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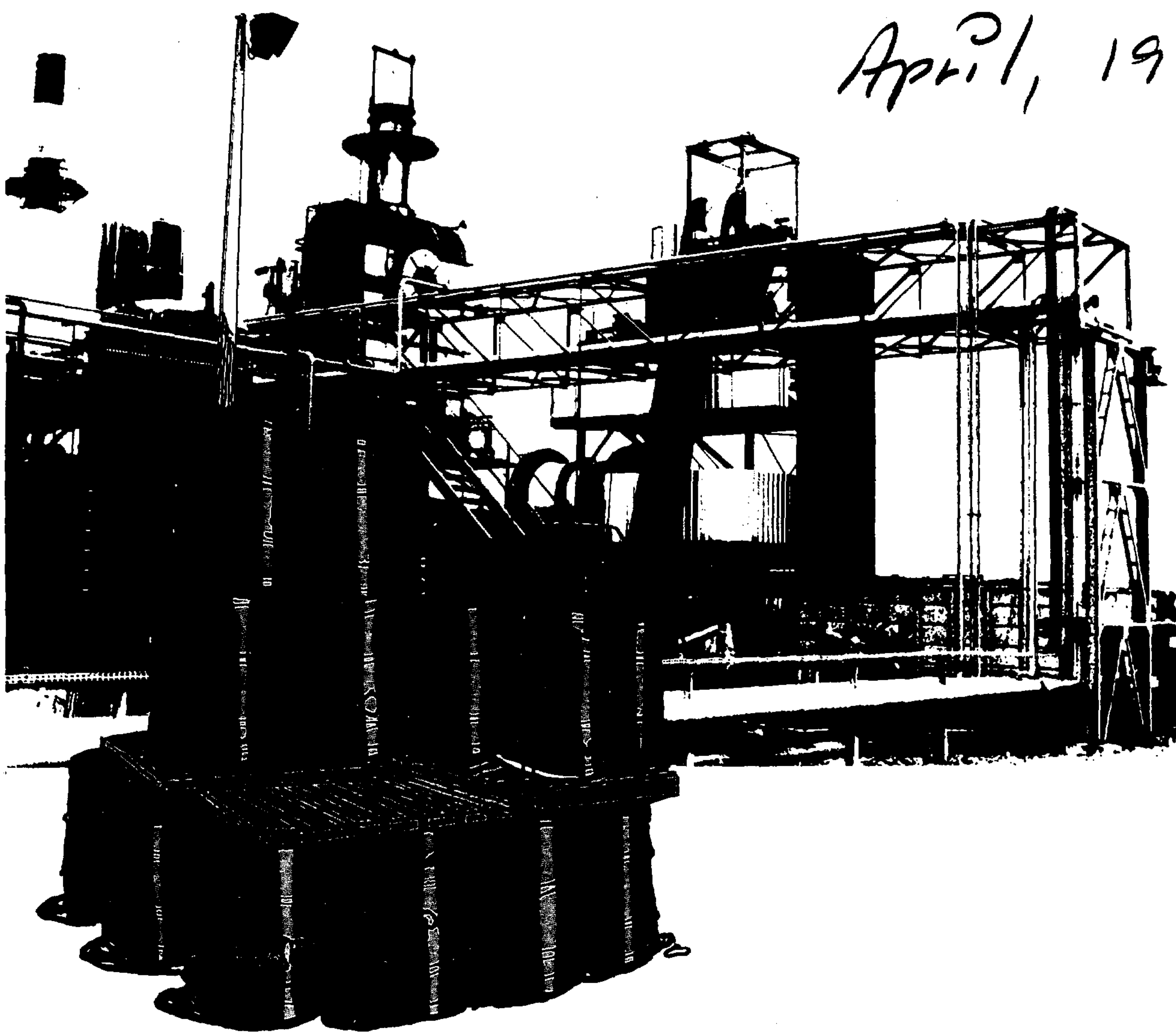
The Safe Disposal of Hazardous Wastes

The Special Needs and Problems of Developing Countries

Volume I

Roger Batstone, James E. Smith, Jr., and David Wilson, editors

April, 1989



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Volume I

A Joint Study

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World Health Organization

United Nations Environment Programme

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Volume I

Roger Batstone, James E. Smith, Jr., and David Wilson, editors

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ABSTRACT

The World Bank, World Health Organization, and United Nations Environment Programme have cooperated in the preparation and issuance of The Safe Disposal of Hazardous Wastes. This three-volume manual is intended for administrators and technical staff, primarily in developing countries, who have responsibilities for waste management, public health and environmental protection. Information presented in this publication includes the classification of hazardous waste, its effects on health and the environment, the planning and implementation of programs in hazardous waste management, hazardous waste treatment, and disposal technologies, including economic and institutional considerations.

The main emphasis of this manual is on the management aspects and on the technologies that may be appropriate for implementing a region-wide hazardous waste management program. Case studies from developing countries have been incorporated into the main text for the purpose of practical illustration. Sufficient information for at least a pre-feasibility assessment of various options for a hazardous waste management program is provided.

A particularly useful section of this manual includes the examples of various operating systems for hazardous waste tracking and disposal, waste survey questionnaires and techniques, and landfill design and management practices.

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VOLUME 3

PREFACE

The inappropriate and often careless handling of municipal and industrial wastes, including those that are hazardous, has all too often created problems worldwide for human health and the environment. Effective control of hazardous wastes is of paramount importance for proper health and environmental protection and natural resource management. Developing countries, as they experience rapid industrial growth, have a particular and urgent need to initiate programmes for hazardous waste management. To assist them in this task, the World Bank, the World Health Organization and the United Nations Environment Programme joined forces to prepare and issue these guidelines.

This three-volume manual is intended for administrators and technical staff primarily in developing countries who have responsibilities for waste management and for public health and environmental protection in general. The document should also prove to be a useful reference for similar officials in the industrialized countries, particularly at the regional and municipal levels. Chapters 1-5 contain information on the classification of hazardous waste, their effects on health and the environment, and the planning and implementation of programmes for hazardous waste management. Chapters 6 and 7 deal primarily with the hazardous waste treatment and disposal technologies, including economic and institutional considerations.

The publication provides a framework for evaluating options such as waste minimization, recycling and waste reduction, and for making decisions on whether a waste generator should handle wastes alone or in combination with other generators at a centralized facility. The full array of treatment and disposal options is presented along with the advantages and disadvantages of each. The user will find a framework for making decisions on the combination of waste handling processes appropriate to local conditions, as well as explicit directions on estimating cost and developing financing for waste handling facilities.

The publication of this manual will add to the guideline material already available from sponsoring organizations on the subject of hazardous wastes. In 1983, the WHO Regional Office for Europe and UNEP jointly issued a guideline document which sets out the principles of formulating and implementing a hazardous waste management policy. In 1985, an ad hoc working group, organized by UNEP, on environmentally sound management of hazardous wastes, adopted the Cairo guidelines on policies and legislation regarding hazardous wastes. Also in 1985, UNEP's International Register of Potentially Toxic Chemicals (IRPTC) published a Waste Management File, which contains information on treatment and disposal options for wastes containing specific chemicals. Finally, the UNEP Industry and Environment Review publishes articles on hazardous waste management regularly.

The preparation of this manual involved the active participation of over 30 scientists and waste management specialists from 12 countries. The work of these institutions and scientists was central to the successful completion of

this manual, and is greatly appreciated. Also, it should be noted that the manual, once its draft was prepared, was distributed to well over 35 experts worldwide for in-depth review, and their comments were carefully considered when finalizing the manual. The help of these reviewers is also gratefully acknowledged.

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CHAPTER 1 - Introduction

1.1 What are Hazardous Wastes?

This manual presents systems for the control, reduction, storage, treatment and disposal of those wastes that contain highly persistent elements, chemicals and compounds with attendant chronic and acute impacts on human health and the environment.

Hazardous wastes are generated from a wide range of industrial, commercial, agricultural and even domestic activities (Chapter 2). Table 1-1 illustrates the widespread distribution of hazardous wastes.

Hazardous wastes may take the form of solids, liquids or sludges. Most definitions exclude domestic solid wastes and aqueous effluents; however, a major source of hazardous wastes is from the pretreatment of effluents in order to meet water pollution controls, an example being heavy metal sludges from electroplating, sludges from treating tannery wastes, etc.

The **degree of hazard** posed by hazardous wastes varies widely. A useful distinction is between those wastes which pose a potentially high risk to human health and those wastes where the hazard is much less, but the quantities are perhaps much greater. Typical wastes in the first category might include low flashpoint flammable solvents, highly toxic pesticides or persistent chlorinated materials such as PCBs, while the latter includes such large volume mineral wastes as metaliferous slags, mine tailings, phosphogypsum or lime sludges. These distinctions are discussed further in Chapter 2.

1.2 Why are we Concerned with Hazardous Wastes?

Hazardous wastes have only come to be recognized as a priority problem over the past 10-15 years. Action to control hazardous wastes has too often been precipitated by an actual or potential environmental disaster.

- Japan was one of the first countries to introduce comprehensive hazardous waste controls, following the Minamata incident in the late 1960s when many people died from eating fish contaminated with mercury which had been discharged to the sea.

