



APPROACHES TO HAZARDOUS WASTES MANAGEMENT<sup>1</sup>

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## APPROACHES TO HAZARDOUS WASTES MANAGEMENT<sup>1</sup>

### INTRODUCTION

Hazardous wastes have become an important environmental and public health issue and concern in many countries in the world. There are two basic aspects of the problem - the "clean-up" of the existing repositories of such wastes and the development and implementation of programmes which would ensure that such wastes are properly dealt with in the future. The first of these concerns is high on the agendas of the highly industrialized countries because of their longer history of generating and then frequently treating and disposing of such wastes in an environmentally unacceptable manner, although in areas of developing countries also, hazardous wastes have been produced and discarded indiscriminately already for years. The second concern, that of providing for adequate treatment and safe disposal of hazardous wastes, should be of high priority in all countries in which industry handles and disposes of hazardous wastes. This includes or will soon include essentially all of the countries of the world.

There is ample evidence that the improper disposal of hazardous wastes can inflict serious damage on the health of people and on the environment. The highly publicized situations such as the Love Canal in New York State; drums of cyanide salts on waste lands where children play in the UK; and paint residues at a building site in the Netherlands, where the residues contaminated basements and drinking-water, while focusing the attention on hazardous wastes, are only the "tip of the iceberg". Such situations could be and, in fact, are repeated many times over in different parts of the world. The potential magnitude of the problem can be illustrated by a mere reference to the tonnages of hazardous wastes which are currently being generated. Estimates developed by the Environmental Resources Limited in the United Kingdom show that for industrialized countries such as the USA, USSR, UK, France, etc., the annual generation of hazardous wastes is upwards of 100 million tonnes, in countries such as Mexico and India it may be between 100 000 and 500 000 tonnes annually, while in Malaysia and the Philippines it could be of the order of 50 to 100 thousand tonnes per year. Even if one assumes that a considerable portion of these wastes are treated and disposed of satisfactorily, the sheer volume of the wastes produced points to a major environmental and public health problem.

The purpose of this paper is to provide a brief overview of the hazardous wastes problem and to the solutions which are available. Following the introduction, the remainder of the paper is divided into four sections. The first section is concerned with definition and classification of hazardous wastes. In the second section the major environmental and health effects arising from improper management of hazardous wastes are highlighted. Management options and technological solutions are dealt with in section three while section four makes a few observations about the current status of the control of hazardous wastes.

### DEFINITION AND CLASSIFICATION OF HAZARDOUS WASTES

To define which wastes are "hazardous" and which are not is in itself not a simple matter. Many governments and international bodies have and continue to struggle with this issue. It is an important first step since it defines largely the scope of the wastes management programme, including legislation and regulations, a governmental authority is charged to implement. While the existing definitions and hazardous waste classification schemes vary from one country to another, a number of observations can be made.

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<sup>1</sup> This review was prepared by Mr G. Ozolins, Manager, and Dr R. Helmer, Scientist, Prevention of Environmental Pollution, World Health Organization, Geneva, and Dr J. Smith, Senior Environmental Engineer, US Environmental Protection Agency. The information contained in this review is largely based on the working documents prepared for the WHO/UNEP/World Bank Technical Manual on Disposal of Hazardous Wastes with Particular Reference to Developing Countries, which is currently under development and on the UNEP/WHO publication "Management of Hazardous Waste", WHO Regional Publications, European Series No. 14, Copenhagen 1983. The Manual, which will outline the various options for treating and disposing of hazardous waste, will be available late 1987.

Concern is essentially with waste that presents either:

- (a) short-term acute hazards, such as acute toxicity by ingestion, inhalation, corrosivity or other skin or eye contact hazards or the risk of fire or explosions; or
- (b) long-term environmental hazards, including chronic toxicity upon repeated exposure, carcinogenicity, resistance to detoxification processes and to biodegradation, the potential to pollute underground or surface waters, or esthetically objectionable properties such as offensive odours.

