HAZARDOUS WASTE TREATMENT TECHNOLOGIES

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Contents

1. Introduction
2. Biological Treatment
2.1 Aerobic and Anaerobic Systems
2.2 Design Issues
3. Physical and Physicochemical Processes
3.1 Process Selection
3.2 Example Applications
4. Thermal Treatment
4.1 Dedicated Waste Incinerators
4.2 Combustion in Industrial Furnaces
4.3 Controlled Air Incinerator
5. Technological Advances
5.1 Biological Treatment
5.2 Physicochemical Processes
5.3 Thermal Processes
6. Conclusions
Glossary
Bibliography
Biographical Sketch

Summary

Hazardous waste management converts the waste material into less harmful or environmentally benign chemicals by biological, physical, chemical, and thermal processes, followed by the disposal or dispersal of the solid, liquid or gaseous products or residues under managed conditions.

Because of the widely differing physical and chemical characteristics of hazardous wastes, treatment technologies have to be carefully matched to each waste type, taking into consideration the nature of the wastes, the degree of hazard reduction required, as well as economic, and other factors.

Advances in biological processes have resulted in systems that permit faster degradation rates and treatment of higher levels of contamination by raising treatment temperature, and improving oxygen transfer rates. Novel physicochemical processes have been developed that use combinations of chemicals, often aided by the passage of an electrical current, to oxidize as well as to recover constituents in the waste from aqueous solutions.

New thermal processes have utilized technologies such as plasma arc combustion and gasification to improve destruction efficiencies and produce an inert, vitrified ash product. Continuing innovation is seen as the key to providing more cost effective and environmentally acceptable solutions to both long-standing and, as yet, unresolved problems with hazardous waste.

1. Introduction

The purpose of hazardous waste management is to mitigate the harm such wastes can cause to humans and to the environment. This can be achieved by converting the waste material into less harmful or environmentally benign chemicals by biological, physical, chemical, and thermal processes, followed by the disposal or dispersal of the solid, liquid or gaseous products or residues under managed conditions.

