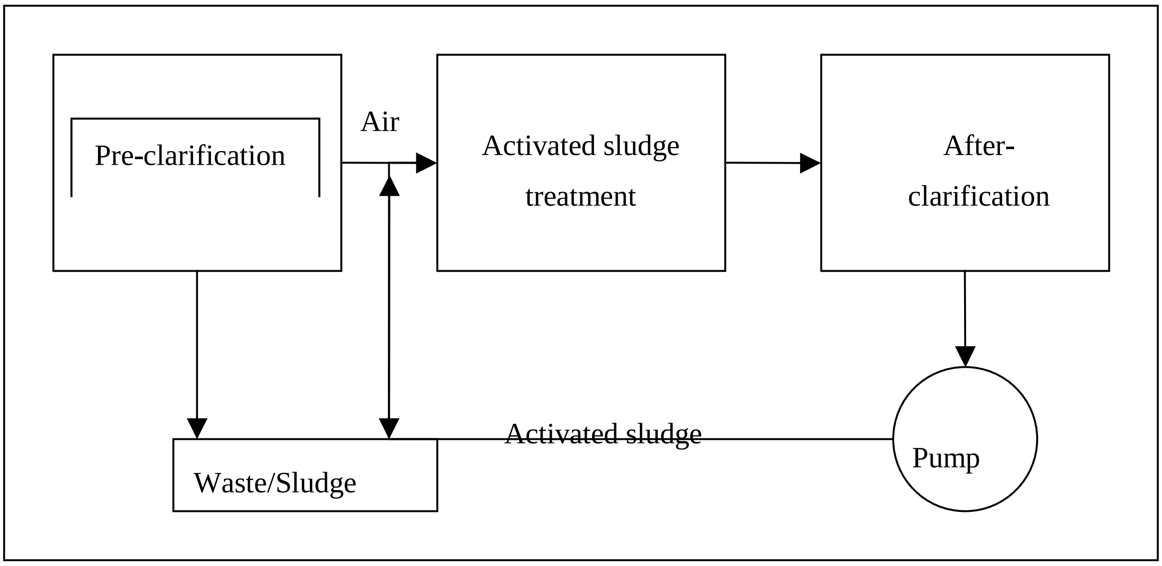

Figure: 7-19 Activated sludge treatment[84]

[83] [Freeman p 9.11]

Percolating Filter Process

The percolating filter process is based upon the same active principles as the activated sludge process. However, these processes (percolating filter processes) are easier to be controlled and they need much less energy. The disadvantage of this kind of biological treatment is that it needs a large size of the reactors. Furthermore, volatile organic materials and odours are transferred to the air. The distinction to the activated sludge process is, that a microbiological layer is generated on the filling material in the reactor. Because of the nutrients and the sewage water, a bio film arises on the plastic inlays. The transformation takes place on the surface of this so called filling materials. The sewage water which has to be treated, is droped into the reactors from the top. The remaining biomass is discharged from the reactor with the water, which leads to the necessity of a final sedimentation of the drainage. The main features of the process are shown in Figure: 7-20.

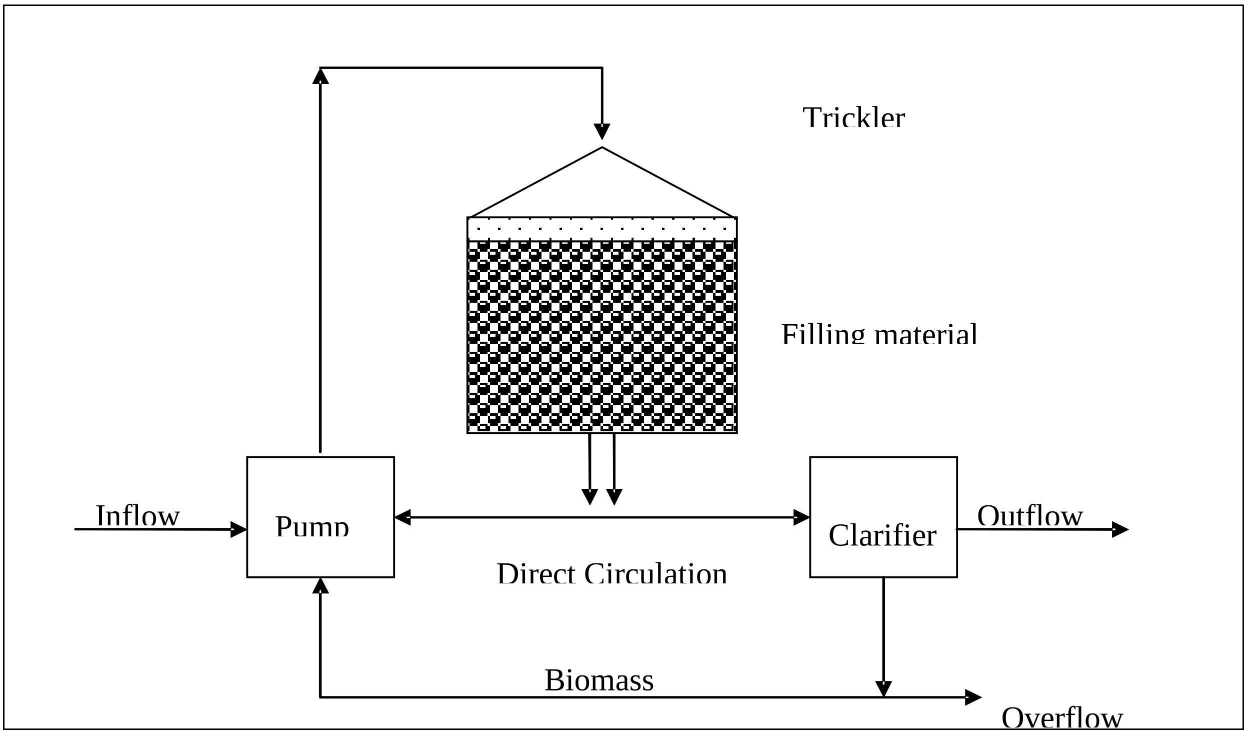

Figure: 7-20 Percolating filter process[85]

Back rinsing of the water is an alternative solution for maintenance and cleaning of the filling materials. The water flows into the reactor in the reverse direction and takes the dirty particles to the top where they are discharged into the water (Figure: 7-21).

[84] [Freeman S.9.5]

[85] [Freeman S.9.10]

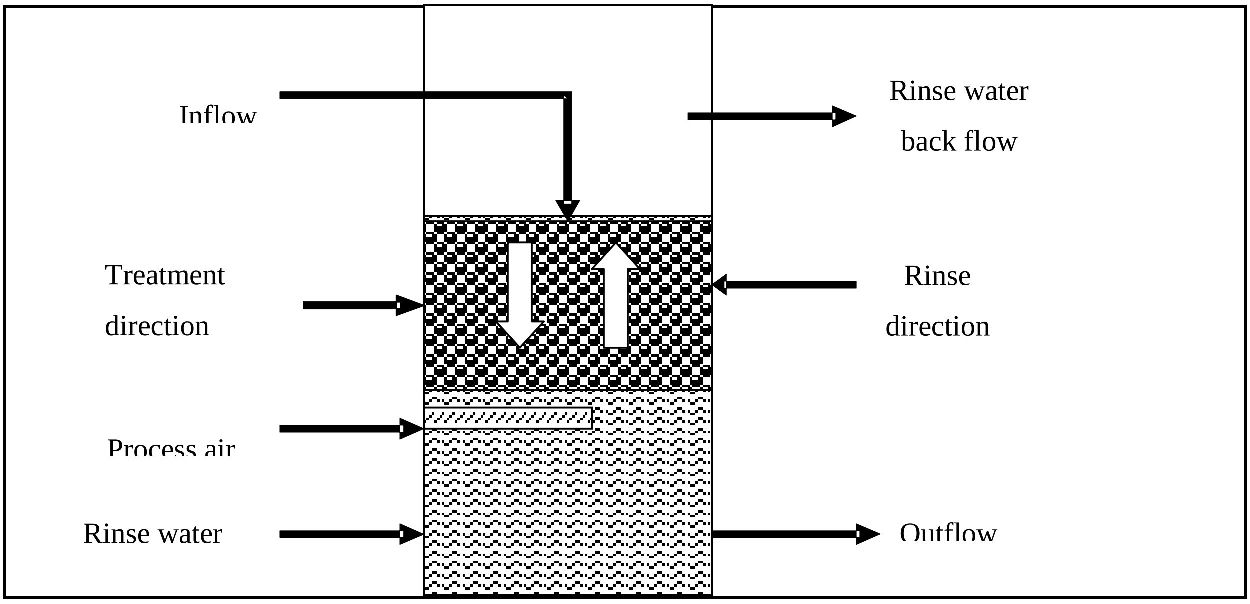

Figure: 7-21 Percolating filter process with back rinsing[86]

7.4.1.2. Anaerobic Processes

At an anaerobic procedure, usually, gaseous methane is generated during the (process of) decomposition of pollutants. If sulphate and nitrate are available, nitrogen and hydrosulphate are generated instead of methane. A thermal utilization of the arising methane is recommended due to its green house effect. An advantage of the anaerobic procedure is the more effective encapsulation of the fermentation which results in a better control over the spreading of odours. The comparably low turnover and the high sensitivity to disturbances (metabolites, NH_3, H_2S) are, however, disadvantageous. Furthermore, an additional composting of the fermentation leftovers is often, necessary.

The degradation process can be divided into the stages of hydrolysis, acidification, acetic acidification and generation of methane (Figure: 7-22) [Bilitewski et al. 2000].

- Hydrolysis
  Hydrolysis means the breaking of long chained compounds like carbohydrates, lipids and proteins into smaller molecules (fatty and amino acids as well as sugar and alcohol).
- Acidification
  In this stage, the split nutrients are fermented to butyric and propionic acid as well as hydrogen and carbon dioxide by fermenting bacteria.

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[86] [Freeman S.9.10]

- Acetic Acidification

  The quite long chained organic acids are converted to acetic acid by acid-forming bacteria. Only this form can be utilized by methanogenic bacteria.

- Generation of Methane

  At the last stage, the acetic acid is converted to methane by methanogenic bacteria.

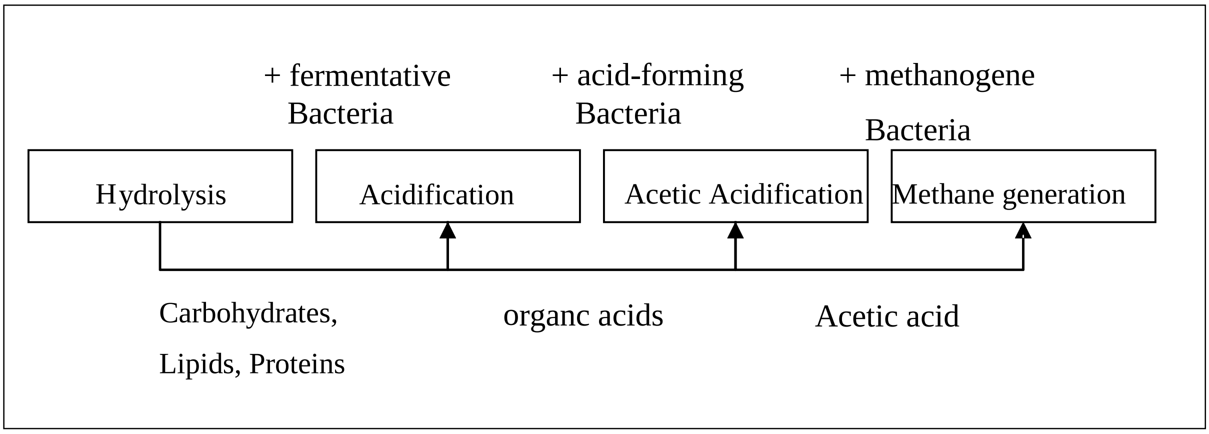

Figure: 7-22 Phases of decomposition in anaerobic treatment

There are three general possibilities for running the process. According to the water content of the substrate, they are differed in dry fermentation, with a water content of less than 35% and wet fermentation, with a water content of 90%. The wet fermentation can be distinguished into a single- or a two-stage process. The difference of the two-stage process is, that hydrolysis and fermentation are separated and run in two different reactors. However, the basic material flows are the same in all three process versions (Figure: 7-23) [Bilitewski et a. 2000].