In defining hazardous waste not only the substances (mostly chemical but also some biological such as hospital waste) which constitute the waste are of concern, but so are their concentrations, chemical reactivity, physical form and total quantity of the given waste which must be dealt with. The latter takes into consideration the wastes which may contain relatively low concentrations of a hazardous substance(s) but the volume of which is so great as to ultimately bring about harmful conditions. In this context it should be mentioned that some countries have introduced requirements that a waste must be present at more than a predetermined minimum quantity before it is considered hazardous. This approach is administratively convenient, but has dangers that the hazardous waste which is generated in small individual batches is overlooked by regulations only to add up to considerable amounts when all the small sources are considered together.

It should be noted that the common practice has been to exclude radioactive wastes and domestic refuse from hazardous-waste management schemes and from the definitions of "hazardous waste" inherent in such schemes. While, admittedly, radioactive wastes are highly hazardous, they are excluded since countries typically control and manage these materials in a separate organizational framework. Domestic refuse, which can contain some hazardous material such as mercury from dry cell batteries, solvents from paint residues, etc., is also excluded since it too may be dealt with by a separate although inter-related organizational framework. This latter point may need some additional consideration in a developing country context because of the prevalence of small home-based industries which may generate and intermix its hazardous waste with normal household refuse.

Given the above considerations, a working definition of hazardous wastes may be expressed in the following way:

A hazardous waste is defined as any waste, excluding domestic and radioactive wastes, which because of its quantity, physical, chemical and infectious characteristics can cause significant hazards to human health or the environment when improperly handled, treated, stored, transported or disposed.

Wastes defined in this way include solids, liquids, sludges and contaminated containers and can arise from a wide range of commercial, agricultural, industrial and domestic sources. In general, they are wastes which cannot be handled effectively by the existing wastewater treatment or regular solid waste disposal systems.

What types of wastes or substances in wastes or waste streams are hazardous and what means are available for identifying or classifying them? Again, this task is fraught with difficulties and different approaches are being used in the different countries. In essence there are three general ways:

- (i) to prepare and issue lists of hazardous substances (qualitatively);
- (ii) to define criteria and a testing procedure by which waste is judged to be hazardous or not;
- (iii) to prepare and issue concentration limits of substances in wastes which are listed as being hazardous.

There are, of course, advantages and disadvantages accompanying each of these approaches. The first approach is the simplest as it requires no testing. It has the disadvantage in that the waste management authority is faced with the burden of deciding which of the large number and varied wastes should be controlled. The other two approaches are based on quantitative criteria, but they are expensive to implement requiring considerable manpower.

The listing of hazardous wastes has been dealt with in two ways - through the use of an "exclusive list" or an "inclusive list". Under the first approach, i.e. exclusive list, the relevant authorities prepare and issue a list of known wastes that present no significant hazards, defining hazardous waste by exclusion, i.e. as any waste not listed. This was used successfully in the United Kingdom. While an advantage of this approach is that it is simple to ensure that listed materials are not hazardous, materials not listed may well be only marginally hazardous.

More widely employed for regulating purposes are listings of hazardous waste (inclusive lists). This approach is now used in many countries. An example of an inclusive list, that issued under a directive by the Council of European Communities, is given in Table 1. The inclusive list offers a greater degree of certainty but suffers from the disadvantage that omissions may well be significantly hazardous.

In describing and defining hazardous wastes, another aspect is the need to classify the major groupings of the wastes. Typically the major groupings include:

I. Inorganic wastes:

- acids and alkalis, which occur through many sectors of industry with acid wastes from surface preparation and finishing metals being major sources;
- cyanide wastes from metal finishing and heat treatment of certain steels;
- heavy metal sludges and solutions containing toxic metals - arsenic, cadmium, hexavalent chromium, lead, mercury, nickel and zinc;
- asbestos wastes arising from lagging materials from power stations, industrial manufacturing plants, gas works, demolition of buildings, etc.;
- other solid residues.

II. Oily wastes:

- generated primarily from processing, use and storage of mineral oils; in some cases they may be contaminated with toxic metals.