- In the UK, a high level committee had been investigating the problem of hazardous wastes for a number of years when, in February 1972, public outrage arose over the discovery of drums containing heat treatment cyanide salts on vacant land where children were playing. Ten days later legislation was enacted.

- The rigid control system on hazardous wastes in the United States which has evolved since 1976 has been driven largely by public outcry over the widespread discovery of pollution caused by past uncontrolled dumping of hazardous wastes.

TABLE 1-1

Some Illustrative Examples of Hazardous Wastes

Sector	Source	Hazardous Waste
Commerce & Agriculture	Vehicle servicing	Waste oils
	Airports	Oils, hydraulic fluids etc.
	Dry cleaning	Halogenated solvents
	Electrical transformers	Polychlorinated Bipheryls (PCBs)
	Hospitals	Pathogenic/infectious wastes
	Farms/Municipal parks etc.	Unused pesticides, "empty" containers
Small-scale industry	Metal treating (electro-plating, etching, anodizing, galvanizing)	Acids, heavy metals
	Photofinishing	Solvents, acids, silver
	Textile processing	Cadmium, mineral acids
	Printing	Solvents, inks and dyes
	Leather tanning	Solvents, chromium
Large-scale industry	Bauxite processing	Red muds
	Oil refining	Spent catalysts
	(Petrochemical manufacture)	Oily wastes
	Chemical/pharmaceutical manufacture	Tarry residues, solvent
	Chlorine production	Mercury

Note: A classification system for hazardous wastes is introduced in Chapter 2.

Hazardous wastes can cause immediate, short-term, public health problems as well as long-term environmental pollution. Proper control of hazardous wastes does cost money, but experience in a number of developed countries suggests that cleaning up the "sins of the past" is much more expensive in the long term. For instance, in the United States clean up of improperly managed wastes has been estimated to cost 10-100 times as much as proper early management. It is therefore important that all developing countries institute controls over hazardous wastes to avoid such excessive costs in the future.

Even though the definition of hazardous waste excludes domestic wastes, in many countries **it may be difficult to totally separate industrial and domestic wastes**. Developing countries will need some strategy to identify and quantify the risks posed by hazardous wastes in order to arrive at a list of priorities for action within their limited resources. Some factors affecting the degree of risk are:

- o reactivity (fire, explosion, leaching);
- o biological effect (toxicity, short and long, exotoxicity);
- o persistence (fate in environment, detoxification potential, multiple factors);
- o indirect health risks (pathogens, vectors); and
- o actual amounts and local conditions (temperature, soil, water, humidity, light, receiving systems, their use pattern, etc.).

1.3 Aspects of a Control System for Hazardous Wastes

Every country needs a national control system for hazardous waste management. Such a system must provide four vital components if it is to be successful:

- o **legislation** and **regulations**;
- o proper **implementation** and **enforcement** procedures;
- o the provision of **adequate facilities** for hazardous waste recycling, treatment and disposal and measures to encourage their use;
- o introduction of **training schemes** for government enforcement officers and plant operators and managers and/or public awareness educational programs.

All four aspects are vital to the proper working of a national control system. No matter how perfect a system may appear on paper, it is worthless if it is not enforced. Similarly, control cannot be enforced if adequate facilities are not available or if enforcement officers are not adequately trained. Thus development of legislation and provision of adequate facilities must proceed in parallel. A few general points may be made regarding the introduction of a control system:

- Good information on present quantities of waste and on present practices is essential so that priorities may be identified.

- A national strategy for hazardous waste management needs to be developed including a plan for the provision of facilities.

- A control system should encompass all aspects of hazardous waste management, from generation through storage, transport and treatment to disposal.

- All parties involved -- generators, transporters, disposers, and government -- have their role and responsibilities.

1.4 Previous International Efforts on Hazardous Waste Management

A number of international organizations have taken an interest in hazardous waste management.

- In 1983, the World Health Organization (WHO) and the United Nations Environment Program (UNEP) published policy guidelines and a code of practice, which sets out the principles of formulating and implementing a hazardous waste management policy. (Suess and Huismans 1983)

- In late 1985, an ad hoc working group on environmentally sound management of hazardous wastes meeting under the auspices of UNEP adopted the 'Cairo guidelines' on policies and legislation. (UNEP 1985)

- UNEP's International Register of Potentially Toxic Chemicals (IRPTC) published a Waste Management File in 1985, which contains information on treatment and disposal options for wastes containing specific chemicals. (IRPTC 1985)

- A workshop in May 1986 organized by ASEAN, UNEP and CDG developed guidelines for establishing policies and strategies for hazardous waste management in Asia and the Pacific. (UNEP 1986)

- The Organization for Economic Cooperation and Development (OECD) and the Commission of the European Communities (CEC) have been preparing an international convention on the transfrontier movement of hazardous wastes. Much work has focused on standardizing a list of hazardous wastes. (OECD 1988)

- The UN Economic Commission for Europe (ECE) and the Council for Mutual Economic Assistance (CMEA) have focused in particular on low-waste and non-waste technologies. (ECE 1979-1987)

Where these efforts have been of particular relevance to developing countries, the focus has generally been on formulating policies and strategies and developing legislation (ECE 1979-1987). Recently, increasing focus is being given to the dumping of hazardous wastes in developing countries where there are inadequate controls to ensure the safe disposal of their wastes.

1.5 Quantities of Hazardous Waste

Obtaining reliable information on the quantities or types of hazardous wastes produced by any country is very difficult. International comparisons are almost impossible because of differences in the classification and definition of hazardous wastes from country to country.

An attempt has been made to estimate the quantities of hazardous waste produced in different countries (Yakowitz 1985). It was estimated that for a number of western European countries, hazardous waste production is about 5,000 tons per billion US$ of gross domestic products (GDP). The figure for the USA is approximately 75,000 tons; the figure for the USA is higher because certain high volume waste water streams are included in the calculations. The corresponding figure for Canada is 10,000 tons.

On the basis of very limited data, it was assumed that waste production in the USSR could be estimated at 10,000 tons per billion US$ GDP, that in other countries with mature industry at 5,000 tons, in newly industrialized countries 2,000 tons and in developing countries 1,000 tons.

Such estimates can at best indicate relative orders of magnitude of hazardous waste production in different countries. Figure 1-1 summarizes the numbers of countries within each of four "bands" of likely hazardous waste production, namely less than 10,000 tons per annum (tpa) 10-100,000 tpa, 100,000 - 1 million tpa and more than 1 million tpa.

From these estimates it appears that around two-thirds of all countries produce less than 10,000 tpa of hazardous wastes. For many developing countries the estimates are in the range of a few hundred or a few thousand tons. While this puts the overall problem in context, it should be remembered that a single heavy industrial plant can produce hundreds of thousands of tons per annum of bulk wastes, although most of these are in the 'grey' region between hazardous and non-hazardous wastes.

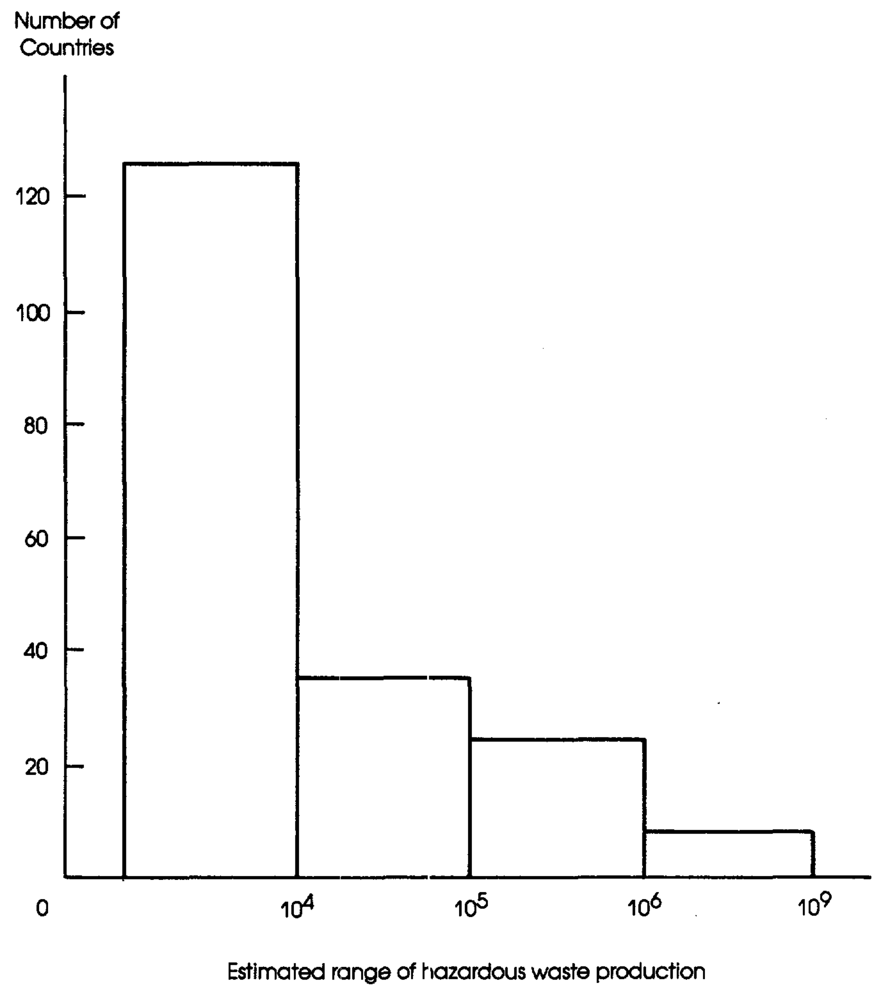
1.6 Progress in Controlling Hazardous Wastes

Considerable progress has been made over the last 10 years in controlling hazardous wastes in a number of developed countries (Forester and Skinner 1987). Progress varies considerably from country to country, but in some countries:

- effective legislation is in place;
- effective manifest systems are being introduced to control waste transport;
- an increasing percentage of operators of hazardous waste treatment and disposal facilities have been licensed;
- in some cases, well engineered and well managed facilities have been provided for hazardous waste treatment, incineration, and landfill is controlled;

FIGURE 1-1

Order of Magnitude of Hazardous Waste Production in Individual Countries



- in a few cases, good collection and transfer systems have been established.