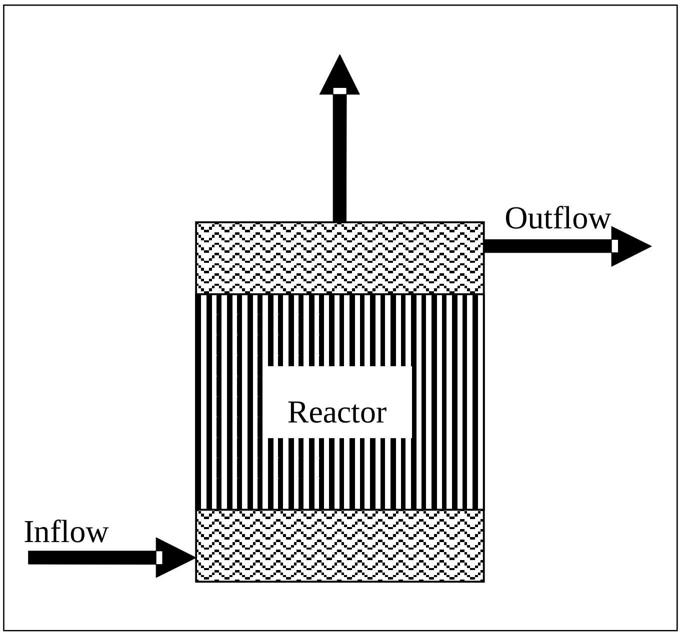

Figure: 7-23 Material flows of anaerobe bio-reactors

7.4.2. Bioreactors

The construction of the reactors depends upon the kind of process. The process can be distinguished in continuous and discontinuous operation mode.

Discontinuous Reactors

This operation mode enables a good degradation of pollutants. The retention time of the sewage water in the reactor is high, that is why the turnover of this facility is low and the needed time of treatment increases. Thus, this operation mode is only applicable for small amounts of waste, which can be intermediately stored.

The sequencing-batch-reactor (Figure: 7-24) is explained more in detail because, it contains all different possible configurations of a discontinuous process. The reactor can be fed with activated sludge by motor-operated mixer. An aerobic as well as an anaerobic process is possible. The mixer is stopped after the conversion and the sludge is sedimented on the ground of the reactor. The sludge and the treated sewage water can be extracted afterwards [Lewandowski., DeFilippi 1998].

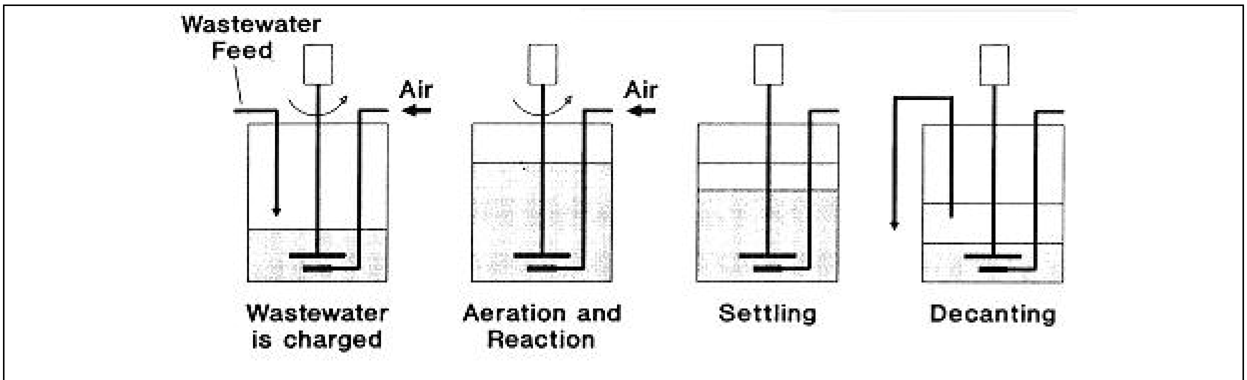

Figure: 7-24 Sequencing Batch Reactor[87]

The rotating reactor is a special design (Figure: 7-25). A bio film which is generated on rotating disks that are half submerged in sewage water. An aerobic degradation arises by the contact of the bio film with the water. [Lewandowski., DeFilippi 1998]

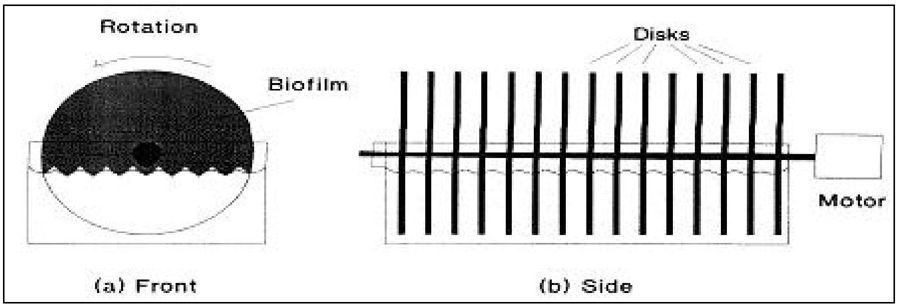

Figure: 7-25 Rotating reactor[88]

[87] [Lewandowski., DeFilippi 1998]

Continuous Reactors

There are multiple versions of those reactors, therefore, only the most important are described.

Filling Material Reactors

The assembly of filling material reactors is affected by the installation of a bio film. There are different versions of the flow path like, down flow and up flow reactors, which, differ according to diverse filling materials and dispositions [Freeman 1995].

Airlift and Jet Reactors

Airlift reactors are built cylindrical. The air is blown into the reaction zone from the bottom and the excessive gas exhausts at the top of the reactor. The inlet of the sewage water also takes place at the bottom area. Jet reactors are built in a similar way, but, the applied air is injected in a turbulent way, which leads to a better mixing of sewage water and air (Figure: 7-26) [Lewandowski., DeFilippi 1998].

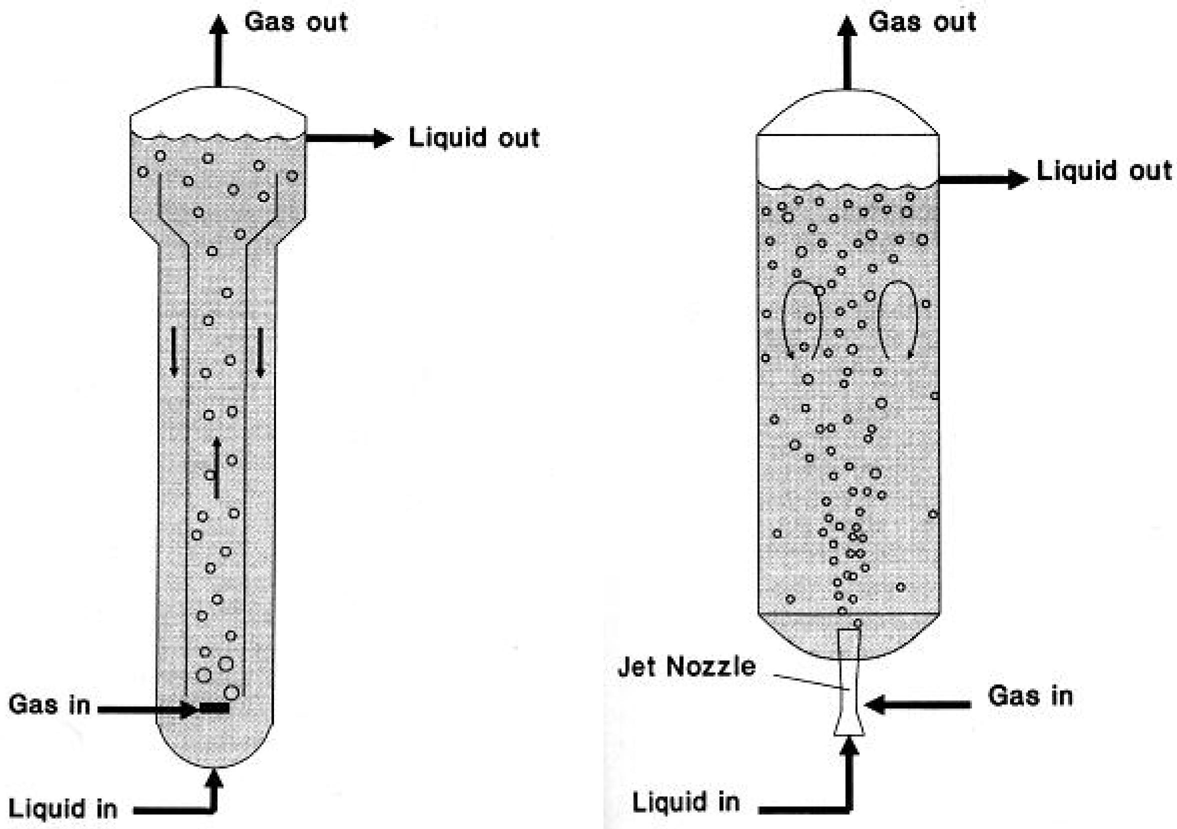

Figure: 7-26 Airlift- und Jet reactor

88 [Lewandowski., DeFilippi 1998 p.78]

Activated Sludge Basin

The activated sludge basin is run aerobic and equipped with a final sedimentation basin, which separates the excessive sludge from the sewage water and returns it to a potential recycling during the process [Lewandowski., DeFilippi 1998].

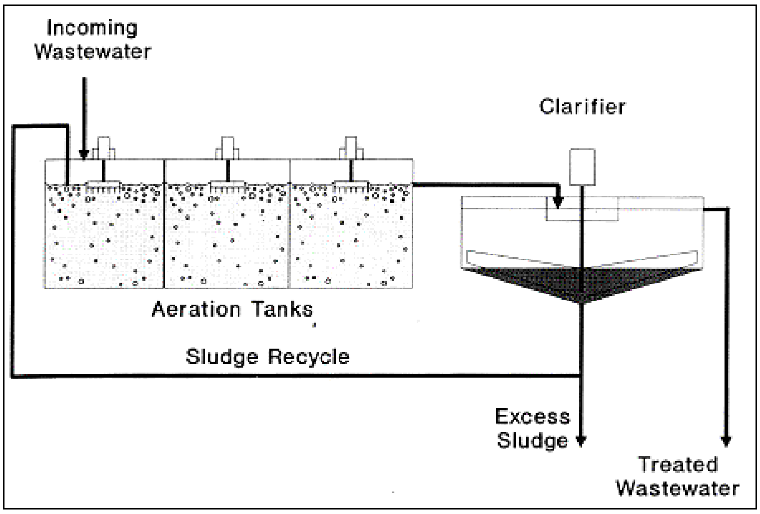

Figure: 7-27 Activated sludge basin with after treatment[89]

Anaerobic sludge reactors

The function is similar to an aeration tank for activated sludge, but there is no need for a secondary clarifier to separate the sludge. The sludge will sediment in the same reactor and can be removed from the bottom of the tank (Figure: 7-28) [Freeman 1998].

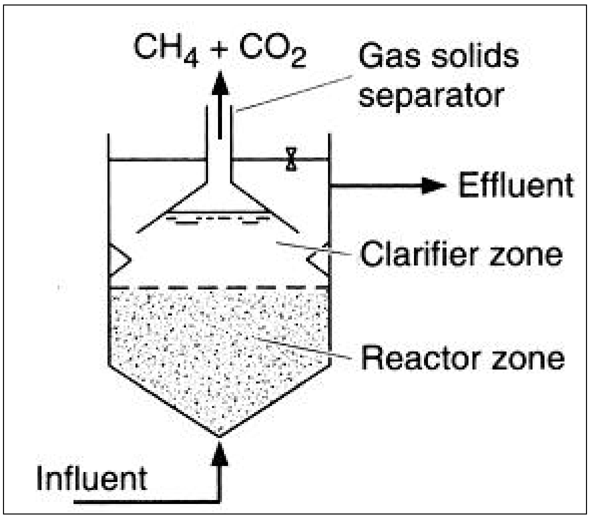

Figure: 7-28 Anaerobic reactor for activated sludge[90]

[89] [Lewandowski., DeFilippi 1998 p 19]

[90] [Freeman 1998 p. 9.14.]

7.4.3. Purification of exhaust air by bio filters and bio scrubbers

Organic substances from the exhaust air can be removed and degraded by following methods. Such bio filters and bio scrubbers are common techniques for industrial applications, to clean contaminated airstreams.