III. Organic wastes:

- halogenated solvents generated from dry-cleaning of clothes, metal cleaning, degreasing and deoiling of textiles and leathers;
- non-halogenated solvents including toluene, methanol, isopropanol and ethanol and many others; they are used widely in industry as for example in the production of paints, inks, adhesives, resins, food flavourings, etc.;
- PCB wastes are generated from the manufacture of PCBs and from decommissioning of equipment in which PCB is used, fluids in transformers and capacitors;
- paint and resin wastes are generated from a variety of formulation and other "tertiary" chemical processes and in application of paints and resins;
- biocide wastes are generated in the manufacture of biocides and use of these compounds.

Extracted from Annex to Council Directive 78/319/EEC,  
20 March 1978 on toxic and dangerous waste

Table 1. List of toxic or dangerous substances and materials  
selected as requiring priority consideration

- 
1. Arsenic and compounds
  2. Mercury and compounds
  3. Cadmium and compounds
  4. Thallium and compounds
  5. Beryllium and compounds
  6. Chromium (VI) compounds
  7. Lead and compounds
  8. Antimony and compounds
  9. Phenolic compounds
  10. Cyanide compounds
  11. Isocyanates
  12. Organohalogenated compounds, excluding inert polymeric materials and other substances referred to in this list or covered by other directives concerning the disposal of toxic or dangerous waste
  13. Chlorinated solvents
  14. Organic solvents
  15. Biocides and phytopharmaceutical substances
  16. Tarry materials from refining and tar residues from distilling
  17. Pharmaceutical compounds
  18. Peroxides, chlorates, perchlorates and azides
  19. Ethers
  20. Chemical laboratory materials, not identifiable and/or new, with unknown effects on the environment
  21. Asbestos
  22. Selenium and compounds
  23. Tellurium and compounds
  24. Polycyclic aromatic hydrocarbons (carcinogenic)
  25. Metal carbonyls
  26. Soluble copper compounds
  27. Acids and/or basic substances used in the surface treatment and finishing of metals
-

## IV. Putrescible organic wastes:

- include wastes from production of edible oils, slaughter houses, tanneries and other animal wastes.

## V. High volume/low hazard wastes:

- examples are drilling mud from petroleum and gas extraction and fly ash.

## VI. Miscellaneous waste:

- these include infectious wastes associated with diseased human or animal tissues, laboratory wastes and explosive wastes.

There are varying degrees of hazard associated with different wastes and waste streams. Consequently it is important that some scheme of assigning priorities be developed. In a number of European countries priorities are assigned on the basis of concentrations of harmful substances in the waste to indicate whether or not the waste should be subjected to a high degree of monitoring and control. An alternative way might be to divide the waste into two classes, namely those of priority concern and those of lesser concern. The first group would include wastes that contain significant concentrations of substances that are highly toxic, mobile, persistent or bioaccumulative. Examples include chlorinated solvent wastes, cyanide wastes and PCB wastes. The second group would include all other wastes.