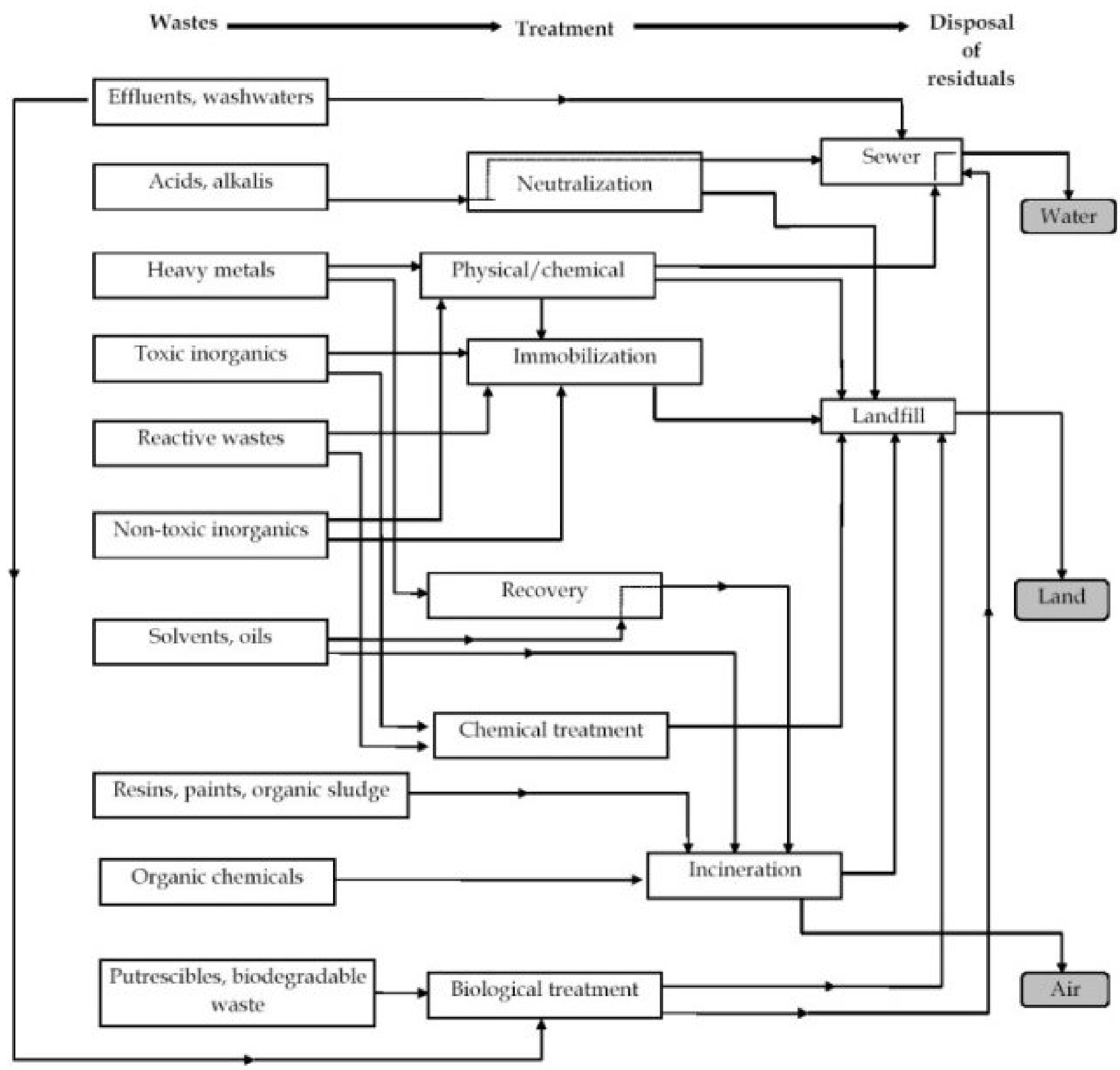

Figure 1. A scheme for treatment and disposal of hazardous wastes.

Alternatively, the wastes can be contained or immobilized so as to prevent or limit the dispersal of the waste mass and the exposure of receptors to the hazard. In addition to degradation, destruction or disposal technologies, the term “treatment” also encompasses processes for the recycling and recovery of wastes, the effect being to remove these materials from the disposal chain, and thus forestall their introduction into the environment.

However, recycling or recovery processes may in themselves generate residues, which are hazardous in nature, and which would therefore have to be directed to other treatment or disposal options to render them safe.

Because of the widely differing physical and chemical characteristics of hazardous wastes, treatment technologies have to be carefully matched to each waste type, taking into consideration the nature of the wastes, the degree of hazard reduction required (i.e. the nature of the residue streams) together with economic and other factors.

Hazardous waste treatment technologies can be placed into broad four categories: physical processes, physicochemical, and chemical processes, biological processes, and thermal processes. A general scheme for the allocation of treatment technologies to different types of hazardous wastes is provided in Figure 1.

2. Biological Treatment

2.1 Aerobic and Anaerobic Systems

Industrial organic wastewater is generally a high-volume discharge of BOD/COD that can vary in the type of organic material present, the constancy of the feed specifications, the content of inorganic nutrients, the presence of substances toxic to the biomass, and the diurnal flow pattern. Biological treatment processes can be broadly classified into two categories depending on the level of oxygen present in or supplied to the waste in the digestion vessel.

A high oxygen concentration (minimum requirement of 0.5 ppm free dissolved oxygen) promotes the growth of aerobic bacteria, biological reactions proceeding via oxidation. Thus, sulphur, nitrogen and phosphorus containing compounds in the wastewater are converted to low-energy end products such as sulphates, nitrates, and phosphates: the energy necessary for respiration, and for the synthesis of new cells is also generated by oxidation of carbonaceous cellular material.

In the absence of oxygen, anaerobic bacteria thrive. The end products of degradation are decomposed liquor that normally requires further treatment prior to discharge, and a gas comprising mainly of methane and carbon dioxide. Effective anaerobic treatment relies on an optimum balance between non-methanogenic and methane-producing organisms in order to ensure that the energy in the waste is not retained in the liquor in the form of partially decomposed organics, but is evolved as a gas.