Hazardous waste disposal is a dynamic problem, and there is on-going work in these countries on standards and licensing procedures. Present priorities vary depending on the stage of development and implementation of the control systems.

- In those cases where the process is only just beginning, an effective system is a priority (1.8).

- In other places, continuing implementation of regulations and provision of adequate facilities, either for landfill or for treatment of hazardous wastes, or both, are seen as high priorities.

- In a number of countries it is not the absence of facilities that presents a problem, but rather competition between landfill and treatment facilities. Landfill tends to be less expensive than waste treatment, so that given a free market, landfills tend to predominate, even though treatment would be better for environmental reasons. In these cases government control of competition is necessary.

- Almost all countries see a need to improve enforcement of and compliance with the regulations that are in place.

1.7 Specific Problems of Developing Countries

Developing countries face a number of specific problems in tackling hazardous wastes.

(i) General control over pollution and waste disposal is often poor

In many countries open dumps predominate, and in the absence of controls hazardous wastes continue to find their way into such dumps. Scavengers may live and work among the wastes, and many dumps are already causing water pollution. Proper management of dumpsites is a high priority in developing countries.

Controls over water and air pollution are often poor, and when such controls are implemented, the treatment sludges and dusts are often hazardous wastes.

Isolated efforts to control specific hazardous wastes are often ineffective without an overall upgrading of waste management practices. Coordination of controls over air and water pollution and hazardous waste is particularly important.

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

Ignorance of the potential harm of hazardous wastes is encountered in all countries, but it is a particular problem among small generators in developing countries. Even though the quantities they produce may be small, the potential problems are not insignificant. For example, the improper disposal of surplus pesticides or pesticide containers may poison humans or pollute sensitive ground water resources. (See Annex 7.1B)

(iii) Stockpiles of waste awaiting treatment or disposal

In some countries, new industries may stockpile their waste on site in the absence of proper facilities for treatment or disposal. After 5, 10 or 15 years space begins to run out or pollution problems arise, and suddenly the problem becomes urgent.

(iv) Limited resources

Some developing countries lack the financial resources and skilled manpower to adequately dispose of hazardous waste. Restrictions on foreign exchange and limited access to hard currencies make it difficult to finance such facilities. A shortage of skilled manpower will impede planning, management, operation and maintenance of facilities, and enforcement of regulations.

(v) Socio-political reasons

Without public education on the issues and a general awareness of the dangers of improper disposal of hazardous waste there is too often insufficient public demand for action. Developing countries may focus on other very real and seemingly more urgent problems and not see hazardous waste disposal as a pressing need and immediate political goal.

Developing countries need to set priorities in controlling hazardous wastes. The available resources must be focused on the most significant problems and short-term solutions implemented to bring immediate problems under control.

It may be necessary to distinguish between long-term solutions, which may involve the establishment of centralized treatment/disposal facilities and short-term solutions which aim to eliminate the worst current practices.

Even in the longer term, there will be a need to develop solutions which are compatible with the limited resources available. Such 'appropriate' solutions are required particularly for small quantities of waste or for those wastes which would appear on the agenda for action.

1.8 Purpose of this Manual

The World Bank, WHO and UNEP have each identified the need for guidance on the assessment and planning aspects of hazardous waste management, with specific reference to developing countries. Among the topics discussed in this manual are the following:

- setting priorities for control;
- establishing an appropriate definition and classification scheme;

- developing a plan to provide the necessary facilities for waste treatment and disposal;

- choosing a short-list of options for treatment and disposal appropriate to the needs of specific countries;

- the economics and financing of facilities.

The manual is aimed at meeting the needs of three distinct but overlapping target audiences.

(i) The first is the most senior technical level within government and industry in developing countries. The aim is to provide sufficient information to enable them to undertake a study of the needs and requirements of their own country, region or community, and to select a short list of potential options for more detailed examination.

(ii) Within funding organizations, the manual will be used to assist in the identification, preparation and appraisal of countrywide hazardous waste management programs and 'stand alone' projects.

(iii) It is envisaged that the manual will form the basis for national and international training courses aimed both at senior and middle management levels within government and industry in developing countries.

1.9 Guide to this Manual

The remaining chapters in the manual are outlined briefly below.

- **Chapter 2** gives a review of health and environmental effects, which aims to give guidance on setting of priorities, and examines the difficult questions of defining and classifying hazardous wastes. A practical classification scheme, which can be adapted to the needs of a particular country, is outlined.

- **Chapter 3** provides a framework for developing a national, regional or local plan to provide the necessary facilities for recycling, treating or disposing of hazardous wastes.

- **Chapter 4** examines methods for waste avoidance, reduction at source, recovery, recycling and reuse.

- **Chapter 5** gives details of the infrastructure required for establishing a hazardous waste management system as well as addressing economic, financial and institutional arrangements.

- **Chapter 6** includes a discussion of the choice of appropriate recycling and treatment technologies.

- **Chapter 7** provides information on final disposal options.

1.10 References 1.1 - 1.9

Economic Commission for Europe. 1979-1987. 161 Monographs on low-and non-waste technologies. Geneva: International Environment Bureau.

Forester, W. S., and J. H. Skinner, eds. 1987. International Perspectives on Hazardous Waste Management. London: Academic Press.

International Register of Potentially Toxic Chemicals. 1985. Treatment and Disposal Methods for Waste Chemicals. Geneva: United Nations Publications, Palais des Nations.

Organization for Economic Cooperation and Development (OECD). 1988. Decision of the Council of Transfrontier Movements of Hazardous Wastes. Document C (88) 90. Paris.

Suess M. J., and J. W. Huismans, eds. 1983. Management of Hazardous Waste - - Policy Guidelines and Code of Practice. European Series No. 14. Washington, D. C.: WHO Regional Publications. (Available in English, French, Russian, Spanish, Chinese and Italian.)

United Nations Environment Programme (UNEP). 1985. Principles for the Environmentally Sound Management of Hazardous Wastes ("The Cairo Guidelines"). Nairobi: UNEP

UNEP. 1986. Guidelines for Establishing Policies and Strategies for Hazardous Waste Management in Asia and the Pacific. Bangkok: UNEP Regional Office.

Yakowitz, H. 1985. Background information concerning hazardous wastes in non-OECD countries, unpublished. Paris: OECD.

CHAPTER 2 - The Health and Environmental Effects of Hazardous Wastes

2.1 Introduction

In the last few years, considerable attention has focused on the question of what constitutes a "hazardous waste." National systems differ both in the methods used for defining wastes and the type of wastes included. These differences arise partly from variations in the institutional and legal frameworks of different countries.

International organizations like the OECD and CEC are currently attempting to establish a cross-reference list of hazardous wastes, as a first step towards harmonization of definitions. The main concern, at present, is to implement stricter controls over the transfrontier movement of hazardous wastes.

For the purpose of this manual, however, we are more concerned with evolving a practical definition of hazardous waste, which can then be adapted to the legal system of any particular country.

Equally important, the possible health and environmental effects of hazardous wastes must be understood and dealt with. In order to do this, we need to understand the chemical and physical properties of hazardous wastes and their potential pathways through ecosystems to man.

Subsequent sections of this chapter consider the following:

- a working definition of the terms "waste" and "hazardous waste";
- broad types of waste which should be included within the scope of "hazardous wastes," and those which should be excluded;
- approaches to the identification and classification of hazardous wastes, which can be used to give a proper working definition;
- details of our proposed classification scheme;
- factors affecting the environmental behavior of chemicals;
- a detailed discussion of the effect of hazardous wastes on human health;
- categorizing hazardous wastes by degree of hazard; and
- environmental effects of hazardous waste disposal.

2.2 Working Definitions

Typically, the concept of "waste" refers to something which no longer has any further value or use.