Bio filter

A bio filter (Figure: 7-29) is working through the adsorption of organic pollutants at the filter material and a following biodegradation by micro organism. In the process, the exhaust air flows through the filter and leaves it cleaned. Because of the large specific surface, there are enough places for settlement of many different types of bacteria and fungi, so, there is a wide range of treatment possibilities. It can be used in bark humus, compost, root wood and mixtures of peat and Erica. The gas temperature of the infiltrated gas should not exceed 40°C and sufficient moisture and nutrients have to be supplied [Igelbüscher 2003].

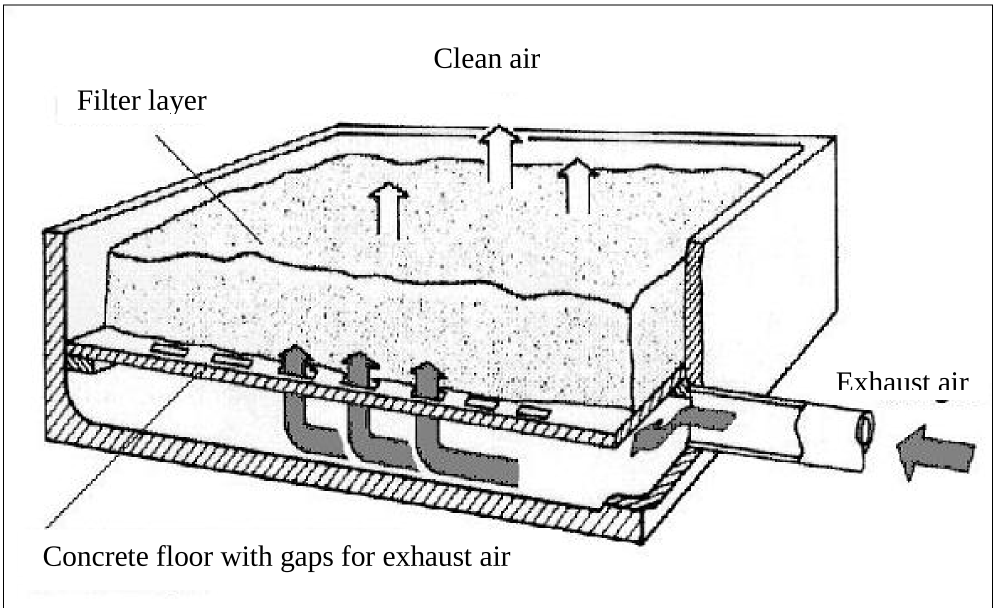

Figure: 7-29 Design of a biofilter[91]

Bio scrubber

Bio scrubber facilities (Figure: 7-30) are used for cleansing of contaminated (by volatile organic substances) exhaust air. The work principle is like the principle of bioreactors in industrial sewage plants (activated sludge system/ filling material columns). Contained pollutants are adsorbed at the surface of the filling material first or, they are metabolised immediately by the micro organisms in the bio layer or in the activated sludge. The distinction to the treatment of industrial sewage is the need of additional water and the impossibility of an anaerobic treatment because of the oxygen in the process

[91] [Igelbüscher 2003]

air. A pre-treatment of the contaminated air is reasonable if, there are toxic dusts or the bioreactor and it is subject to clogging by non degradable substances.

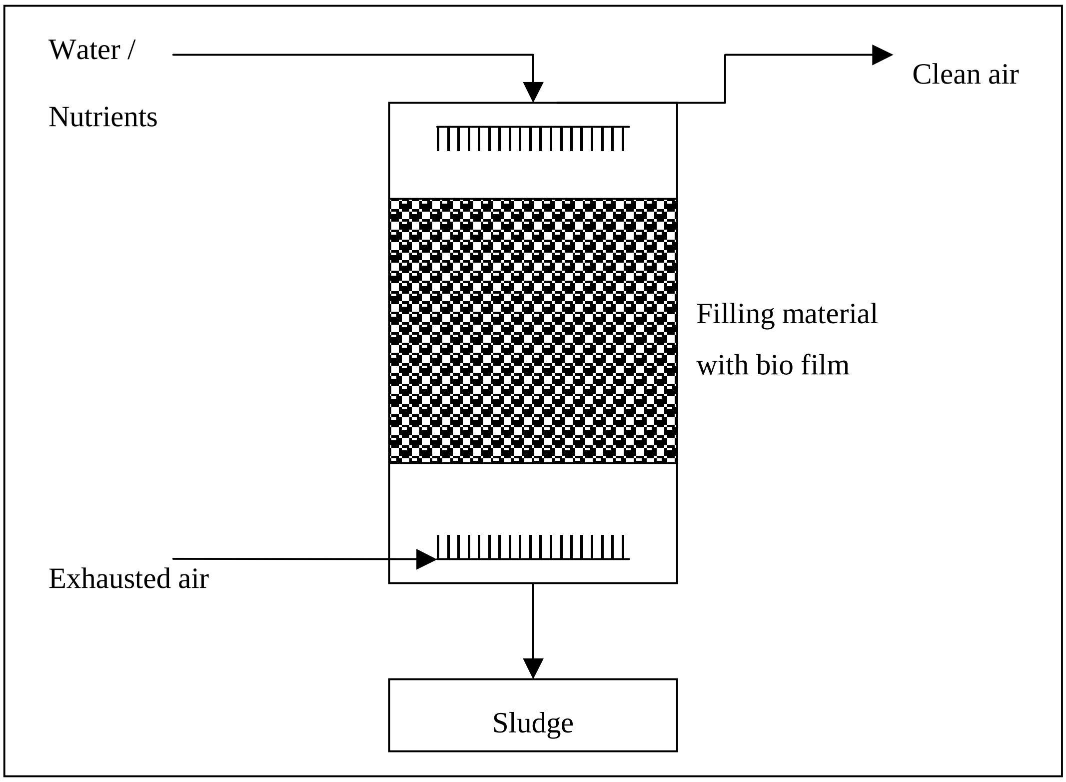

Figure: 7-30 Configuration of a filling material column

7.4.4. Composting of industrial waste

Composting of hazardous waste is more complicated than composting of biogenous waste, due to the stable compounds and disturbing substances. It is necessary to inoculate the material with micro organisms regularly, as they are rare to be found in the environment and their cultures often, have to be accreted in laboratory. Only, a few bacteria and fungi are able to crack and metabolise the hazardous compounds in the substrate or, there is a stepwise degradation by different organism, though the reproduction rates of these are interacting. The degradation process is equivalent to the aerobic treatment of industrial sewage. To avoid a discharge of leachate, the composting facility should be encapsulated [Freeman 1998].

<u>Process parameter</u>

To get an optimised rotting process, some parameters have to be monitored continuously. There is an optimum level for each parameter and the purpose of the monitoring is to hold the ideal conditions for the micro organisms. At least, an avoidance of exceeding or under running of critical values is required.

- **Temperature** is determined by the microbiological degradation through thermopile bacteria. But, a temperature exceeding over 50 to 55°C, inhibits the growth of these bacteria and so, it is undesired in hazardous waste treatment processes.
- **pH** set up for treatment is recommended from 6 to 7.5. In case its under run, it can be raised by calcium hydroxide. To decrease pH, non-toxic acids like ammonium sulphate can be used.
- **Oxygen content:** Composting is an aerobic process. Therefore, as high as possible contact surface between substrate and oxygen is needed. But, even an anaerobic zone could realize and support the degradation of certain toxic or halogenated substances.
- **Moisture content** is appropriate in the range from 45 to 55 mass percent. High contents of moisture could lead to anaerobic zones and an unacceptable leachate water exposure. If, the moisture content decreases below 10 % ,an inhibition of the micro organisms is expected.
- **Availability of nutrients:** It is of great importance for the micro organisms that, nutrients are available. Without the possibility to incorporate carbon, nitrogen and phosphor, the growth is inhibited and they cannot metabolise any pollutants. Nutrients should be inserted in a dissolved form and they should not get immobilised.

7.5. Hazardous waste incineration

Incineration of hazardous waste is a common technique to eliminate pollutants and to reduce the risk potential to the environment, significantly. The associated volume reduction increases the capacity of hazardous waste disposal sites. Some kinds of hazardous waste are not allowed to be burned without pre-treatment, because of physical, chemical or toxic properties. Many hazardous wastes have a high caloric value to be used as fuel. Nevertheless, it is reasonable to accomplish the combustion by special burners for an optimal burnout. The major elements in incineration of refuse are carbon, oxygen, nitrogen and sulphur.

Oxidation of carbon: $C + O_2 \rightarrow CO_2$

In case of imperfect combustion the carbon is not oxidised completely, so, it is decomposed to toxic carbon monoxide: $C + 1/2\ O_2 \rightarrow CO$

Oxidation of sulphur: $S + O_2 \rightarrow SO_2$

The generated gas reacts with water to form sulphurous acid.

Oxidation of nitrogen: $N + x\ O_2 \rightarrow NO_x$

Three kinds of nitrogen oxides relative to their synthesis can be defined. Thermal NO_x results because of the high temperatures (from 1200°C high increase) in the combustion zone. Nitrogen contented in the combustion air (71%) reacts with oxygen to form different nitrogen compounds.

Fuel NO_x results like the thermal NO_x through high temperatures. The distinction is simply the origin of the nitrogen out of the fuel.

The last of the three kinds is the prompt NO_x, which is a product of the impact of different types of hydrocarbon radicals [Koppe 2000].

Depending on the kind of waste, other pollutants evolve during burning, which may require a special treatment of the exhaust air. Especially to mention are:

- **Dioxins und furans** emerge under following conditions: Existence of chlorine, hydrocarbon radicals due to imperfect combustion or within a certain temperature range
- **Hydrogen chloride HCL:** If waste that contains chlorine is burned, a significant amount of hydrogen chloride is generated. There are hazards for the environment (e.g. acid rain) and the working safety.
- **Heavy metals** get in the combustion chamber via the fuel. Because of the high volatility of the elements and their compounds, they reach the exhaust stream, where they are adsorbed as particulate matter.

7.5.1. Combustion in furnace chambers

The incineration of gaseous and fluid hazardous waste takes place in the so called combustion chambers (Figure: 7-31). They are cylindrical furnaces in which the hazardous waste is blown into. The atomisation is realised by the input of the combustion air, the better the waste is pulverised the bigger is the contact surface. Therefore, it is possible to eliminate the pollutants at 1300°C within a fraction of seconds.

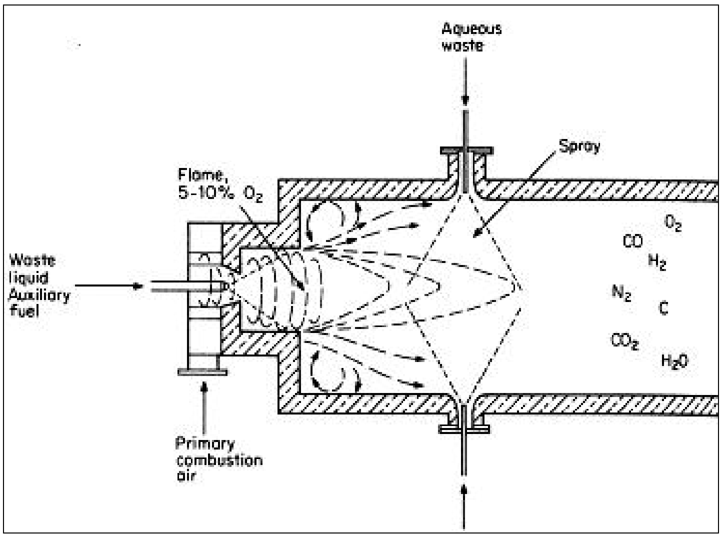

Figure: 7-31 Body structure of a combustion chamber[92]

[92] [Freeman 1998 p. 8.10]

This method can be driven in direct, cross or reverse flow principle, depending on what is required. Another possibility is to burn the material understoichiometrically to avoid the formation of nitrogen oxides [Bilitewski et al. 2000].

7.5.2. Combustion in rotary furnaces

Combustion in rotary furnaces (Figure: 7-32) is a widely-used and safe and effective technique to oxidise primary paste-like waste like, sludge and solvents, and also for solid waste with a low melting point. To ensure a complete burnout, the residence time of the waste is between 50 and 70 minutes. The furnace is a cylinder with 1 to 5 meters in diameter and an inclination of 3 to 5 %. It has a reheating chamber at the end with installed secondary burners for a complete combustion of the flue gas [Bilitewski et al. 2000 and Igelbüscher 2003].