Many treatment processes do not fall strictly within the above categories: for instance in stabilization ponds differences in depth could result in an essentially anaerobic layer of biomass in the upper regions. The presence of facultative bacteria capable of thriving in both aerobic and anaerobic conditions is believed to have an important role in biological processes, and combinations of treatment processes can be used to achieve a required discharge specification.

2.2 Design Issues

Biomass for aerobic processes is generally held in the psychrophilic range (10–30ºC, but see below) while two temperature ranges are quoted for anaerobic treatment, the mesophilic (32–37ºC) and the thermophilic (40–55ºC). The former of these is most widely used, a major consideration being whether a waste can generate sufficient methane to satisfy the heat requirements of the process.

The concentration of microorganisms in the digestion tank is measured as “mixed liquor suspended solids” (MLSS) or “volatile suspended solids” (VSS). Since it is the biomass that degrades the waste material, maintaining an optimum concentration of MLSS is vital for successful treatment. This is achieved by a sludge recycle system. The BOD loading on a biological system in terms of kg BOD/m^3 of reactor volume/day is a function of the MLSS content of the waste liquor.

In conventional aerobic activated sludge systems the BOD loading is relatively low (0.1–0.5 kg BOD/kg MLSS/day). Higher loading levels decrease BOD removal efficiency, increase sludge production and induce sludge bulking, and therefore activated sludge systems are typically restricted to a maximum loading of about 2 kg BOD/m^3/day. In aerobic biological filters the biomass is attached as a thin film to the surface of inert supporting media packed into a tower or bed. About 60% of the applied BOD is converted to sludge and, as the excess is washed out of the system, a sludge/liquid separation stage is required.

Organic loading in aerobic fixed culture systems vary from 1–8 kg BOD/m^3 tower volume/day, while aerobic fluidized bed systems are claimed to tolerate loadings of up to 16 kg BOD/m^3/day. In terms of influent strength, these loading rates translate to 3000–8000 ppm BOD. Average retention times in aerobic systems range from 20 minutes in biological filters to 24 hours in activated sludge plants.

Anaerobic digestion systems are usually operated in the mesophilic range (32–37ºC). Since oxygen is toxic to methanogenic bacteria the waste has to be kept anoxic. Industrial wastes seldom contain methanogenic bacteria and their digestion usually requires an initial inoculation with actively digesting sludge. Although soluble ions of heavy metals are toxic above 2 ppm, their insoluble precipitates are not. Soluble sulfides are also toxic above 100 ppm. Sodium and potassium ions cause strong inhibition above 10000 ppm. Chlorinated hydrocarbons can induce complete failure of a digester at concentrations of 1 ppm.

Whereas the sludge yield for aerobic processes is about 60% of applied BOD, an anaerobic process only converts 10–40% of the BOD to sludge. Sludge production is slow and therefore retention times of five to thirty days are required to build up sufficient biomass in the reactor. In order to make the process economical, sufficient methane has to be generated to sustain the temperature in the digester. Therefore anaerobic digestion is generally applied to strong wastes with a BOD of above 6000 ppm. BOD loading varies from about 1 kg BOD/m^3/day for a conventional single-stage reactor with no sludge return, to 3 kg BOD/m^3/day for a contact process equipped with a sludge- recycle system.

High rate digestion can be achieved with a multi-stage process with the first mixed and heated stage providing stabilization of the sludge, and the second, and subsequent, stages providing settling and thickening of the digested sludge. Digestion gas contains about 60% methane, and has a typical heat value of 220 kJ/m^3 with about 0.94 m^3 of gas formed per kilogram of VSS destroyed.

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Biographical Sketch

Dr. Gev Eduljee is Director of ERM’s Technical Services Division. He is a specialist in waste treatment and disposal, particularly on hazardous waste and high-temperature incineration, on which he has written extensively. He has undertaken environmental assessments and health risk assessments of contaminated land, and waste treatment and disposal facilities. He is a registered auditor, having undertaken audits of waste facilities throughout Europe. Prior to joining ERM, Dr Eduljee worked for Rechem International Ltd, a leading hazardous waste treatment and incineration operator, as manager of their environmental monitoring unit and as a development engineer in toxic and hazardous waste management. He has acted as the UK expert on PCBs for the International Electrochemical Commission.