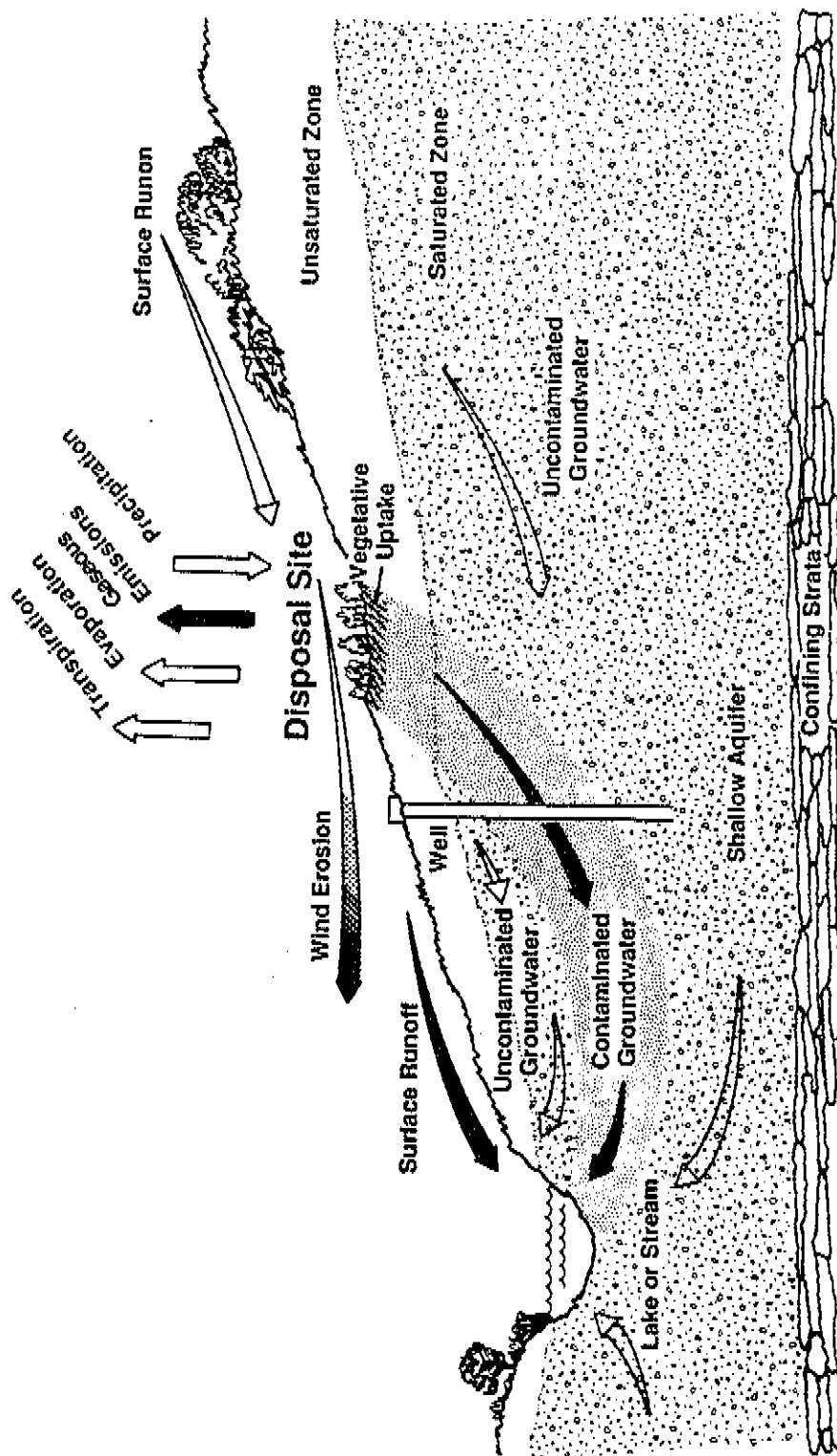
## HEALTH AND ENVIRONMENTAL EFFECTS

Improper disposal of hazardous waste causes adverse effects on human health and the environment. It will continue to do so until hazardous wastes are no longer considered as "normal" waste and are singled out for specific treatment and ultimate disposal. The normal practices of waste disposal such as land-filling, land treatment, impoundment, burning, direct discharge to a water course or the sewer, will need modification when dealing with hazardous wastes for it is through such disposal practices that the harmful substances enter the environment and reach human as well as non-human targets.

The principal hazard of improper waste disposal is contamination of soil and groundwater, in particular the latter. This arises largely from having deposited the waste containing hazardous substances in land fills or on the ground. Once there, the hazardous substances can in time be transferred by various routes to reach water supplies, be taken up by plants and vegetation, and even re-enter the atmosphere. Figure I illustrates in a simplified manner the mechanisms through which hazardous substances can enter the human environment after being "disposed of" in a land fill.

Another common way of disposing of waste (including hazardous waste) is by incineration or open burning. Unless incinerators are specifically designed for handling specific types of hazardous wastes, it is quite likely that some toxic substances will be released either into the atmosphere or be retained in the combustion residue which then in itself presents a hazardous waste problem. The open burning of waste can readily produce/release toxic gases and particles into the atmosphere. As in the case of incinerators, the residue will contain many of the hazardous substances, either in their original or altered state.