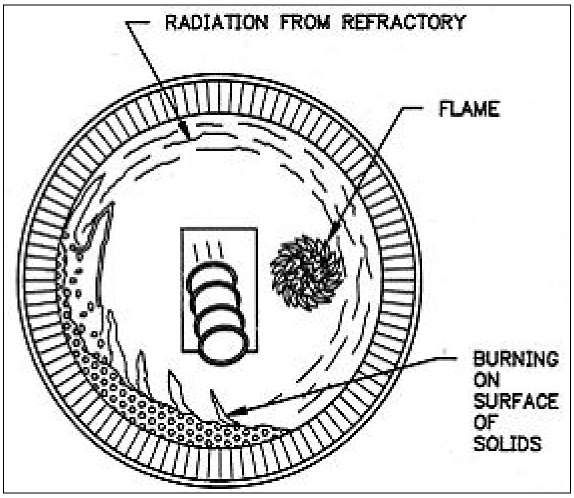

Figure: 7-32 Operation mode of a rotary furnace[93]

Another specific feature of this method is the use of a high amount of air, two or three times stoichiometrically needed [Igelbüscher 2003]. Waste gets in the combustion chamber by an inlet and arrives at the starting zone where the temperature reaches 400°C. Then the waste stream slides to the melting and vaporisation zone, there the volatile components are calcinated and solid substances melt at 900°C. After that, the chemical compounds get oxidised in the combustion zone at 1200°C. In the reheating zone, the refuse is burnt a second time at 1500°C to ensure a complete burnout [Bilitewski et al. 2000].

The rotary furnace can be driven in direct flow principle as in reverse flow principle, too (Figure: 7-33 and Figure: 7-34). However, the reverse flow is recommended only at wastes with high content of water, so that vapour can be carried out immediately. By Doing so, the reactor could be built a bit shorter for a good burnout. Indeed, the waste must not produce a high amount of smouldering gas. It

[93] [Freeman 1998 p.8.24]

will not be converted completely because of the residence time of less than 5 seconds in the reheating chamber.

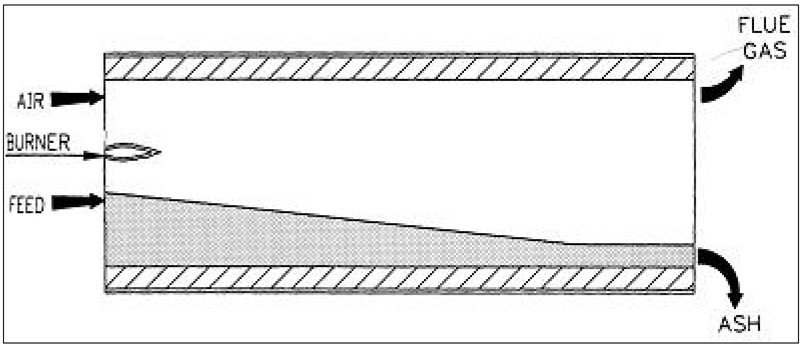

Figure: 7-33 Direct flow principle[94]

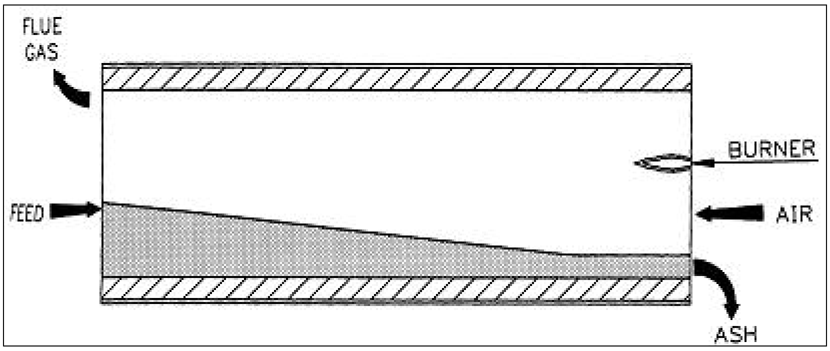

Figure: 7-34 Reverse flow principle[95]

7.5.3. Combustion in fluidised-bed furnaces

Homogenous and gaseous, fluid and paste-like hazardous waste can be burned in a so-called fluidised-bed. But, the combustion temperature and the residence time are relatively low, so, some pollutants cannot be destroyed and hence, this option is rarely used in hazardous waste incineration. Basically, two types of fluidised-bed tracking exist, the steady state and the circulating fluidised-bed. In addition, intermediate stages can be divided into internal and external ash recirculation. Normally, steady state fluidised-bed combustion is to be used only for incineration of sewage sludge [Igelbüscher 2003].

7.5.4. Hazardous waste as fuel

Because of their partly high heating values, hazardous waste could be used in different industrial processes. It can reduce the need of expensive fuels or even substitute them. Before implementation, it has to be checked if the facility setup has to be changed, conditioning systems for hazardous waste got

94 [Freeman 1998 p 8.25]

95 [Freeman 1998 p 8.25]

to be installed or even sumptuous additives are necessary. Such costs have to be compared to those like storage, transport and disposal. There are only a few wastes that are not allowed to be used, owing to their potential harm on the workers or a negative impact on the production process. To this, counts organic cyanide compounds, polychlorinated biphenyls, insecticides and radioactive substances. [Freeman 1998].

Applications can be found in processes, where the elimination of the pollutants through high temperatures is assured:

- cement kilns,
- lime kilns,
- industrial digesters,
- asphalt producing facilities,
- blast furnaces.

7.6. Pyrolysis of hazardous waste

Pyrolysis is an outstanding form of thermal treatment, it is comparable to the method of waste incineration, yet, it is a reaction without oxygen. Also, the range of temperature is lower than by normal combustion; it is between 400 and 800°C. This impedes the stripping of heavy metals. Despite the fact, that the useful products are extracted, it is more of a disposal. This is due to the fact that the major aim is the decomposition of pollutants and waste.

By using pyrolysis long-chain molecules are cracked and volatile substances are calcinated. Products are pyrolysis gas (CO_2 and H_2) and the pyrolysis coke. Even the extraction of oils and tars is possible depending on the source material [Freeman 1998 und Igelbüscher 2003].

First reaction is calcination of the volatile substances and cracking of long-chain compounds in smaller and more volatile ones.

Long-chain hydrocarbons → short-chain and volatile hydrocarbons

Further chemical reactions demerge hydrogen and carbon black, off the carbon particles

$$C_yH_x \rightarrow C_pH_q + H_2 + \text{carbon black}$$

If temperature is high enough and oxygen is present, carbon is burned partially to CO and also CO_2

$$C_yH_x + (x\text{-}n/2\text{+}y/4)\ O_2 \rightarrow n\ CO + (x\text{-}n)\ CO_2 + y/2\ H_2O$$

The emerging vapour decomposes the hydrocarbons to carbon monoxide and hydrogen

$$C_yH_x + xH_2O \rightarrow x\ CO + (x+\ y/2)\ H_2O$$

Vapour reacts with CO to CO and H_2 in following reactions.

$$CO + H_2O \rightarrow CO + H_2$$

Evolving carbon black reacts with vapour, oxygen and carbon dioxide

$$C + H_2O \rightarrow CO + H_2$$

$$C + CO_2 \rightarrow 2CO$$

$$C + O_2 \rightarrow CO_2$$

Pyrolysing Waste is purified by mills or crushers and then putt in the reactor. There, waste substances are heated to a temperature of 400 to 800 °C getting thermally decomposed. Volatile hydrocarbons will be intercepted and combusted by additional burners in a secondary combustion chamber. Resulting exhaust gases recirculate in the pyrolysis process. Pyrolysis gas gets out on top of the reactor, and it will be quenched and filtered and the pyrolysis coke will be removed through the reactor bottom (Figure: 7-35) [Freeman 1998].

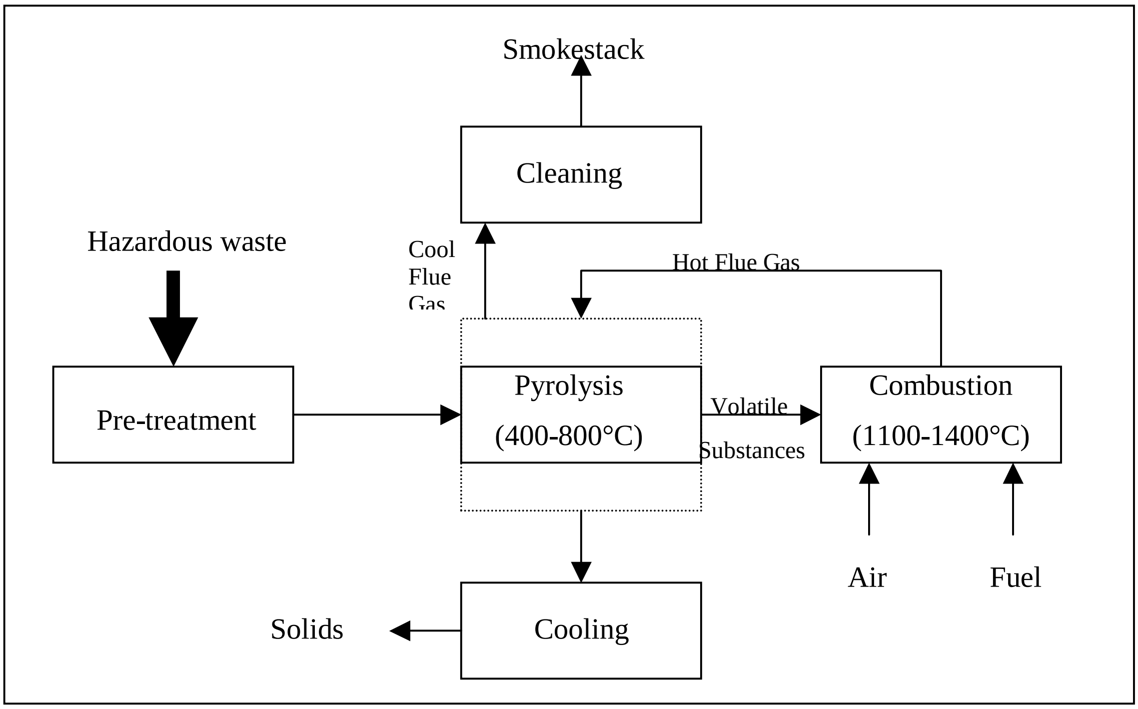

Figure: 7-35 Scheme for Pyrolysis[96]

7.7. Disposal of hazardous waste

Landfilling should be the last resort for disposal, because the potential risk is not getting minimised, it remains to the same degree. Under environmental aspects, a treatment of hazardous waste always should be preferred to the deposition. Generally, only pre-treated waste should be landfilled to prevent emissions through leachate or outgassing, as far as possible.

[96] [Freeman p. 8.203]

7.7.1. Landfilling of hazardous waste

Till this day severe mistakes have been made doing landfilling aboveground of hazardous waste. A major problem displays the wrong choice of landfill body. As hazardous waste often had been landfilled in cavities, they could not be drained at free level, so, the water has to be pumped for an undetermined time. Also, the geo-hydraulic conditions are inadequate in certain cases. This leads to the conclusion that, these cavity land fills are more or less dangerously contaminated sites. In contrast to a household waste site, it can not be assessed when a hazardous waste landfill is stabilised to an inert state by micro biological processes. A household waste site reaches this state after hundreds of years by chemical and micro biological processes. At this stage the environmental dangerous emissions of leachate and landfill gas dropped to a minimum. This process will not occur at hazardous waste landfills, due to the fewer stabilisation processes. So, the refuse is located at the site for an undefined period. Therefore, some specification standards are required by the particular laws. This includes i.a.:

- Leachate drain at free level
- Location has to be suitable (to be proved)
- Basement and surface have to be consisting of sophisticated drain and sealing systems
- Maintenance after closing of the landfill is subject to prior significance

Thus, enclosed cavity landfills are not to be used for hazardous waste disposal. [Tabasaran 1997]

Figure: 7-36 shows such type of landfill commonly used in past till that day. Advantages are that, the landfill is hidden and it has a good ratio of basement to volume. Also, there are no problems through acclivity and structure stability for the part in the cavity. But, uncontrollable exposure of leachate water to the ground respective to the groundwater my occur. In addition, the capable leachate has to be pumped off the cavity for a given time.