This definition, however, has been complicated by the issue of wastes versus products; in other words, if a waste can be recycled or can be used in some way, it has acquired value and is no longer considered a waste. This, in turn, requires a definition of what is recyclable. There is some evidence that relaxation of controls for recyclable wastes may increase the risk of environmental damage resulting from the mismanagement of recyclable wastes. Examples of such mismanagement abound and include the use of contaminated waste oil for dust control; the long-term, uncontrolled storage of materials pending recycling; using metaliferous wastes as building or road construction materials; or using wastes as fuel substitutes, burning them under uncontrolled conditions.

For these reasons, the definition of waste adopted in this manual makes little reference to recycling and does not suggest that any relaxation of controls be considered for recyclable wastes.

A waste is thus defined as a moveable object which has no direct use and is discarded permanently.

All wastes must receive proper treatment and disposal so as to protect the environment and enhance the quality of life. Hazardous wastes are a special category of wastes which, due to their toxicity, persistence, mobility, flammability, etc., require more stringent regulatory and technical controls when compared to wastes such as municipal refuse. Later in this chapter, the range of possible health and environmental problems that can arise because of the improper management of hazardous wastes are discussed.

The following definition of hazardous wastes was prepared under UNEP auspices by the Ad Hoc Working Group of Experts on the Environmentally Sound Management of Hazardous Wastes in December 1985:

"Hazardous wastes means wastes other than radioactive wastes which by reason of their chemical reactivity or toxic, explosive, corrosive or other characteristics causing danger or likely to cause danger to health or the environment, whether alone or when coming into contact with other wastes, are legally defined as hazardous in the State in which they are generated or in which they are disposed of or through which they are transported."

2.2.1 Inclusions and Exclusions from the Definition

Thus defined, hazardous wastes can include solids, liquids, gases, sludges, containerized gases or contaminated containers, and can originate from a wide range of commercial, agricultural, and industrial sources. In general, hazardous wastes cannot be handled safely and effectively by the existing wastewater treatment or domestic waste disposal systems.

A number of specific exclusions are mentioned within the definition:

- Radioactive wastes are considered hazardous, but are excluded from the definition, since most countries control and manage these material in a separate organizational framework;

- Domestic refuse can cause significant environmental pollution and may also contain small quantities of hazardous substances (e.g., mercury from dry cell batteries, solvents from paint residues, etc.). Again, these wastes are normally controlled by a separate, though interrelated, organizational framework. However, some countries with well developed control systems are now turning attention to separating and/or eliminating the hazardous components in domestic waste.

The UNEP Working Group also gave consideration to the quantity of waste:

- For small quantities, all countries have chosen to exclude "hazardous wastes" from household waste. At the same time, some countries also exclude small generators of hazardous waste as well. The cutoff point for regulation is important. The United States, for example, recently reduced the threshold for control from 1000 kg/month to 100 kg/month, thereby increasing the number of regulated generators of hazardous waste by tenfold;

- For large quantities, regulators may wish to control wastes containing relatively low concentrations of pollutants, since the volume will still render them hazardous to the environment. However, because of the practical problems in implementing controls over such wastes, some countries exclude certain large volume wastes, such as mining or agricultural wastes, from control under hazardous waste legislation.

As mentioned above, most countries choose to control waste-water effluents separately from hazardous wastes. However, in the United States, wastewater stored or treated in surface impoundments, settling ponds, lagoons, etc. is controlled within the regulations governing the management and handling of hazardous wastes. The reason for this is simple: there is growing concern that such effluents contain hazardous substances that can leave with the wastewater stream percolating into groundwater reservoirs or appearing in sludge which may later be landfilled in municipal dumps or other areas not equipped to handle potentially toxic or hazardous material. This is another factor contributing to the large amounts of toxic waste reported for the US (See Chapter 1, Section 1.5).

Wastes listed in Annex 2 are considered hazardous according to current standards and knowledge. This list, however, is not static and has evolved over time, as more toxicological, and other data, have been gathered on the health effects of various wastes, particularly chemical wastes.

2.3 Identification and Classification of Hazardous Wastes

In developing an organized approach to hazardous waste assessment and management, a system of waste identification and classification must be formulated (see Table 2-1). In many countries, such a system is an integral part of a legal definition of hazardous waste. Most countries have used a definition based on an inclusive listing of the following factors:

- particular types of hazardous wastes;
- industrial processes from which the wastes are defined as hazardous; and
- substances, either specific or classes, the presence of which is indicative of a potential human health and or environmental hazard.

TABLE 2-1

A Proposed Waste Classification Scheme

Industrial/Waste Groups	Agriculture Forestry and Food Production A	Mineral Extraction B	Energy Generation C	Metal Manufacture D	Manufacture of Non-metal Mineral Products E	Chemical & Related Industries F	Metal Goods Engineering and Vehicle G
I Inorganic Wastes							
Acids and Alkalis	x		x	x		x	x
Cyanide Wastes				x			
Heavy Metal Sludges and Solutions				x	x	x	x
Asbestos Wastes					x	x	
Solid Residues n.o.s.				x		x	x
II Oily Wastes							
III Organic Wastes							
Spent Halogenated Solvents						x	x
Non-halogenated Solvent Wastes	x					x	x
PCB Wastes						x	x
Paint and Resin Wastes						x	x
Biocide Wastes	x				x	x	x
Organic Chemical Residues			x	x		x	
IV Putrescible Organic Wastes	x					x	
V High Volume/Low Hazard Wastes		x	x			x	
VI Miscellaneous Wastes							
Infectious Wastes	x						
Laboratory Wastes						x	
Explosives Wastes						x	x

Note: n.o.s. = not otherwise specified

TABLE 2-1 (continued)

A Proposed Waste Classification Scheme

Industrial/Waste Groups	Textile Leather and Timber Industries H	Manufacture of Paper Printing and Publishing J	Medical and Other Health Services K	Commercial Personal Services L
I **Inorganic Wastes**				
Acids and Alkalis	x	x		
Cyanide Wastes				
Heavy Metal Sludges and Solutions	x			
Asbestos Wastes				
Solid Residues n.o.s.				
II **Oily Wastes**	x			
III **Organic Wastes**				
Spent Halogenated Solvents	x			x
Non-halogenated Solvent Wastes	x	x		
PCB Wastes				
Paints and Resin Wastes	x	x		
Biocide Wastes	x	x		
Organic Chemical Residues n.o.s.				
IV **Putrescible Organic Wastes**	x			
V **High Volume/Low Hazard Wastes**				
VI **Miscellaneous Wastes**				
Infectious Wastes			x	
Laboratory Wastes			x	
Explosives Wastes				x

Note: n.o.s. = not otherwise specified

In some cases, a listing of one or more of these criteria is used as a definition. In other cases, reference is also made to a particular concentration level for each hazardous substance.

Other criteria may include the toxicity of an extract of the waste, usually obtained by means of a specific leaching test. Toxicity is generally defined by reference to concentrations of specific substances in the extract:

- o the ignitability or flammability of the waste;
- o the corrosiveness of the waste; and
- o the reactivity of the waste.

Each of these approaches have their advantages and disadvantages. The use of inclusive lists provides a relatively simple approach, requiring no testing and also give a certain flexibility to the waste controlling authorities in making qualitative judgements with respect to an individual waste disposal option. It has the disadvantage, however, of placing the burden of decision on the waste controlling authorities as to which of the industrial process wastes should be controlled.

Supplementing (or replacing) such lists with testing procedures and/or concentration limits has the advantage of presenting a clear and accurate description of wastes, theoretically leaving no doubt as to whether the waste should be classified as hazardous or not. These precise definitions, however, require detailed testing protocols and a surveillance system which, in practice, may pose problems as regards manpower, laboratory facilities, etc. for both waste generators and controlling authorities.

The U.S. Toxicity Characteristic Leaching Procedure (TCLP) is designed to identify wastes likely to leach hazardous concentrations of toxic constituents into the groundwater as a result of improper management. During the procedure, constituents are extracted from the waste in a manner designed to simulate the leaching actions that occur in landfills. The extract is then analyzed to determine if it possesses any of the toxic contaminants listed in Table 2-2. If the concentrations of a particular toxic constituent exceeds the level listed in Table 2-2, the waste is classified as hazardous.

In the TCLP test (Federal Register 1986) , a 100 gm sample is employed. For wastes containing less than 0.5% solids, the waste--after filtration through a 0.6-0.8 um glass fiber filter, is defined as the TCLP extract. Separation is accomplished with pressures of up to 50 psi. The particle size of the solid phase is reduced, if necessary, to a size of about 9.5 mm. The sample is then weighed and extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. If the sample after mixing with distilled deionized water has a pH <5.0, the extraction fluid is made by adding 5.7 ml of 1.0 N Glacial acetic acid to 500 ml of distilled deionized water, adding 64.3 ml of 1.0 N NaOH and diluting to a liter. If the sample after mixing with distilled deionized water has a pH >5.0, add 3.5 ml 1.0 N HCl, slurry for 30

TABLE 2-2

Toxicity Criteria

Contaminant	MCL (ppm)
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium (total)	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0
Endrin	0.02
Lindane	0.4
Methoxychlor	10.0
Toxaphene	0.5
2,4-D	10.0
2,4,5-TP Silvex	1.0

seconds, cover with a watchglass, heat to 50 degrees C and hold for 10 minutes. If the sample after cooling has a pH <5.0, the extraction fluid previously described is used. If the pH is >5.0, the fluid is made by diluting 5.7 ml glacial acetic acid with distilled deionized water to a volume of 1 liter. A special extractor vessel is used when testing for volatiles. Following extraction, the liquid extract is separated from the solid phase by 0.6-0.8 um glass fiber filter filtration.