The discharge of insufficiently treated hazardous waste into water courses as is often done, permits the hazardous substances to be dispersed over wide areas. The net result of this mode of disposal is (i) that water used for human consumption and recreation or for agricultural uses can become contaminated, (ii) that some of the substances are taken up by living organisms and enter the food chain, or (iii) that some of the hazardous wastes may be deposited in the sediment from where it can be released at later times. Hazardous substances released as a consequence of accidental spills pose potential harm to biota and human health in a similar fashion.



**Contaminant Transport from a Land Disposal Site**

FIGURE I

The potential effects on human health are many and varied. They depend on the hazardous material involved, its concentration, the route(s) of exposure, the length of exposure and some other considerations. As stated previously, there are two types of concern, i.e. the short-term acute hazards and the longer term hazards arising from repeated exposures to small concentrations of the substances involved. The latter being either of chronic toxicity only or posing the risk of cancer or mutagenic or teratogenic effects.

With regard to hazardous waste disposal sites there are, theoretically at least, five different routes of human exposure possible:

- direct ingestion through drinking;
- inhalation of contaminants that volatilize from heated water;
- absorption through the skin during washing and bathing;
- ingestion through consumption of food derived from plants or animals exposed to groundwater; and
- absorption through the skin when handling contaminated soil.

Factors governing these five routes are listed in Table 2, demonstrating the difficulties and uncertainties associated with the estimation of each one of them. Apart from the minor likelihood of ingestion of contaminated soil by children and the occupational waste contacts by disposal site workers, there is only ingestion of contaminated groundwater by people living in the area to be considered as the most likely exposure route. Higher susceptibility may be assumed for the elderly and small children as target population sub-groups at risk for related exposure estimates.

Consequently, exposure assessment follows largely the pattern used for drinking water starting with an estimate of the likely concentrations in the groundwater followed by an estimate of the amounts ingested with the drinking water derived therefrom, and - for systemic toxicants - of the absorption rate in the gastro-intestinal tract.

Environmental factors governing the probability of release into underground aquifers are measured through water solubility, volatility and soil mobility. Persistence in the environment is determined by the physico-chemical properties of a substance and classified according to half-life times.

Various practical attempts have been made by responsible regulatory agencies, particularly the US EPA, to develop a sound risk assessment basis for the enforcement of hazardous waste regulations, and proposals for practical guidelines have been developed. Regulatory schemes have to distinguish between health risks for non-carcinogens, to which a margin-of-safety approach can be applied, and for carcinogens which are subject to lifetime exposure assessment before the actual risk can be characterized.

In summary, improvement of the risk assessment of hazardous wastes depends on progress in the science of predictive toxicology, progress in understanding the environmental fate of contaminants, progress in exposure modelling, and progress in reducing multi-contaminant problems to manageable schemes. It is better, however, to use for the time being an imperfect scheme for the public health evaluation process than to make remedial action decisions without explicit regard to the possible degree of public health protection that can be achieved.

#### POSSIBLE SOLUTIONS

The proper management of hazardous wastes hinges on several possibilities or options. They are:

- (i) avoidance or minimization of the quantity of hazardous waste which is generated;

Table 2. Possible intake routes for exposure to groundwater  
contaminants and related factors<sup>1</sup>

Data and Assumptions Necessary to Estimate Human Dose of a  
Groundwater Contaminant from Knowledge of its Concentration in Groundwater

1. Direct Ingestion Through Drinking
  - Amount of water consumed each day (generally assumed to be 2 litres for adults and 1 litre for 10 kg child - References 2, 18).
  - Fraction of contaminant absorbed through wall of G.I. tract.
  - Average human body weight.
2. Inhalation of Contaminants
  - Air concentrations resulting from showering, bathing, and other uses of water.
  - Variation in air concentrations over time.
  - Amount of contaminated air breathed during those activities that may lead to volatilization.
  - Fraction of inhaled contaminant absorbed through lungs.
  - Average human body weight.
3. Skin Absorption from Water
  - Period of time spent washing and bathing.
  - Fraction of contaminant absorbed through the skin during washing and bathing.
  - Average human body weight.
4. Ingestion of Contaminated Food
  - Concentrations of contaminant in edible portions of various plants and animals exposed to contaminated groundwater.
  - Amount of contaminated food ingested each day.
  - Fraction of contaminant absorbed through wall of G.I. tract.
  - Average human body weight.
5. Skin Absorption for Contaminated Soil
  - Concentrations of contaminant in soil exposed to contaminated groundwater.
  - Amount of daily skin contact with soil.
  - Amount of soil ingested per day (by children).
  - Absorption rates (skin, G.I. tract).
  - Average human body weight.