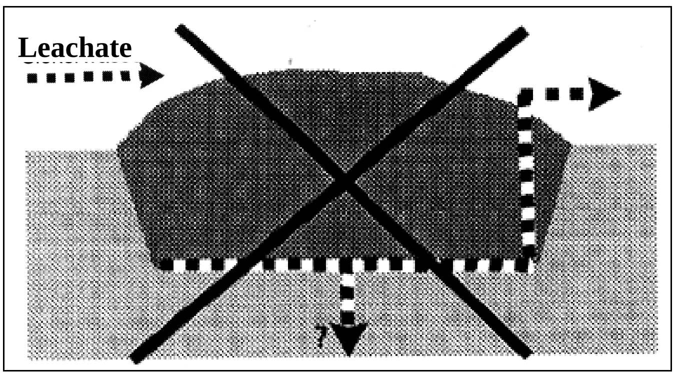

Figure: 7-36 Landfill in an enclosed cavity[97]

[97] [Tabasaran 1997]

The planar waste dump is more applicable (Figure: 7-37). In case, there is an inclined base area, a free level leachate drain is ensured and an infiltration of contaminated leachate is manageable and could be reduced to a minimum. Indeed, it has a worse basement volume ratio, it is obtrusively visible and problems of structural instability could occur .

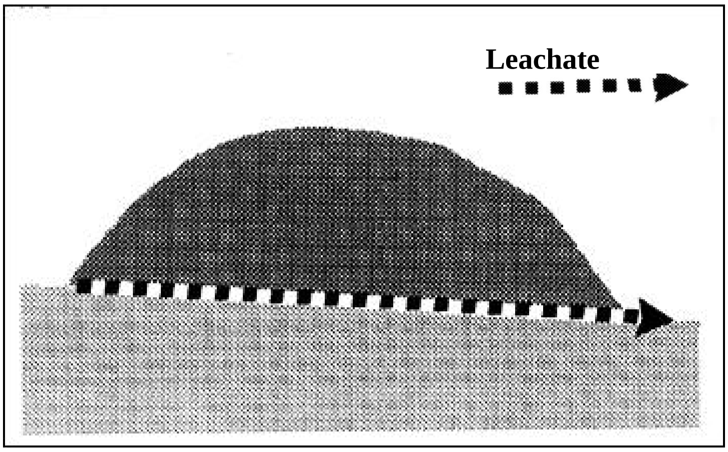

Figure: 7-37 Planar landfill site on inclined area[98]

The deposition of hazardous waste is recommended in a vale or a one sided cavity like Figure: 7-38. It combines the advantages of the previous two kinds of landfills. The landfill body is hidden as much as possible, there is a appropriate volume- basement area ratio, a free level drain is ensured and exposure of leachate to the ground is monitored and minimised.

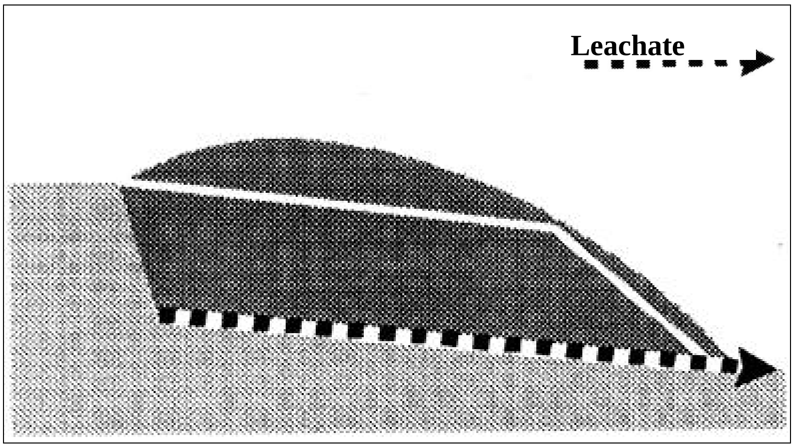

Figure: 7-38 Landfill in a vale respective a one sided cavity[99]

The advantages are to be effective under the conditions of an applicable and safe underground. An example of such an underground is shown in Figure: 7-39. That is the construction of a hazardous waste landfill according to the technical instructions on waste as it is applied in Germany. Anyway,

[98] [Tabasaran 1997 p.192]

[99] [Tabasaran 1997]

hazardous waste landfills all over the world should comply with these standards. However, the thickness of the mineral sealing demands the biggest attention. In this layer, metal ions and also organic substances are impeded by adsorption. Synthetic layers are dense hydraulically, unless cracks or leaky welds exist. Between the waste and the basic sealing, there is the drain system containing drain layer and drain pipes. To prevent emissions by gases, wind-blown dispersals and odours in the landfill have to be sealed on top. This also, prevents the infiltration of precipitation water into the body. It contains of a balancing layer, a synthetic sealing web, a drain layer, a mineral sealing and a recultivation layer [Tabasaran 1997].

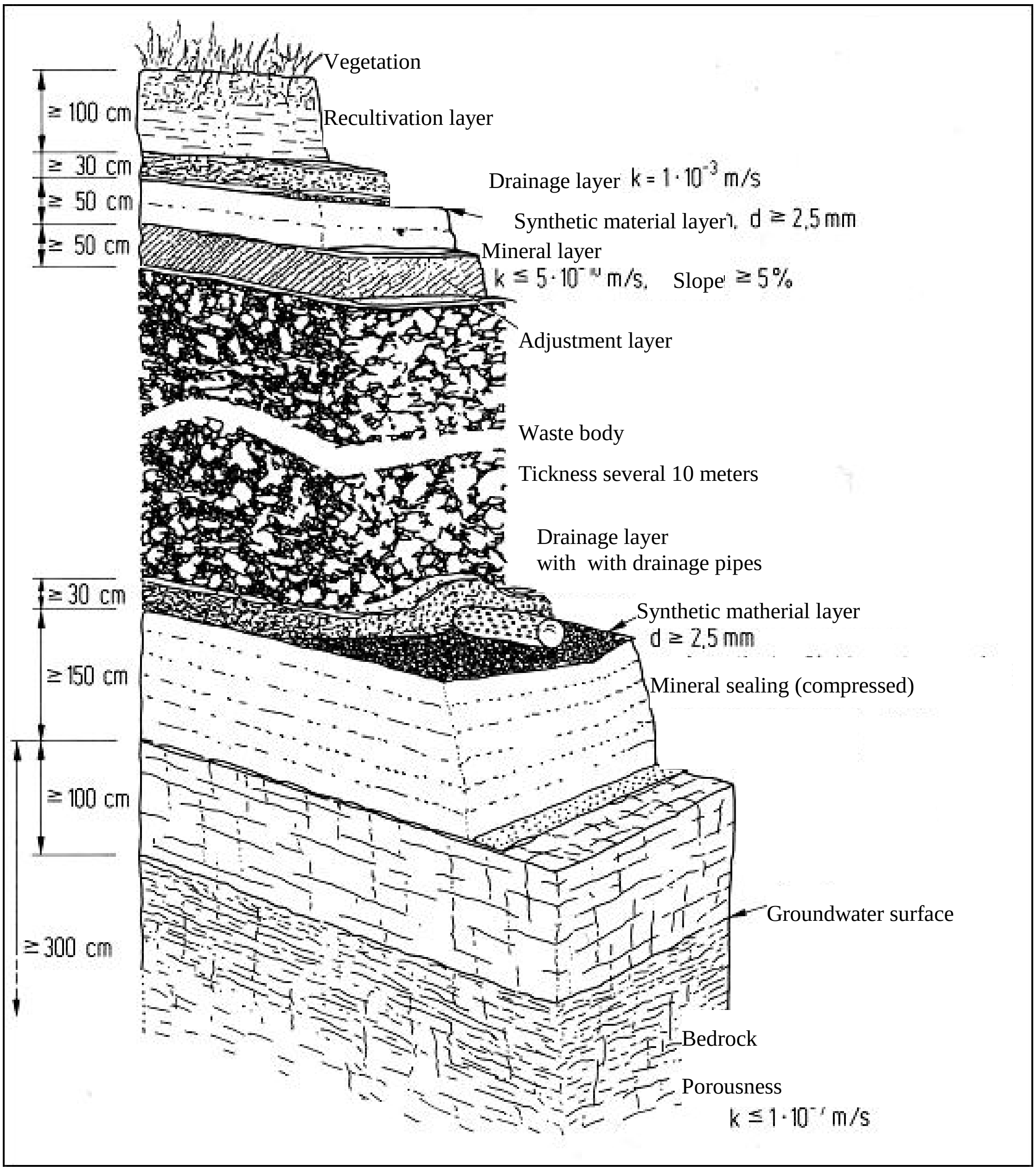

Figure: 7-39 Aboveground hazardous waste landfill[100]

[100] [Tabasaran 1997]

Landfill base seal and top seal are not the only safety features, which should help to safeguard the landfill body. The consideration to prevent malfunctions and the rising claims on handling with waste leads to basic idea of the multi-barrier concept. In this concept several self-contained safety barriers should prevent harm to the environment originating by the landfill. The concept includes following barriers [Bilitewski wt al. 2000]:

1. Barrier: Waste pre-treatment,
2. Barrier: Geology and hydrology of the site,
3. Barrier: Landfill body with predictable behaviour,
4. Barrier: Landfill base seal with seepage water catchments and treatment,
5. Barrier: Surface sealing and separate catchments of precipitation,
6. Barrier: Use, maintenance and the possibility to control and repair the barriers.

The pre-treatment of hazardous wastes is supposed to assure the immobilization of the waste, which should be deposited, at the best. This could be reached with chemical-physical pre-treatment, combustion, pre-sorting and separate collection of hazardous waste.

The geology and hydrology of the site of a hazardous waste landfill has a major role. The underground should ensure only, a little discharge and transportation of containments. Discharged containments should be fixed fast in the landfill surrounding grounds, to prevent a damage of the environment. Therefore, it is highly recommended for hazardous waste landfills not to be built in parts with heavy jointed underground or parts with karst formations, drinking water or spas dependencies, water-priority areas or flood plains.

The behaviour of the landfill body has to be predictable to that effect that, based on long-term considerations, no unacceptable emissions are expected. This is reached with a great inner and outer firmness of the landfill.

By the use of an adequate maintenance, dangers for the environment should be excluded. Therefore, long-term safeguards and inspections of the landfill behaviour are used[Bilitewski et al. 2000].

7.7.2. Underground landfill

The requirements to barriers are high. Man-made barriers are getting safer and safer. But, they are out of all proportion to the mightiness of natural barriers. For example, subsurface cavities from mining activities can give safety, that no man-made barrier can give. Additionally, most of the potential disposal sites are so deep, that, there are no interactions of contaminants, which could be dangerous for humans and environment. By using former mining sites, little investment costs are expected. Furthermore, only an underground landfill can warrant a maintenance-free recultivation of useful areas aboveground after closing down the disposal site. Then, it could even be used agriculturally. So, a non-restrictive use of the surface areas is ensured. In contrast to surface landfills, only underground landfills can permanently close off hazardous waste maintenance-free [Tabasaran 1997].

Options of subsurface disposal:

Basically, there are three versions of subsurface disposal possible, depending on the position of the disposal cavities:

- the disposal cavity is situated vadose (above the ground-water table),
- the disposal cavity is situated in aquiferous layers,
- the disposal cavity is situated under the ground-water table.

In the first case, at least every side and the ceiling have to be sealed by waterproof geological formations to ensure a maintenance-free closing-off of toxic and leachable hazardous waste. Additionally, a rising of the ground-water table to the level of the deposited waste is not acceptable.

In the second case, only wastes with low water solubility can be deposited; excluding the risk of changing the composition of the ground-water. Thus, no long-term isolation of the waste from the biosphere is possible; only an emission-neutral deposit is imaginable, because there is no warranty that the hazardous waste could mingle with ground-water.

If the disposal cavities would be in waterproof geological formations under the ground-water table, the third version of subsurface disposal was given, e.g. underground landfills in evaporite. State-of-the-art accepts only the installation of underground landfills in evaporite, although, other geological formations like anhydrite, granite or other crystalline rock and clay would give enough safety [Tabasaran 1997].