If compatible, the initial liquid phase of the waste is added to the liquid extract and these liquids are analyzed together.

The characteristic of ignitability/flammability is a concern because these wastes could cause fires during transport, storage or disposal. Typical examples are waste oils and used solvents. These wastes often have the properties of:

(a) being a liquid, except for aqueous solutions containing less than 24% alcohol, that has a flash point less than 60 degrees C;

(b) a non-liquid capable, under normal conditions, of spontaneous and sustained combustion;

(c) an ignitable compressed gas; or

(d) an oxidizer.

Materials that might be considered hazardous because of corrosivity are: an aqueous material with pH <2.0 or pH >12.5; or a liquid that corrodes steel at a rate greater than one-quarter inch per year at a temperature of 55°C. Wastes with high or low pH can react dangerously with other wastes or cause toxic contaminants to migrate from certain wastes. Wastes capable of corroding steel can escape from their containers and liberate other wastes. Examples of such corrosive wastes include acidic wastes and used pickle liquor.

A reactive waste might be expected to have one or more of the following properties:

(a) normally unstable and reacts violently without detonating;

(b) reacts violently with water;

(c) forms an explosive mixture with water;

(d) generates toxic gases, vapors or fumes when mixed with water;

(e) contains cyanide or sulfide and generates toxic gases, vapors, or fumes at a pH of between 2 and 12.5;

(f) is capable of detonation if heated under confined conditions or subjected to a strong initiating force; and

(g) capable of detonation at standard temperature and pressure. Examples of reactive wastes include water from TNT operations and used cyanide solvents.

The choice of the most appropriate system depends upon the use to which the classification system will ultimately be put. For the purpose of this manual, three objectives are considered of particular importance:

- to allow the waste controlling authority to use its knowledge of industry to draw up a short-list of wastes;
- to identify wastes in a way that is consistent with the discussion of technologies for recovery, treatment and disposal; and
- to provide the waste controlling authority with a framework appropriate for establishing their own hazardous waste control system.

To achieve these objectives, the classification scheme proposed here is a qualitative listing, using a combination of some specific types of waste with classes of substances specific substances and industrial processes to identify waste types.

2.4 Proposed Classification Scheme--Notation of Health/Ecological Concerns

A proposed waste classification scheme linking waste types to industrial categories is shown in Annex 2. The purpose of the annex is to enable planners to identify the major types of wastes associated with broad industrial groups. The industrial groups used for the waste classification scheme are defined in Table 2-3.

Further details of each waste type including examples of particular waste streams are included in Table 2-1. These listings are examples of the most important waste streams likely to be encountered.

A brief description of each waste type including major subcategories and sources of generation, is given below.

(A) Inorganic Wastes

Acids and alkalis are among the major components of the total amount of hazardous waste generated. They occur in many sectors of industry, although in terms of quantity, acid wastes come mainly from the surface preparation and finishing of metals.

The major hazard with acids and alkalis is their corrosive action, complicated--in some cases--by the presence of toxic constituents.

Cyanide wastes are generated primarily in the metal finishing industry and in the heat treatment of certain steels.

The principal hazard associated with cyanide waste is their acute toxicity.

TABLE 2-3

<u>Industrial Groups</u>

A Agriculture, Forestry and Food Production

- o agriculture, forest management, fisheries;
- o animal and vegetable products from the food sector;
- o drink industry;
- o manufacture of animal feed.

B Mineral Extraction (excluding Hydrocarbons)

- o mining and quarrying of non-metallic minerals;
- o mining and quarrying of metallic minerals.

C Energy

- o coal industry, including mineral extraction, gasworks and coking;
- o petroleum and gas industry including oil and gas extraction, and refined products;
- o production of electricity;
- o production of water;
- o distribution of energy.

D Metal Manufacture

- o ferrous metallurgy;
- o non-ferrous metallurgy;
- o foundry and metal working operations.

E Manufacture of Non-Metal Mineral Products

- o construction materials, ceramics and glass;
- o salt refining;
- o asbestos goods;
- o abrasive products.

F Chemical and Related Industries

- o petrochemicals;
- o production of primary chemicals and chemical feedstocks;
- o production of inks, varnish, paints and glues;
- o fabrication of photographic products;
- o perfume industry and fabrication of soap and detergent products
- o finished rubber and plastic materials;
- o production of powders and explosives;
- o production of biocides.

TABLE 2-3 (continued)

Industrial Groups

G	**Metal Goods, Engineering and Vehicle Industries** o mechanical engineering; o manufacture of office machinery and data processing of equipment; o electronic and electrical engineering; o manufacture of motor vehicle and parts; o manufacture of other transport equipment; o instrument engineering; o other metal good manufacturing industries n.o.s.
H	**Textile, Leather, Timber and Wood Industries** o textile, clothing and footware industry; o hide and leather industry; o timber, wood and furniture industry; o other non-metallic manufacturing industries n.o.s.
J	**Manufacture of Paper and Products, Printing and Publishing** o paper and cardboard industry; o printing, publishing and photographic laboratories.
K	**Medical, Sanitary and other Health Services** o health; hospitals, medical centres and laboratories; o veterinary services.
L	**Commercial and Personal Services** o laundries, dyers and dry cleaners; o domestic services; o cosmetic institutions (e.g., hairdressers); o other personal services n.o.s.

Heavy metal sludges and solutions of most concern are those containing the toxic metals, arsenic, cadmium, hexavalent chromium, lead, mercury, nickel, zinc, and copper. These wastes are generated from a wide range of manufacturing processes, including chlorine production, pigment production, wood preserving, battery production, textiles, metal plating and tanning.

Asbestos wastes normally arise from lagging wastes, power stations, industrial manufacturing plants, gas works, dock yards, hospitals and educational establishments. Materials containing asbestos may also appear as waste from the demolition or rebuilding of locomotives and railway carriages, and from building and demolition sites.

The health hazards associated with inhalation of asbestos fibers and dust stem from the carcinogenic potential of the material. Asbestos cement pipes and sheets are typically much less of a problem than loose fibers or dust.

Other solid residues are generated from a variety of sources of which the most significant is the smelting and refining of metals. Dusts and sludges generated from these processes typically contain toxic metals including nickel, arsenic, zinc, mercury, cadmium and lead.

(B) Oily Wastes

Oily wastes are generated primarily from the processing, use and storage of mineral oils. Examples include waste lubrication and hydraulic fluids, bottom sludges from oil storage tanks, waste cutting oils and interceptor waste. In some cases, these materials may be contaminated with toxic metals (e.g. sludges from leaded petrol storage tanks, etc.).

(C) Organic Wastes

Halogenated solvents are generated primarily from dry cleaning operations, metal cleaning in the engineering industry and, to a much smaller extent, from degreasing and deoiling processes in the textile and leather industries. The hazards associated with these wastes are a result of their toxicity, mobility, and relatively high persistence in the environment.

Non-halogenated solvent wastes include a large number of hydrocarbons and oxygenated hydrocarbons, of which some of the most commonly used are white spirit, toluene, methanol, isopropanol, and ethanol. They find wide application throughout industry in the production of paints, inks, adhesives, resins, solvent-based wood preservatives, toiletries, food flavorings, cosmetics, and also for plant and equipment cleaning and as thinners. They are also used as degreasants in the engineering and vehicle manufacturing industries and are used for the extraction of natural products from animal and vegetable sources.

The toxicity of these materials varies greatly, and in many cases the major hazard posed is flammability.

PCB wastes are generated from the manufacture of PCBs and from the decommissioning of equipment in which PCBs are used, principally as dielectric fluids in transformers and capacitors, and also as hydraulic fluids and heat transfer fluids. The major concerns with PCBs is associated with their high persistence and bioaccumulation potential.

Paint and resin wastes are generated from a variety of formulation and other tertiary chemical processes, and also in the application of paints and resins to finished products. They are typically combinations of solvents and polymeric materials including, in some cases, toxic metals.

Biocide wastes are generated both in the manufacture and formulation of biocides and in the use of these compounds in agriculture, horticulture and a variety of other industries. The range of biocides used runs into several thousand compounds. (For information on their classification, see Annex 2).

In addition to the concentrated organic waste streams described above, organic chemical residues are also generated from coal carbonization and by-products operations; and from the manufacture or primary, secondary, and tertiary chemical products. Distillation residues and filter materials are common components. These waste streams include both halogenated and non-halogenated chemicals, and are generated by a broad range of industries, including petroleum refining and the manufacture of chemicals, dye stuffs, pharmaceuticals, plastics, rubbers, and resins.