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<sup>1</sup> From: Rodricks, J.V. (1984) Risk Assessment at Hazardous Waste Disposal Sites. Hazardous Wastes, Vol. 1, No. 3, 333-362.

- (ii) treatment of hazardous waste prior to disposal;
- (iii) disposal of the waste in an environmentally sound manner.

All three of these possibilities are important and are not exclusive of each other. When dealing with a given hazardous waste problem, very often there is a need to utilize a combination of the three general approaches outlined above.

#### Avoiding waste

Environmental and economic considerations dictate both the promotion of increased recycling and/or external reutilization of waste before disposal is considered. The first priority in hazardous waste management, in fact, is to reduce waste generation at the source. Waste reduction is not only good from an environmental standpoint, because less waste needs to be disposed, but it is also good business. If discarded hazardous material can be used to an advantage, it can reduce costs for raw material while at the same time eliminating or lessening the quantity of waste which must be treated and/or disposed.

The goal of all industries is, or at least should be, to reduce the amount of wastes that they produce or to reduce the hazards associated with those wastes. The major waste reduction schemes available are summarized below:

- (i) Process modification - Often the industrial processes may be altered in such ways that the use of raw materials is optimized and the amount of waste can be reduced. For example, the larger plating industries have switched to counter-current washing systems rather than single batch washing. This process modification has all but eliminated the necessity to treat large volumes of waste water containing heavy metals.
- (ii) Waste segregation - Many industries historically have combined their waste-water streams, gaseous effluents, or solid waste materials and treated or disposed of the entire volume. Segregating the hazardous waste streams from non-hazardous ones decreased the volume of hazardous waste, making it easier to treat.
- (iii) Waste reuse - In certain situations waste material can be used with very little processing as a raw material. Needless to say such changes can reduce production costs and minimize the waste problem.
- (iv) Waste recycle - Recycling differs from reuse in that the waste must first be treated before it can be used in a manufacturing process. Waste organic solvents provide the best example of "recycling" waste.
- (v) Waste exchange - Waste exchange, based on the concept that what is waste from one industry may be useful raw material in another, is an organized attempt to increase utilization of industrial residues. It is a rather common practice for industries to list waste through industrial trade association publications, or to form a formal association specifically dedicated to facilitate waste exchanges.
- (vi) Product substitution - It is not always possible to reduce the waste that is produced or reduce the associated hazard. In such cases consideration may be given to changing the whole manufacturing process whereby new products made from raw materials may offer an advantage in reducing the amount of waste.

#### Treating hazardous wastes

There are many technologies available for treating hazardous wastes before they are ultimately disposed of. Their aims are to modify the physical and/or chemical properties of the waste. Through the application of these technologies the waste can be reduced in volume, and the toxic components can be immobilized or detoxified. It should be noted, however, that essentially no technology offers absolute safety and there is some level of risk associated with most procedures.

Selection of a treatment process depends on many factors such as the nature of the waste, the desired characteristics of the output stream, and economic and energy considerations. The available treatment technologies can be divided into four groups, namely:

- (i) physical treatment;
- (ii) sludge processing;
- (iii) chemical treatment;
- (iv) biological treatment.

Physical treatment includes various methods of phase separation and solidification. At the most basic level, phase separation encompasses lagooning, sludge drying in beds, and prolonged storage in tanks. All three depend on gravitational settling. Lagooning and tank storage are widely used to separate oil and water from mixed wastes.

Solidification processes convert the waste into an insoluble, rock-hard material and are used as pre-treatment prior to land-fill disposal. This is usually done by mixing the waste with various reactants to produce a cement-like product. This technique has been used for disposal of asbestos waste. Arsenical waste also needs careful disposal and encasing in cement is highly desirable if the arsenic cannot be recovered.