Basically, there are two different types of landfills in evaporite:

- the mining-landfill
- the cavern-landfill.

The mining-landfill (as shown in Figure: 7-40) has the following details [Tabasaran 1997]:

- salt as geological barrier,
- biosphere is long-term protected by closing-off of the waste,
- wastes can be separately deposited,
- accessible during operating stage,
- water drainage unnecessary,
- wastes are returnable during operation stage,
- storage of repositories, bulky and free flowing wastes possible,
- sealing of the pits at aquiferous overburden,
- no special sealing at deposit area necessary,
- chambers and walks can be individually sealed
- gradual enclosure of wastes by convergence of the salt rock strata,

- dry waste disposal through professional closing-off of pits

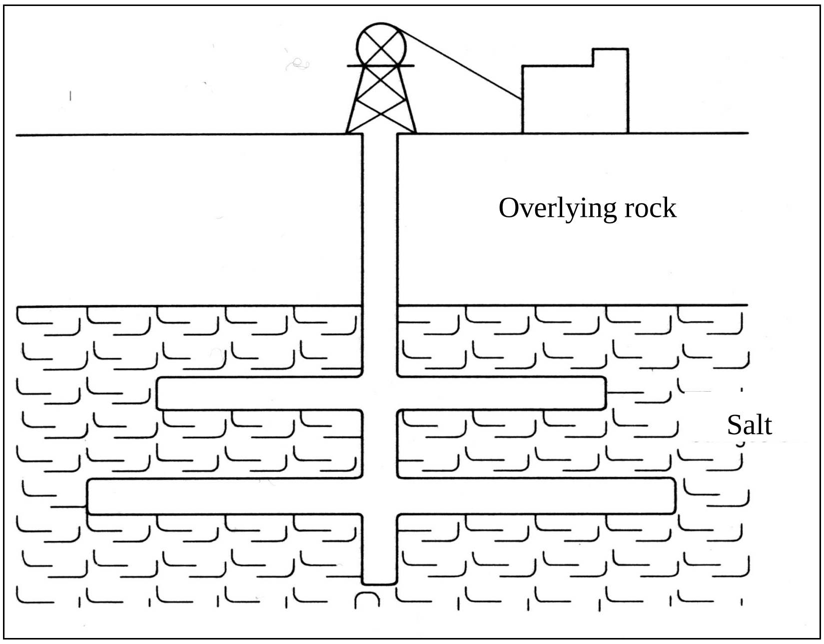

Figure: 7-40 Mining in salt[101]

A schematic demonstration of a cavern shown in Figure: 7-41. Characteristically for this type of landfill are the following characteristics: [Tabasaran 1997]:

- salt as geological barrier,
- biosphere is long-term protected by closing-off of the waste,
- in one cavern no separate deposit of different wastes is possible,
- sealing of the pit at aquiferous overburden,
- no return of waste,
- deposit of free flowing and pumpable wastes by using in-situ compression,
- gradual enclosure of wastes by convergence of the salt rock strata,
- wastes only in dry pumped caverns,
- dry waste disposal through professional closing-off of pit

These two types of Subsurface disposal can be combined to get the vantages of both versions. Within one facility the good accessibility of a mining-landfill can be used and the downthrow-technique of cavern-landfills.

In consequence of the fact, that the wastes are not returnable, the attention has to be turned on a safe and long-termed closing-off of the waste from the biosphere. This has to be clearly verified [Tabasaran 1997].

[101] [Tabasaran 1997 p 203]

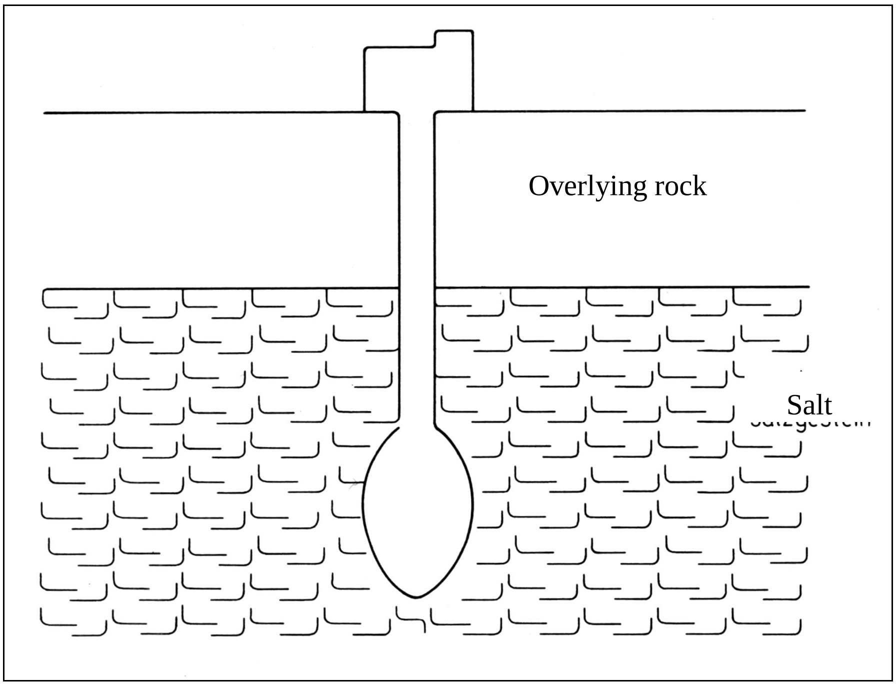

Figure: 7-41 Cavern in salt[102]

Special requirements on the site are [Bilitewski et al. 2000]:

- enough space,
- impermeability for gases and liquids,
- warranty for formation of safe cavities,
- no aquiferous layers near the cavities,
- adequate mightiness of the evaporite in the deposit area,
- the site has to be in a region, which is not endangered by earthquakes.

Site-related security-appraisals are necessary to meet the requirements.

Furthermore, the wastes have to meet certain terms. Only, wastes with the following details can be deposited in an underground landfill [Bilitewski et al. 2000]:

- adequate strength for the chosen type of facility and the conditions of disposal,
- not pyrophorous and not explosive according to the conditions of disposal,
- warranty that the waste do not transfer or afford agents of infectious diseases,
- no increase of volume, no formation of pyrophorous, toxic or explosive materials or gases or other dangerous reactions of the wastes among each other or with the evaporite.

[102] [Tabasaran 1997 p 204]

7.8. Practicable methods and measures for hazardous waste

This chapter introduces some methods for treatment of hazardous waste. Furthermore, it explains the safe handling of hazardous waste at storing, transport and disposal. Especially, the practicability in the developing world takes a centre stage.

7.8.1. Practicable measures for safe handling of hazardous waste

In chapter 6 and this chapter 7 was shown how to store, transport and if necessary, deposit hazardous waste safely. But, these measures are very costly. For example, Special-purpose vehicles, repositories, interim storages and technical equipment make the handling of hazardous waste environmentally sound but cost-intensive. In the developing world this measures are hardly practicable. This is due to the high investment costs and technical complexity. In the following, some things about employment protection and safe handling of hazardous waste is explained. They do not need much technical equipment, thus, they can be realized in the developing world.

Basically, safe working clothes are necessary for workers, which handle with hazardous waste. These are protective clothing, protective gloves, safe footwear and respirators if, necessary. Furthermore, it is comparatively simple to store the wastes as safe as possible. The repositories must be leak-proof, fire-proof and resistant against the containing materials. A top-cover is necessary, if the materials are volatile. The repositories periodically have to be checked for leakages. Additionally, it is important to store the repositories on an even, impermeable ground. Separate, lockable rooms give an additive safety.

There are similar requirements for transportation. The wastes should be covered and fixed with belts and bands. Routes with a bad risk should be avoided. City centre and protected areas (e.g. for drinking water) are not suited for transportation-routes. The cargo-area should have collecting tray in case of transporting liquid hazardous waste. This could be flat trays of steel, which are fixed on the vehicle.

By Using these simple measures, it is possible to reach an acceptable safety for people and environment, with low costs.

At surface disposal the safety should not be cut back. In case of leaving the wastes in the landfill body for incalculable time, a maximum of safety is indispensable. It has to be an important aim for the developing world to reach the worldwide standards. Until then, the landfills should be built as safe as possible. That needs a base seal, a surface sealing and a seepage water catchments preferably, with treatment. This safety steps should be used within the bounds if possible.

For technical purposes, only underground landfills in evaporite are accepted. But, it is assumed that other geological formations also, can be used for disposal. These are anhydrite, granite or other crystalline formations. So, no disused mining facilities in evaporite are needed. This is a good chance for the developing world to deposit their hazardous wastes subsurface.

7.8.2. Choice of process

On the basis of the existing conditions there have to be some site-specific criteria. These are:

- cost-effectiveness,
- low consumption of resources,
- low consumption of energy,
- low technical complexity,
- simple practicability.

Considering the aforementioned conditions, the following processes are possible:

- filtration (deep bed filtration, cake filtration, maybe cross-flow filtration),
- cutting-off process depending on density (flotation, sedimentation),
- chemical precipitation,
- cementation,
- containment,
- sorption,
- oxidation and reduction,
- evaporation,
- wet combustion,
- aerobic (and anaerobic) biodegradation.

The recycling processes, except adsorption on activated carbon and stripping with air, are not explained, because they are technically very complex and are not practicable for medium-sized businesses in the developing world.

For technical and economical reasons, a complete treatment of the waste streams is difficult. On this account, a considerable reduction of hazardous waste or rather, the potential for danger must be reached with a minimal technical complexity.

Depending on the physical condition of the material streams, there are different kinds of treatment. All treatment-steps are realizable with simple means and do not need special knowledge. Almost all, can work continuously or discontinuously.

Treatment of solid waste

There is only, a little amount of solid hazardous wastes from industry. These are mostly easily soluble (salts), but, also low volatile. So, a protective coating has to be built around them (containment); or the solvent has to be bound chemically or physically (sorption). Also, a dissolving out of the solids is possible. Figure: 7-42 shows a kind of treatment. Here, a higher stability of the wastes is reached by combination of containment and sorption. The treatment-steps also can be used individual at any time.

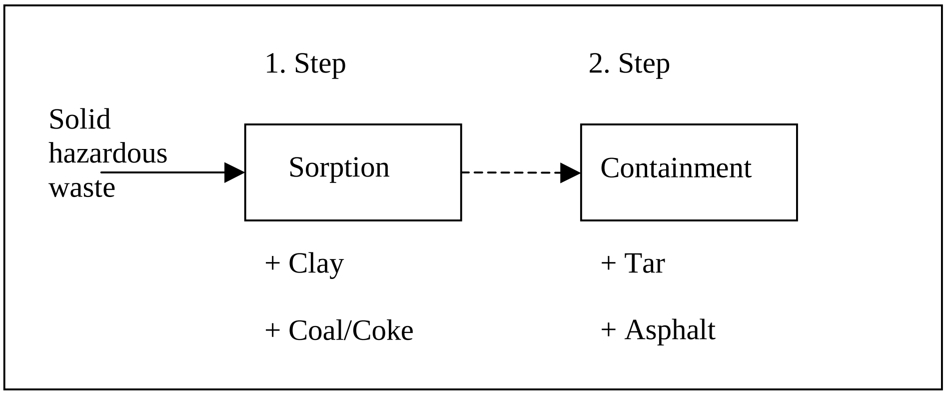

Figure: 7-42 Treatment of solid hazardous waste

Treatment of paste-like waste

Paste-like waste, is a mixture of particles, which are dispersed in a solvent and can be separated with simple cutting-off processes. A sand-filter or a settling pond can be used for separation. Depending on the water content, a sorption is also possible. It should be used for the separated solids. Sedimentation is the easiest kind of treatment, continuously practicable in little batch-reactors (maybe a barrel) as well as in huge clarifiers. Flocculants and precipitants can be used to ensure a good result of the treatment. An agitator (maybe hand-operated) improves the stirring with the additives. It should be shut down for the cutting-off process. The residual solids should be mixed with clay to immobilize the remaining pollutants. Filtration need not be more difficult than sedimentation. For example, a sand-filled reactor is sufficient to separate particles out of a mixture of materials, but it is not possible, if, the water content of the waste is too low. A stretched tissue is particularly, suitable for those wastes. The separated solids should be also mixed with clay. A combination of all three (Figure: 7-43) or two processes is possible and easily practicable. But, dissolved substances will not be separated by passing these treatment-steps.