(D) Putrescible Organic Wastes

Putrescible organic wastes include wastes from the production of edible oils, as well as leftovers from slaughter houses, tannaries, and other animal-based products. The proper handling of putrescible wastes is of particular importance in developing countries where extreme climatic conditions can exacerbate the possible health hazard associated with these organic wastes.

(E) High Volume/Low Hazard Wastes

High volume/low hazard wastes include those wastes which, based on their intrinsic properties, present relatively low hazards, but may pose problems because of their high volumes. Examples include: drillings muds from petroleum and gas extraction, and fly ash from fossil fuel-fired power plants, mine tailings, or metaliferous slags.

(F) Miscellaneous Wastes

In addition to the waste classes described above, there are a number of other miscellaneous waste types which have not been addressed. These include: infectious wastes associated with diseased human or animal tissues; redundant chemicals, which may have deteriorated or exceeded their shelf-life, and come from retail shops, commercial warehouses, and governmental and industrial stores; laboratory wastes from manufacturing and research facilities; and explosive wastes from manufacturing operations or surplus munitions. Although these wastes typically do not represent a large proportion of total hazardous waste generation, special provision should be made to ensure their safe and proper disposal.

2.5 Potential Pathways of Release to the Environment

The potential pathways by which hazardous wastes can enter the human environment are summarized in Figure 2-1. Some pathways correspond to a direct input to an environmental compartment, such as the evaporation of a chemical to the atmosphere. Other pathways represent indirect inputs, such as the atmospheric deposition of wind-borne particulate matter to surface waters. The relative importance of each pathway is not only dependent on the physical, chemical, and biological properties described earlier but also on the characteristics of both the disposal site and the underlying geology.

2.5.1 Groundwater Movement and Contamination

The characteristics of the subsurface environment have a major influence on the aqueous transport of chemical contaminants and micro-organisms from disposal sites. Of particular importance is the presence of an unsaturated zone beneath the land disposal site. This is the zone, above the water table, where water generally moves vertically until it encounters the groundwater flow (when the movement becomes horizontal). It is an advantage to have an unsaturated zone beneath the landfill because this severely restricts leachate movement from the site and therefore increases the opportunity for attenuation by chemical and biochemical processes.

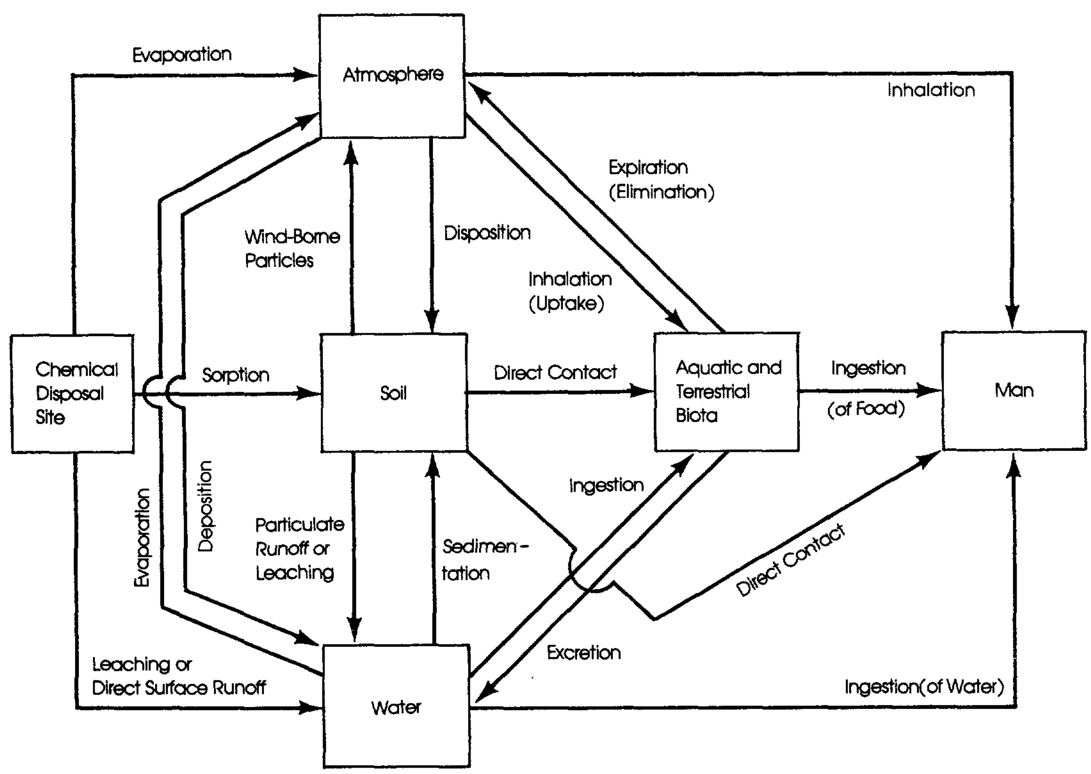
In recent years much attention has been paid to the transport of contaminants, particularly organic compounds, in the saturated zone. It is important to note that some chemicals will dissolve/dilute in water, while others--with low chemical solubility--will lead to compounds that are called "floaters." It has been found that some organic solvents can migrate through the sub-surface environment, particularly those with a lower density than water. Appropriately, the "floaters" spread across the top of the water table. By contrast, dense organic liquids, called "sinkers," migrate vertically down the aquifer. Contaminant flow rates in the saturated zone are highly variable and depend to a large extent on the characteristics of the aquifer. Transport times are generally shorter in a sand aquifer than a clay one, but transport can be more rapid in the latter if the clay is fractured. The actual time scales regarding the movement of contaminants out of a waste site are generally very long. It can take decades for a contaminant to migrate from a disposal site to nearby drinking wells. Once the chemical appears in the well water, however, it may remain there, in elevated amounts, for many years, even if remedial action is taken at the disposal site. Furthermore, the arrival of one pollutant in well water may signal the arrival of dozens more contaminants, entering the water over the course of many years.

2.5.2 Surface Water Contamination

Open water bodies near to disposal sites can receive hazardous wastes directly from surface runoff. In addition, the groundwater flow of

FIGURE 2-1

Physical and Biological Routes of Transport of Hazardous Substances, their Release from Disposal Sites, and Potential for Human Exposure



chemicals may also lead to inputs of contaminants to surface waters. Aerobic conditions, which generally prevail, can facilitate the chemical and biological degradation of organic compounds, while volatilization will also be more pronounced in surface waters than in groundwater. One must be concerned about bioaccumulation and the toxicity of some wastes--at low concentrations--to fish and other aquatic biota.

2.5.3 Other Pathways of Release

Those organic compounds with a high vapor pressure will show a tendency to be released to the atmosphere from disposal sites. The vaporization rates of chemicals from buried wastes in landfill sites are much smaller than when wastes are spread over the land, or placed in surface impoundments. Nevertheless, the quantities of volatile wastes lost to the atmosphere at landfill sites can be very large on an annual basis. Fires at disposal sites will lead to an increase in the vaporization of volatile compounds.

Wind-blown dispersal is another potential pathway of release to the environment (affecting people through inhalation). Certain solid wastes, asbestos for example, are particularly susceptible to wind-blown dispersal. The mobilization of contaminated soil or the contaminants themselves may be a particular problem at poorly managed sites, or where remedial activities require the use of many large vehicles.

It is conceivable that vegetation growing on land near waste sites, or on rehabilitated (former) landfill sites, will take up hazardous chemicals via root absorption either from contaminated soil or from the waste itself. Some chemicals may be translocated from the roots to the upper parts of the plant. The deposition of wind-blown contaminated soil particles onto the surface of the plant is another potential exposure pathway (particularly for vegetation growing in the vicinity of poorly managed landfills.

2.6 Factors Affecting the Environmental Behavior of Chemicals

This section describes the major physical, chemical, and biological processes which can affect the environmental behavior of hazardous chemicals at waste disposal sites. Reference will be made to a variety of chemicals.

Most attention is paid in this section to the behavior of chemicals at land disposal sites as these are the predominant methods of hazardous waste disposal. The wastes encountered at these sites can be complex mixtures of organic and inorganic hazardous chemicals in combination with other non-hazardous wastes. Such wastes can be in the form of solids, sludges or liquids or mixtures of all three. Major environmental risks include the leaching of chemicals and subsequent contamination of water sources as well as release to the air. In this respect, the geology and hydrogeology of the site, as well as local climatic conditions, are all important factors which influence the behavior of hazardous waste.

2.6.1 Physical and Chemical Factors

A number of physical and chemical factors are important in determining the behavior of chemicals in the environment. They are:

- Leaching;
- Adsorption/Desorption;
- Volatilization; and
- Bioaccumulation, etc.

These factors can act in a complex and interrelated series of reactions which may themselves be dependent on the geochemical characteristics of the disposal area.

Generally, the higher the water solubility of a compound, the greater the potential for leaching from the landfill site. Many hazardous organic compounds display low water solubilities. However, the presence of partially water miscible solvents, such as chloroform, can enhance the leaching of organic compounds from landfill sites, as can the formation of emulsions. Many inorganic chemicals ionize on contact with water to produce dissolved ions. In the case of trace metals, solubility is controlled mainly by speciation, but it can be further reduced by adsorption and ion exchange. In some cases, the metal can form complexes which enhance solubility. Cyanide may also enhance the solubility of trace metals. The fatty acids produced by bacterial degradation of domestic wastes can also form soluble complexes with metals.