Sludge processing has become important since improvements in industrial waste water treatment, unfortunately it is often accompanied by the production of increasing quantities of increasingly difficult-to-handle sludges. Sludges withdrawn from primary or simple sedimentation are as much as 97% water. There are two different basic approaches for dealing with sludges - to reuse them or to consider the sludges as waste material and to dispose of them. In both cases some treatment is indicated. If the sludges are to be reused as plant nutrients the sludge needs to be stabilized so it will not cause nuisances, pathogens need to be eliminated to prevent disease problems, toxic organics need to be degraded, etc. The degree of treatment provided for sludges which are to be disposed of varies, however most systems try to provide for maximum reductions in volume and/or mass.

The typical technologies for sludge processing include conditioning, digestion, composting, thickening, dewatering and solidification. The purpose of conditioning, often by treating with ferric chloride and lime, is to increase the rate and/or extent of dewatering. The principle purpose of digestion (anaerobic and aerobic) is to render the sludge less putrescible, to reduce the pathogenic content and to reduce sludge quantity.

Composting, properly carried out, will dewater, destroy objectionable odour, destroy or reduce disease organisms and produce an aesthetic and useful organic product. Thickening serves to reduce the sludge volume to be stabilized, dewatered or disposed of. Sludge dewatering can be achieved through drying beds, vacuum filtration, centrifugation, pressure filtration, or drying lagoons.

Chemical treatment methods are used to facilitate the complete breakdown of hazardous wastes and more usually to modify the chemical properties of the waste, e.g. to reduce water solubility or to neutralize acidity or alkalinity. The techniques involve oxidation, heavy metal precipitation, chemical reduction, neutralization, oil/water separation and solvents/fuels recovery.

Chemical oxidation techniques are used, for example, for treating aqueous cyanide wastes which are highly toxic. Plating effluents often contain in solution various heavy metals such as copper, nickel or zinc. These can be removed by the addition of an excess of slaked lime or sodium hydroxide to precipitate them as water-insoluble compounds. An example of chemical reduction is the treatment of chromic acid in waste. Aqueous solutions of highly corrosive mineral acids may be readily neutralized. Combustible organic solvents are frequently toxic and can be explosive. Most of this waste is recoverable and, indeed, often is recovered at the source.

Biological treatment similar to that used for sewage treatment is also employed in treating many industrial wastes. Hazardous waste is occasionally amenable to such treatment, even though concentrations of toxic materials present are often lethal to microorganisms. The in-plant biological treatment of dilute aqueous effluents is well established, and microorganisms have been developed to selectively degrade specific toxic chemicals. The natural microbiological activity in topsoil is also used in farming for degrading some organic chemicals, notably oily wastes. Composting may also be useful for certain organic chemical products.

#### Disposal of hazardous wastes

A number of different hazardous waste disposal schemes are being practiced to bring about the elimination or lessening of adverse impact on human health and the environment. They are all designed to deal specifically with hazardous wastes and not wastes in general. There are six or seven basic approaches to safe disposal such as secure sanitary landfills, codisposal of hazardous and municipal waste, land spreading, deepwell disposal, underground mine storage, dumping at sea and incineration. Each of these approaches is briefly referred to below.

Landfill. Disposal of hazardous wastes in secure landfills is a relatively common and effective means of disposal, which is practiced in many countries. It, of course, presupposes that appropriate disposal sites are available and that the design, construction and operation of the landfill are made in a manner to prohibit or limit contact between the landfill contents and the surrounding environment. The primary concern at landfills is to prevent groundwater contamination through the control of formation of leachate and its migration away from the disposal site. While many hazardous wastes can safely be disposed of at a properly selected and managed site with minimal impact on the environment, landfill cannot be regarded as suitable for all wastes.

Codisposal. Under this scheme the hazardous wastes are integrated with municipal waste in the same landfill. Codisposal often has the advantage that the hazardous wastes are absorbed and diluted by the municipal wastes. If properly operated such codisposal sites can serve to stabilize the hazardous wastes along with the municipal wastes. The joint disposal requires careful management, however, to ensure that the natural attenuation capacity of the municipal waste is not destroyed or overloaded.