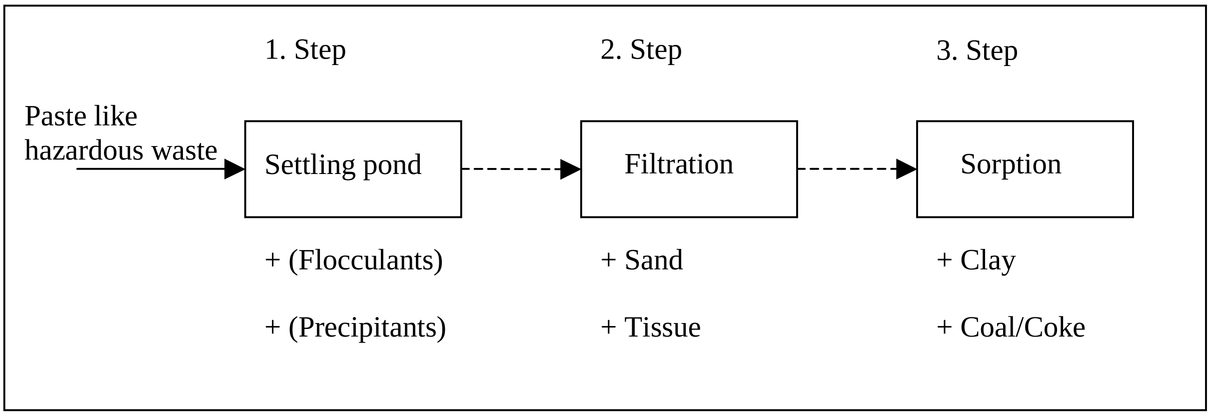

Figure: 7-43 Treatment of pastry hazardous waste

Treatment of liquid waste

Liquid wastes only have a little solid fraction. Almost, all pollutants are dissociated in a solvent or mixed with other liquid substances. Dissolved substances can be easily transferred into the solid phase by addition of precipitants as well as by reducing the temperature. Thus, the waste stream can be treated similar to the paste-like wastes by sedimentation or filtration (Figure: 7-44). The waste stream can contain further pollutants, which could not be precipitated. An oxidation- and reduction step is necessary to transfer the substances into detachable chemical compounds (solid or gaseous). Be careful in case of synthesis of gases; highly inflammable hydrogen is formed at the most reactions. The usage of an agitator to reach an optimal reaction is necessary. The resulting solids can be separated as at any solid/liquid-mixture (Figure: 7-45). With waste, containing no toxic pollutants, biodegradation of organic pollutants is possible. Because, of the yet, dissolved compounds, a bioactive scrubber is recommended in this case.

Volatile organic substances can be separated from the liquid phase by stripping with air. Therefore, only a compressor is required for the air supply; however, an after-treatment of the exhaust air is necessary to avoid emissions. Any combination of the treatment-steps is possible, but the biodegradation should be at the end of the process chain, to avoid a possible toxicity of the waste stream.

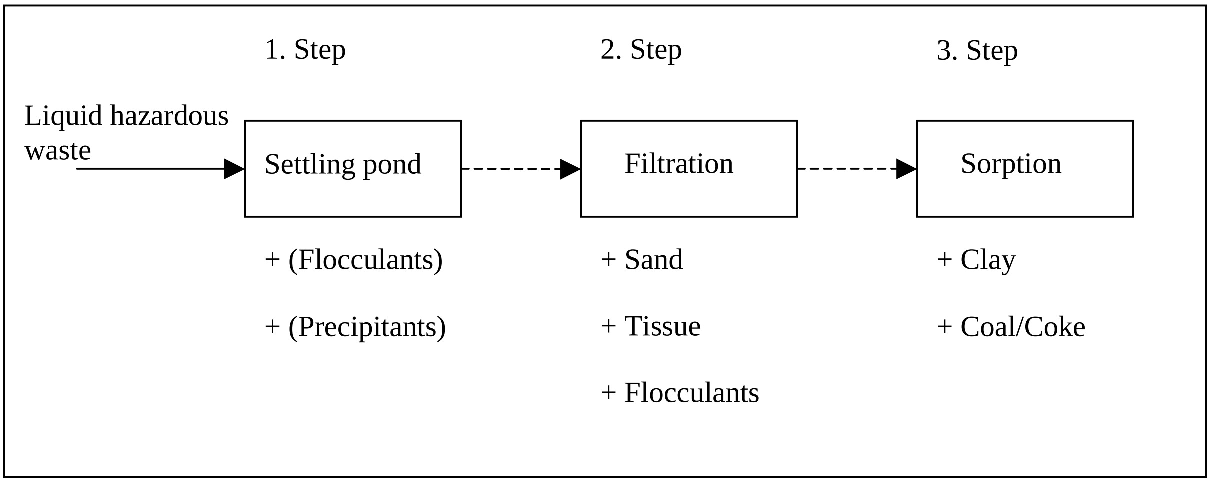

Figure: 7-44 Treatment of dissolved hazardous substances

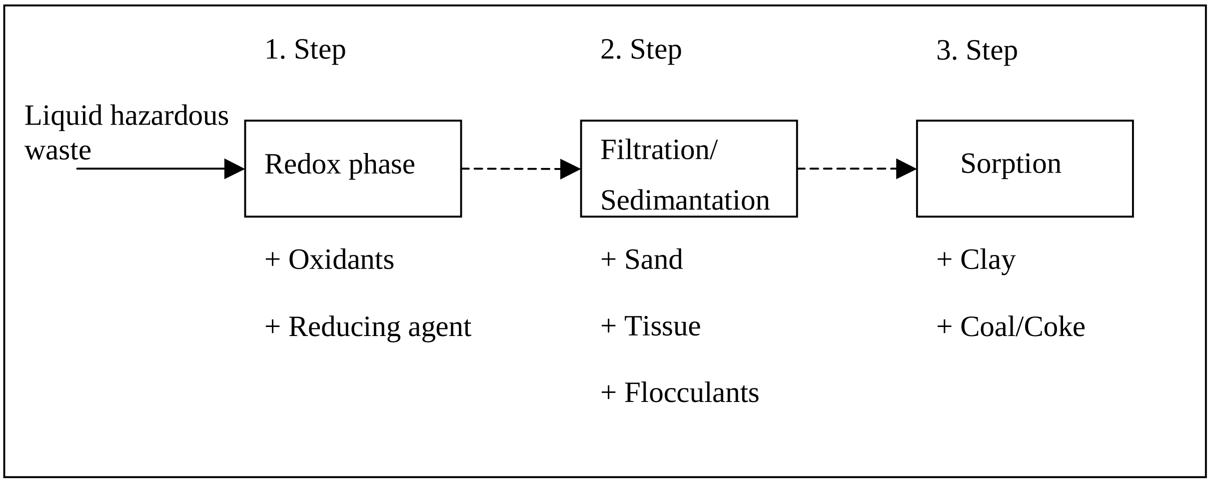

Figure: 7-45 Treatment of hazarous liquid mixtures

Treatment of gaseous waste

Gaseous waste streams either can be loaded with dusts or consisting of a homogenous gas mixture. Dusts partially, can be filtered or washed out. The gas scrubber is easily realizable through a water-filled reactor. An adsorption on activated carbon is also less complicated, if it is changed, periodically. The usage of a bioactive scrubber or bioactive filter is also practicable, for readily biodegradable organic substances. Because, of a lower technical complexity, a bioactive filter has to be preferred. Substances and mixtures of materials with a high heating value can be burned for an energetic recovery. A combination of the different kinds of processes is advised to increase the performance of separation (Figure: 7-46).

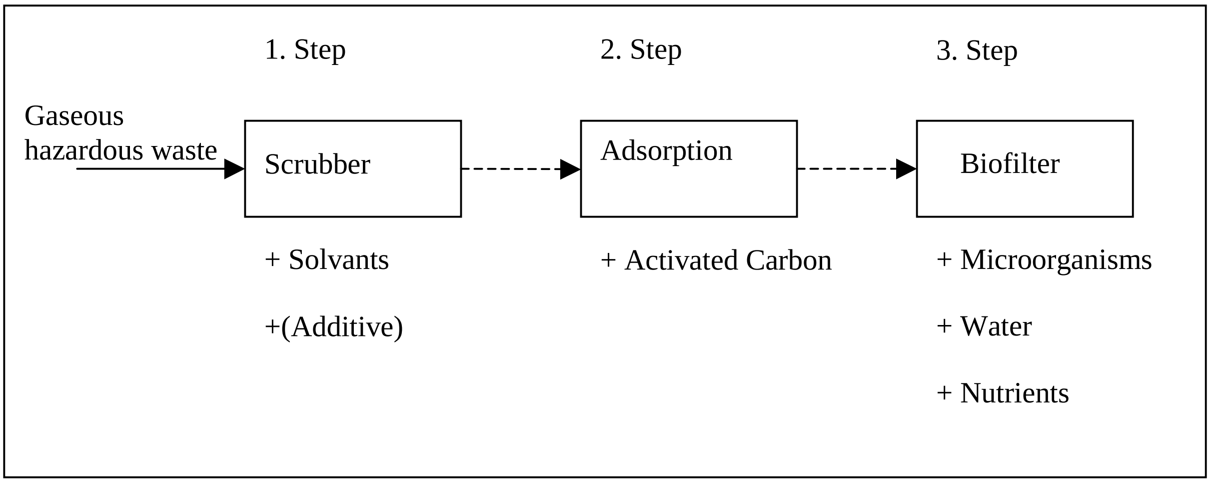

Figure: 7-46 Treatment of gaseous hazardous waste

7.8.3. Advanced process flows of selected industries

Because of industry-specific incidental wastes, different processes for treatment have to be chosen for each industry. Realizable Process flows for textile-, metal- and fertilizer industry are created in the following section. It must be pointed out, that, not the most effective but the most efficient treatment steps to reach the given criteria are chosen.

7.8.3.1. Textile industry

I textile industry following hazardous wastes are incurred: heavy metals, organic compounds, very acidic bases and dyestuffs and pigments. The flow chart in Figure: 7-47 shows the schematic procedure of a possible treatment of the hazardous waste incurred. Basically, there are two different waste streams (exhaust gas, waste water) forming in textile industry, which have to be treated separately. Also, sludge can be formed by distillation processes. The exhaust gas contains different volatile organic compounds (e.g. formaldehyde) which can be removed by biodegradation. An adsorption on activated carbon is also possible but it is more cost-intensive. A biological treatment can use a bioactive filter or scrubber. The usage of bioactive filters is recommended for low toxic substances and low flue gas volumes, because of the limited capacity. A bioactive scrubber is suited for good water soluble substances and anaerobic degradable materials.

The stream of waste water has to take several treatment steps. It begins with a precipitation. Thereby, the concentration of heavy metals is minimized by addition of precipitants (e.g. sulphide). The forming salts can be removed by filtration. In case of enough space or discontinuous operation, sedimentation of the salts is also possible. Further, a treatment step called neutralization follows. This is useful to remove caustic soda extensively by addition of additives. A biological treatment is necessary to remove the extant dyestuffs from the waste water. But, it can be only, used for non-toxic dyestuffs. For toxic dyestuffs, a removal by ultrafiltration is possible. Afterwards, the cleaned water can be discharged into runoff ditch or sewer system. Instead of these four treatment steps, evaporation is also possible. But, this option is only efficient for low amounts of waste water .

Sludge with a high amount of pollutants is treated by immobilization. This means, that free water is bounded and the movement of dissolved and dispersed substances is prevented. This can be reached by addition of clay (sorption) and containment in asphalt. In spite, of the addition of hazardous waste, the asphalt is deemed, to be safe and can be used for road construction (Figure: 7-47).