The adsorption of compounds onto soil particles or waste material is an important phenomenon which tends to restrict the movement of both organic and inorganic chemicals from the landfill site. In addition, the process of adsorption maybe an important factor in retarding the migration of oil wastes. The soil adsorption coefficient of a chemical describes its potential for binding to soil particles. For organic compounds it appears that the partitioning between water and organic carbon is the most important factor. A compound with a low soil adsorption coefficient will generally tend to migrate from the landfill site. For example, phenol is not only highly water soluble but also has a low soil adsorption coefficient; these characteristics are reflected by rapid leaching of phenol in many landfill sites.

Volatilization, as noted previously, is a potential route by which hazardous wastes migrate out of landfills. This phenomenon may be particularly important for certain organic compounds and can occur at a significant rate for chemicals such as chloroform, which have a high vapor pressure. Conversely, leaching can be expected to be more important for those chemicals with a low vapor pressure, particularly if the compound also has a low soil adsorption coefficient. It should be stressed that factors other than the vapor pressure, such as the diffusion coefficient, can also have an important influence on the transport of compounds in a landfill. For example, disposal site characteristics such as temperature, soil moisture, and soil pH, as well as the water solubility of the compound, all influence the extent of volatilization. Thus, the elevated temperatures encountered at many disposal sites--the product of microbial activity--will enhance the upward movement and evaporation of many volatile organic compounds. Nevertheless, the downward migration of these compounds has still been found to be important, particularly when large quantities are disposed of, as occurs for waste solvents.

Some chemicals, like methylene chloride and ethylene dichloride, have high vapor pressures and high solubilities and thus can be lost by leaching and volatilization.

For organic compounds, the octanol/water partition coefficient 'P' is often used as an index of the bioaccumulation potential for a chemical in the aquatic environment. This coefficient is somewhat correlated with a compound's molecular weight. Thus, a chemical such as DDT, which has a high P value, displays a marked potential for bioaccumulation in aquatic organisms. This coefficient is also proportional to the soil adsorption coefficient, although not linearly, reflecting the importance of the soil organic matter in the adsorption of organic compounds. Therefore, this coefficient also provides an insight into the importance of a compound's ability to bind with soil particles. This is of particular relevance for particle transport from the landfill site, either by wind-blown dispersal, or by runoff during heavy rainfall.

2.6.2 Degradation of Chemicals

The persistence of hazardous organic chemicals is an important determinant of their environmental fate. Certain compounds can undergo either chemical or biological degradation at land disposal sites, while others are resistant to any transformation and may even be toxic to soil micro-organisms. The pattern of degradation is not only influenced by the conditions in the landfill. Degradation may also be initiated during the transport of chemicals in the leachate, surface water, or groundwater. The major chemical processes associated with the degradation of organic contaminants at disposal sites have been identified as hydrolysis, biodegradation, photolysis, and oxidation; the latter is thought to be of particular importance in the degradation of phenols and aromatic amines. Nevertheless, the overall significance of chemical reactions in degrading toxic substances at disposal sites is largely unknown. For this reason, simply because a contaminant undergoes efficient chemical degradation in the laboratory, it should not be assumed that degradation will occur to the same extent--if at all--in disposal areas.

In certain instances, reactive chemicals can come into contact at the same disposal site, resulting in fires or explosions. Figure 2-2 summarizes the undesirable reactions which can occur when incompatible wastes containing hazardous compounds are mixed together. These reactions include:

- Exothermic reactions which may result in fires or explosions; these may be caused by alkali metals and strong oxidizing agents.
- Production of toxic gases such as arsine, hydrogen sulphide, hydrogen cyanide, and chlorine.
- Production of flammable gases such as hydrogen and acetylene.

FIGURE 2-2

Compatibility of Selected Hazardous Wastes

		1	2	3	4	5	6	7	8	9	10	11	12
1	Oxidising Mineral Acids	1											
2	Caustics	H	2										
3	Aromatic Hydrocarbons	H F		3									
4	Halogenated Organics	H F GT	H GF		4								
5	Metals	GF H F			H F	5							
6	Toxic Metals	S	S				6						
7	Sat Aliphatic Hydrocarbons	H F						7					
8	Phenols and Cresols	H F							8				
9	Strong Oxidising Agents		H	H F		H F		H		9			
10	Strong Reducing Agents	H F GT			H GT				GF H	H F E	10		
11	Water and Mixtures containing Water	H			H E		S				GF GT	11	
12	Water Reactive Substances	← Extremely reactive, do not mix with any chemical or waste material →											12

E	Explosive
F	Fire
GF	Flammable Gas
GT	Toxic Gas
H	Heat Generation
S	Solubilisation of Toxins

Hazards are also associated with certain types of wastes which are unstable under ambient conditions or with motion (e.g. silane metal hydrides, alkalis metals/alloys, and organic peroxides).

Photodegradation is commonly identified as an important mechanism for the breakdown of organic compounds in the environment. However, this process will only be of any significance in the top few centimeters of the disposal site surface which is exposed to UV light. Photodegredation may be of greater importance for those compounds which have vaporized from the site, or entered surface waters.

It is currently considered that biological transformation is a significant degradation pathway for many contaminants in disposal sites. These microbial transformations may take place either at the land disposal site or in groundwater. Microbial activity may lead to the degradation of a contaminant to harmless, or less hazardous products, but may also result in the biosynthesis of persistent and toxic compounds. For example, microbial transformation of three solvents--trichloroethylene, perchloroethylene, and 1,1,1-trichloroethane--can lead to the formation of vinyl chloride, a compound resistant to further breakdown and a proven carcinogen. The degradation of many contaminants is most efficient under aerobic conditions, but these conditions only arise at the surface of the disposal site. The environmental conditions required for biodegradation are well known for some chemicals. In the case of cyanide these are: temperatures in excess of 10 degrees C, a pH of 6-7.5, and a maximum cyanide concentration of 100 mg/1.

The anaerobic conditions which predominate in landfill sites favor the bacterial reduction of sulphates, nitrates, and carbohydrates. Sulphate is reduced to sulphide and nitrate is reduced to nitrite or ammonia. The microbial production of sulphide under anaerobic conditions can cause a marked reduction in the concentration of dissolved metals in leachate by the precipitation of insoluble sulphides. This attention mechanism is particularly important for some metals, notably inorganic mercury.

In anaerobic conditions, bacterial activity is also responsible for the production of "landfill gas." Although landfill gas is generally associated with the disposal of domestic wastes, it may still occur at sites receiving hazardous wastes in combination with domestic refuse. Generally, the major components of landfill gas are carbon dioxide and methane, but hydrogen sulphide can also be a minor constituent. Several factors influence the rate of landfill gas production and its composition; the main parameters being temperature, moisture content, waste density, and pH value of the waste material. The optimum pH range for methane production is 6.4-7.4 and the optimum temperature range for anaerobic decomposition is 29-37 degrees C. The decomposition of some organic components in waste is so slow that significant concentrations of methane may be produced for many years after the waste has been deposited. The major problem associated with landfill gas is the serious risk of fire and explosion which occurs when the concentration of methane falls within the range of 5-15%. Proper precautions must be taken. In addition, landfill gas can also be a factor in flushing volatile organics from the fill.

2.7 Effects of Hazardous Wastes on Health and the Environment

Mixing chemical wastes containing incompatible chemicals may cause explosions and fires (see Figure 2-2). Contact with strong acids or alkali may cause corrosion and etching of the skin as well as severe corneal damage. Skin absorption of certain pesticides may cause acute poisoning. Most empty containers or jars for hazardous chemicals can--if not properly disposed of--result in incidents of severe poisoning if left unguarded at waste storage or dumping sites. Children are especially vulnerable. In the developed world, one of the main causes of child mortality--between the ages of 1 and 10--are accidents which involve accidental poisoning. If chemicals are introduced on the consumer market and no provisions made to collect the empty containers, bottles, or jars, they are likely to be stored in households or disposed of in an uncontrolled way. This has resulted in a substantial number of poisoning cases involving small children.

As previously noted, the release of chemical waste into the environment may result in long-term exposure of the population, causing adverse health effects due to poisoning. The following example is illustrative. Water containing a large amount of cadmium was discharged from the Kamioka zinc mine in Japan into a river that was used for drinking water downstream from the mine. The river water was also used for irrigating paddy rice. Because of the large amounts of cadmium in the water used for both drinking and irrigation purposes, the long-term exposure of the local population to this chemical resulted in serious kidney malfunctions in a large percentage of the population. The effects, which were most severe in pregnant women with low calcium intakes, as well as those women suffering from close-spaced births, included de-calcification of the skeleton, multiple bone fractures, invalidity, and death (Itai-itai disease).