Land spreading. Land spreading is commonly used for the disposal of domestic wastewater sludge, and for some hazardous wastes. When employing this technique, care must be exercised in protecting the soil and groundwater from hazardous materials such as the heavy metals which are present in the waste. For this purpose, in some countries limits have been set which specify the amount of the given hazardous substances which can be applied to the soil.

Deepwell disposal. Deepwell disposal involves injection of liquid waste into subsurface porous formations isolated from potable water and mineral bearing strata. Certain types of waste can be regarded as both economically and environmentally favourable for deepwell injection. These include natural brines from oil deposits, which can be reinjected into underground formations without special treatment, salt-bearing solutions, and brines from industrial solution mining. Spent acids may also be included in this category, provided they can be quickly neutralized. In recent years there has been a steady increase in the use of wells for the disposal of hazardous wastes.

Underground mine storage. The storage of hazardous waste in deep underground mines is another disposal option. The solid waste is packaged, usually in drums or special containers, and stored in specially prepared rooms. Salt mines are often used because the excellent properties of salt deposits prevent the interaction of wastes with other geologic formations. An advantage of this type of disposal is that the waste may be reclaimed in the future if so desired. Not all waste can, of course, be disposed of in this manner, as for example wastes which could lead to the formation of an explosive, flammable, toxic or otherwise hazardous gas/air mixture.

Incineration. When burned at the proper temperature for a sufficient period of time and with adequate emission controls, most organic hazardous wastes can be destroyed or made harmless. The wastes which can be dealt with by incineration include solvent waste and sludges, waste mineral oils, varnish and paint wastes and sludges, plastics, rubber and latex waste sludges and emulsions and many others. There are some environmental problems regarding incineration in the form of air pollutants which may be emitted and in the need to dispose of the residue which is left. Very often this residue itself contains hazardous substances. Nonetheless, incineration if properly handled is a useful means of treating/disposing of large quantities of hazardous waste.

#### CURRENT STATUS OF CONTROLLING HAZARDOUS WASTES

Considerable progress has been made in recent years in dealing with the problem of hazardous wastes in a number of developed countries. More often than not there is now legislation in place which calls for concerted action to dispose of hazardous wastes in an environmentally sound manner. The steps which have been taken include:

- (i) controls on waste transport;
- (ii) licensing of operators of hazardous waste treatment and disposal facilities;
- (iii) special facilities have been established for hazardous waste treatment, incineration and control of landfill;
- (iv) special collection and transfer systems have been established;
- (v) waste minimization.

In most of the developing countries, however, increased efforts are required to begin to address the problem adequately. The current situation may be illustrated by the following:

- (i) General control over waste disposal is often poor.

In many countries, open dumps predominate, and in the absence of controls, hazardous wastes continue to find a way into such dumps. This poses a major problem since such dumps are already causing water pollution, fires, explosions, greater groundwater pollution than already occurring and related health and environmental problems.

- (ii) Generators may be unaware of the hazard of their waste.

This is a problem encountered to some extent in all countries, but might be expected to be a particular problem amongst small generators in developing countries. The fact that quantities may be relatively small is to some extent a mitigating circumstance, but it does not necessarily mean that the potential problems are insignificant.

- (iii) Stockpiles of waste awaiting treatment or disposal.

In some countries, industries may have stockpiled their waste on site, in the absence of proper facilities for treatment or disposal. The agricultural community may have large quantities of pesticides which have lost their strength and need disposal.

- (iv) Limited resources.

In general, there are limited resources of finance and of skilled manpower. Skilled manpower is necessary for planning, management of facilities, operation and maintenance and for enforcement of regulations.

It is quite clear that particularly in the developing countries, the setting of priorities for dealing with the hazardous waste problem is essential. Only in this way can the limited resources be directed to those problems which are the most significant. It may be necessary to distinguish between long term solutions, which would involve the establishment of centralized treatment/disposal facilities and short term solutions which would aim at eliminating the worst of current practice. Even in the longer term, there will be a need to develop solutions which are compatible with the available resources.

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