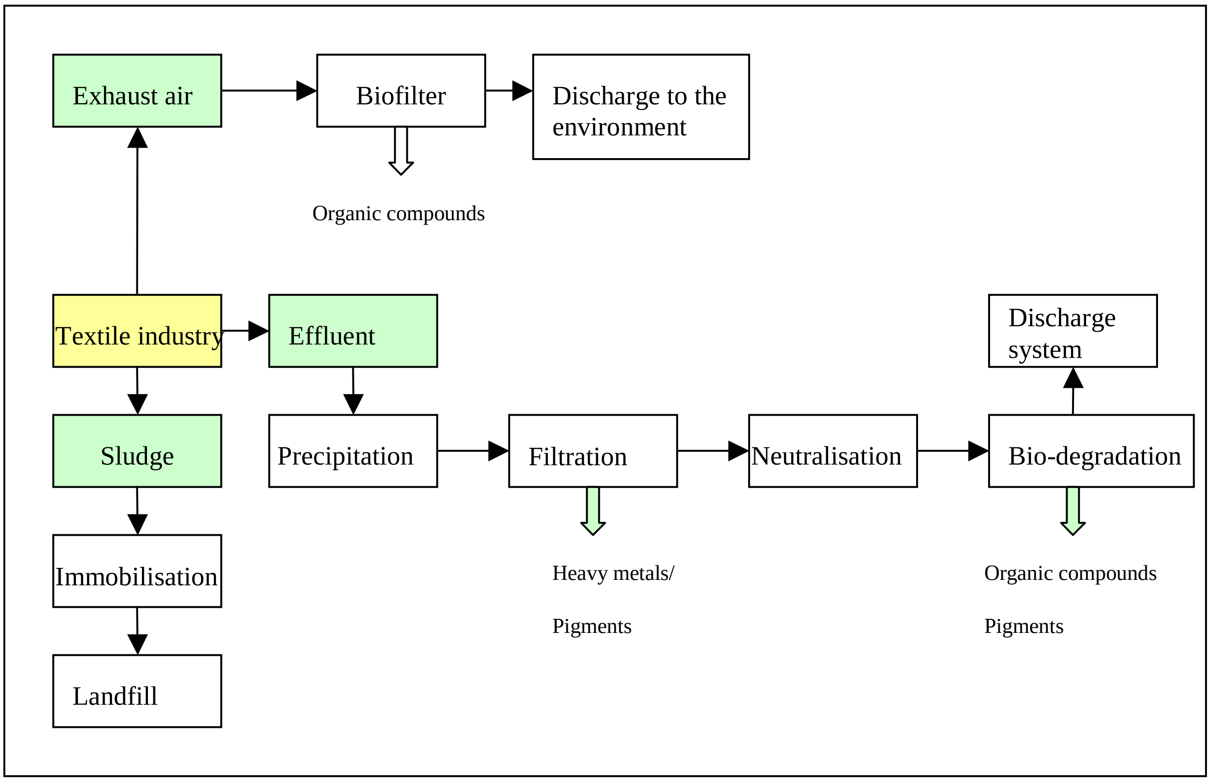

Figure: 7-47 Treatment in textile industry

7.8.3.2. Metal industry

In the metal-working processes various pollutants are formed. These can be heavy metals (lead, cadmium, chrome, chopper, etc.) cyanide, BTX, organic compounds, oils, fats and sludge of metals. Furthermore, exhaust gases are formed, containing volatile and organic toxicities (mercury, halogenated hydrocarbons, BTX). They can be treated adsorptive by bioactive filtration.

The waste water, containing some of the toxic pollutants, which are specified above, is treated in several successive treatment steps. Ultrafiltration is used to degrease the waste water. After removing oils and fats, the water is fed to an oxidation- and reduction step. By the addition of chlorine gas, the cyanides are oxidized into carbon dioxide and nitrogen. Iron is given to the water to transfer chrome-VI into chrome-III. Then, the precipitation of the heavy metals is followed, for example by cementation. Thus, it gives a chance to recover the heavy metals, separated by filtration. Now, the water is freed from organic compounds by wet oxidation. These can be fed to the exhaust-gas stream and conducted via the bioactive filter. Now, the cleaned water can be discharged into runoff ditch or sewer system. The residual sludge can be dehydrated by filtration (cake filtration). The filtrate is fed to the waste-water treatment and runs together with the process-waste-water through the different treatment steps. Because of the low water content of the sludge, it can be deposited at a landfill (Figure: 7-48).

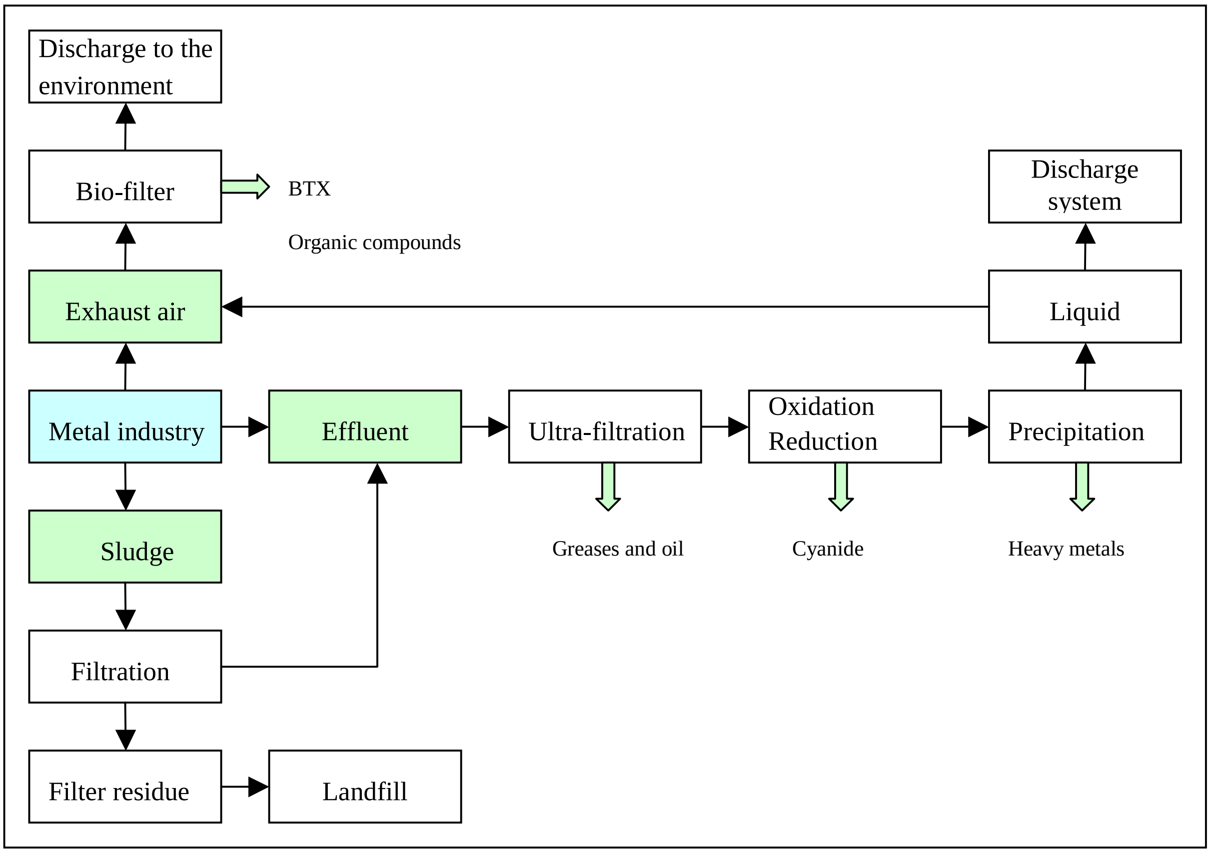

Figure: 7-48 Treatment in metal industry

7.8.3.3. Fertilizer industry (phosphate fertilizer)

The fertilizer industry produces the most of the quantity of hazardous waste. Because of the usage of different resources, there are also diverse waste streams, which have to be treated. The production of phosphate fertilizers is technically complex because of the necessity of a sulphuric acid plant for the supply of sulphur trioxide. From the sulphuric acid plant comes exhaust gas. This contains besides, sulphur dioxide and sulphur trioxide, also, a certain concentration of heavy metals, due to the roasting of pyrite. By the usage of scrubbers, the pollutants can be transferred from gaseous into liquid phase. On this way, they can be discharged into the waste-water treatment of the phosphate plant. The acidic waste water can be also discharged to this sewage system. But, a separate treatment of waste water in a neutralization step, is also possible. The sludge from the phosphate plant is radioactive, caused by the included radon gas. So, it has to be stabilized and immobilized at the best possible rate. The main component is the phosphogypsum, which can be only deposited because of the known impurities. At the synthesis of phosphate fertilizer, exhaust gases like sulphur trioxide and particularly fluorides are forming. These can be removed from the exhaust-gas stream by scrubbers. A treatment of the waste water from the scrubbers is indispensable. It can be treated separately or together with waste water from other sources. At first, the dissolved fluorides are transferred with caustic potash into calcium fluoride, which can be precipitated by addition of precipitants like poly-acrylamide.

$$Ca(OH)_2 + 2\ HF = CaF_2 + H_2O$$

By addition of the lime the pH is rising and gypsum is formed. This fact supersedes an upstream neutralization step. Heavy metals can also be transferred into a water-insoluble salt by the caustic potash. The residual solids can be separated by filtration; sedimentation is under certain conditions also possible. The potential residual phosphoric compounds can be removed from the waste-water stream by bioactive phosphate degradation (Figure: 7-49).

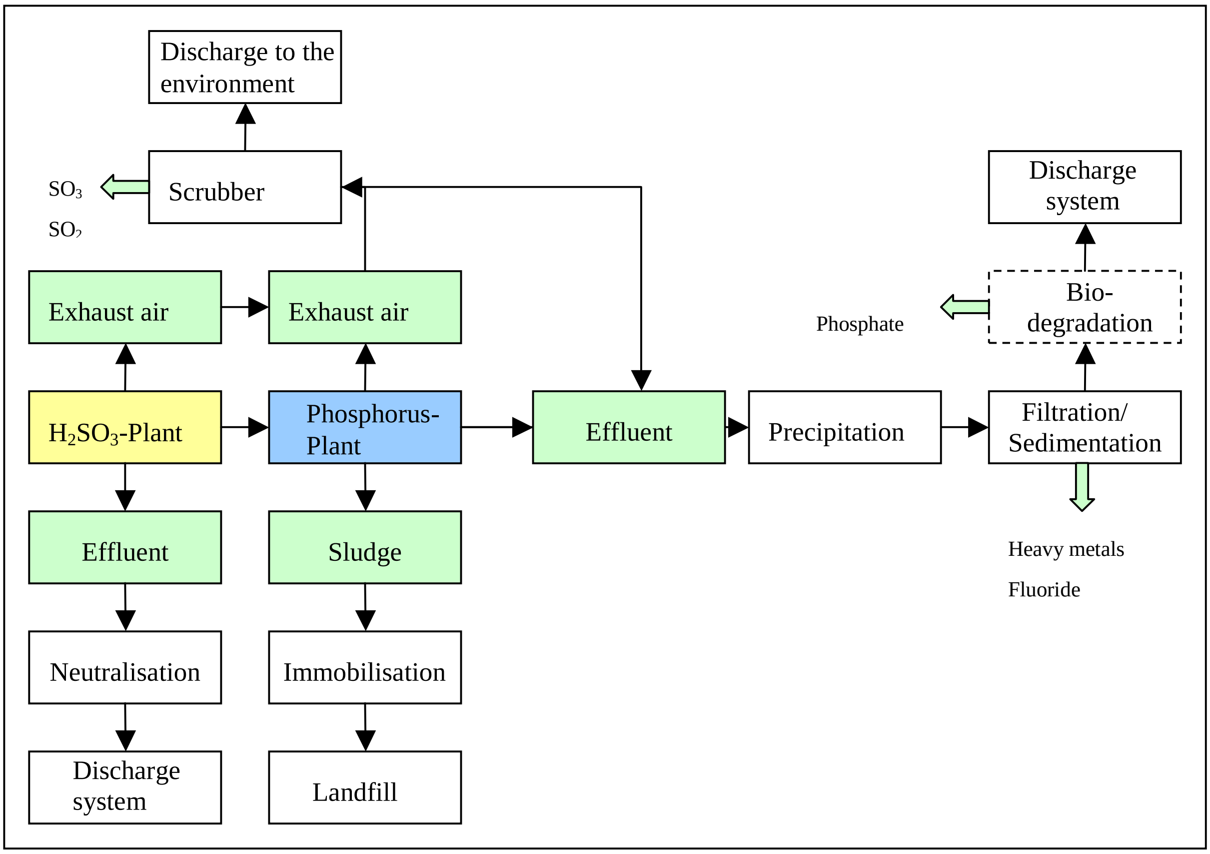

Figure: 7-49 Treatment in Fertilizer industry

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