The cadmium intake interfered with normal calcium metabolism, resulting in the de-calificaiton of bone tissue (osteomalacia). In many industrial countries both the body burden and the kidney content of cadmium have been considerably raised due to environmental exposure from chemical waste or cadmium impurities in fertilizers. However, so far no adverse health effects have been reported. These increased levels have, nontheless, caused a great deal of concern and measures have been taken to limit population exposure until a satisfactory safety margin has been identified between cadmium levels present in the kidneys and levels at which impaired function is likely to occur.

In other areas of Japan, industrial use of mercury catalysts resulted in the presence of mercury in the effluents from wastewater treatment plants entering coastal waters. The mercury was then converted, by micro-organisms present in seawater, into methylmercury, a highly toxic form of mercury. At Minamata Bay and the Agano River at Niigata, methylmercury accumulated in fish and shellfish. As seafood is an important part of the Japanese diet, many local inhabitants were poisoned and developed severe neurological symptons, such as impaired vision and hearing loss and difficulties in walking or standing. Children exposed <u>in utero</u> exhibited cerebral palsy syndrome or retarded psycomotor development. These

Japanese outbreaks of methylmercury poisoning are still the best documented cases on record. Nevertheless similar outbreaks have occured in other countries.

In some regions, the body burden of methylmercury has increased due to the regular consumption of contaminated fish and shellfish. Measures have therefore been taken to regulate both the intake and the mercury content of fish, as well as limiting the amount of mercury discharged into the environment. Chemical elements, like mercury, are indestructable and hence can only be redistributed into the environment. By contrast, organic chemicals are often degraded in the environment to elemental components or simple organic compounds such as carbon dioxide and water. However, some chlorinated or halogenated organic compounds are extremely persistent in the environment and tend to accumulate in the food chain or in the biosphere in general. Examples of such compounds include: PCBs, dioxins, and chlorinated hydrocarbons; the latter being used extensively in the past as pesticides (e.g. DDT, dieldrin, and aldrin). PCBs and dioxins may be formed by incineration of waste containing hydrocarbons and chlorides. They are spread with atmospheric emissions and precipitate in the environment. Once released, they often end up in human food chains, lodging in fatty tissues in the bodies of humans and animals. It is known that in some industrialized countries, notably Sweden and Japan, levels of PCBs and dioxins in breast milk and human fat are on the increase. The health significance of this increase is still uncertain, as the body burden at which adverse health effects might occur is still unknown. However, experience from accidental high level exposures has shown that these compounds may cause serious effects on human health.

Leakages from landfills and dumping sites often contain large amounts of nitrates. This has often resulted in high levels of nitrates in adjacent drinking water wells. Levels of nitrates in drinking water exceeding 45 mg/l run a risk of methemoglobinemia in infants. This condition, which interferes with the oxygen transportation in the bloodstream, can be fatal. There are several reports in the literature about severe methemoglobinemia in infants caused by contaminated drinking water.

Another important consequence of finding nitrate in leachate from landfills, is the simple fact that the site is leaching contaminants into the environment. If industrial residuals are being placed in the site as well, then the possibility exists for a whole host of contaminants to find their way into drinking water (including some which are considerably more deadly than nitrate).

Other land disposal catastrophes can be noted. For instance, at Love Canal in New York State, chemicals and vapors began to leak into homes and schools causing adverse health effects and eventually resulting in the complete evacuation of the town. In the United Kingdom, drums containing heat treatment cyanide salts were discovered on waste land used by children as a playground.

2.7.1 Hazard Identification and Risk Assessment

To prevent and/or control adverse effects on health and the environment, it is necessary to control all chemical and infectious materials introduced into the human environment. The chemical nature of each product should be determined, together with impurities, by-products and degradation products. The potential effects of these substances on health and the environment should then be assessed together with a quantitative estimation of levels occuring in the environment. Exposure commitments for human populations, as well as other organisms, should be undertaken in the final risk evaluation. From such an evaluation, measures should then be taken to ensure that unacceptable adverse effects are avoided. The effectiveness of these control measures should then be monitored on a continuous basis.

Hazard Identification

Each waste material should be assessed for organisms that are pathogenic to man and animals. Such an assessment can usually be made and verified from information regarding the source of the waste. The chemical composition of each waste material must also be determined in order to evaluate potential systemic toxicity together with other effects, such as mutagenic, cytogenetic, and carcinogenic effects, as well as effects on reproduction and foetal/neonatal growth and development. In most cases, such information can be found in the literature, such as the World Health Organization's health criteria documents, national safety data sheets available from ILO or other sources of toxicological literature. When the required information is lacking it may then be necessary to perform laboratory tests.

As can be seen from Table 2-2, all the contaminants studied in the TCLP test are of concern in drinking water because of their adverse health effects. The MCLs set are approximately 100 times the drinking water guidelines for those contaminants. Arsenic, cadmium, chromium, and lead, for example, are of concern because of their possible carcinogenicity, while barium effects the muscles and can cause gastroenteritis or muscle paralysis. Endrin is a potent teratogen and reproductive toxin. Chronic exposure to it can effect the nervous system, heart, lungs, liver and kidneys.

Once a substance is identified in waste, a good place to look for information first is the Guidelines for Drinking-Water Quality (World Health Organization 1984). They will tell you the health effects and provide a recommended safe concentration in water.

Table 2-4 lists the 25 most frequently identified substances that were found at a large number of hazardous waste sites. Table 2-5 lists some health effects information that may prove useful when working with wastes. Again, the recommended levels are for drinking water. Designations are as follows: Cancer Group A = human carcinogens; B = probable human carcinogens; B1 = at least limited evidence of carcinogenicity in humans; B2 = usually a combination of sufficient evidence in animals and inadequate data for humans; C = possible human carcinogen (limited evidence of carcinogenicity in animals in the absence of data on humans); D = not classified (inadequate data); and E = no evidence of carcinogenicity for humans.

TABLE 2-4

25 Most Frequently Identified Substances at 546 Superfund Sites

Rank	Substance	Percent of Sites
1	Trichloroethylene	33
2	Lead and compounds	30
3	Toluene	28
4	Benzene	26
5	Polychlorinated biphenyls (PCBs)	22
6	Chloroform	20
7	Tetrachloroethylene	16
8	Phenol	15
9	Arsenic and compounds	15
10	Cadmium and compounds	15
11	Chromium and compounds	15
12	1,1,1-Trichloroethane	14
13	Zinc and compounds	14
14	Ethylbenzene	13
15	Xylene	13
16	Methylene chloride	12
17	trans-1,2-Dichloroethylene	11
18	Mercury	10
19	Copper and compounds	9
20	Cyanides (soluble salts)	8
21	Vinyl chloride	8
22	1,2-Dichloroethane	8
23	Chlorobenzene	8
24	1,1-Dichloroethane	8
25	Carbon tetrachloride	8

Source: Adapted from McCoy and Associates. 1985. Hazardous Waste Consultants 3(2):2-20. Lakewood, Colorado.

TABLE 2-5

HA Summary Table

	10-kg Child			70-kg Adult					
Cancer Chemical	One-day HA(ug/L)	Ten-day HA(ug/L)	Longer-term HA(ug/L)	Longer-term HA(ug/L)	RfD (ug/kg/day)	DWEL (ug/L)	Lifetime HA (ug/L)	ug/L at 10^{-4} Cancer Risk	Group
Acrylamide	1,500	300	20	70	0.2	7	--	1	B2
Alachlor	100	100	100	100	10	350	--	15	B2
Aldicarb	10	10	10	40	1.25	40	10	NA	E
Barium	1,500	1,500	1,500	1,500	51	1,800	1,500	NA	D
Benzene	235	235	--	--	--	--	--	70	A
Cadmium	43	43	5	20	0.5	18	5	NA	D
Carbofuran	50	50	50	180	5	180	36	NA	E
Carbon Tetrachloride	4,000	160	71	250	0.7	25	--	27	B2
Chlordane	63	63	0.5	0.5	0.045	2	--	2.7	B2
Clorobenzene	4,300	4,300	4,300	15,000	43	1,500	300	NA	D
Chromium	1,400	1,400	240	840	4.8	170	120	NA	D
Cyanide	200	200	200	800	22	770	154	NA	D
2,4-D	1,100	300	100	350	10	350	70	NA	D
DBCP	200	50	--	--	--	--	--	2.5	B2
Dichlor-o-,m-	9,000	9,000	8,900	31,250	89.3	3,125	620	NA	D
Benzenes p-	10,700	10,700	10,700	37,500	107	3,750	75	175	C

TABLE 2-5 (continued)

HA Summary Table

Cancer Chemical	10-kg Child One-day HA(ug/L)	10-kg Child Ten-day HA(ug/L)	10-kg Child Longer-term HA(ug/L)	70-kg Adult Longer-term HA(ug/L)	RfD (ug/kg/day)	DWEL (ug/L)	Lifetime HA (ug/L)	ug/L at 10^{-4} Cancer Risk	Group
1,2-Dichloro- ethane	740	740	740	2,600	--	--	--	38	B2
1,1-Dichloro- ethylene	2,000	1,000	1,000	3,500	10	350	7	NA	C
cis-1,2-DCE	4,000	1,000	1,000	3,500	10	350	70	NA	D
trans-1,2-DCE	20,000	1,430	1,430	1,430	10	350	70	NA	D
Dichloro- methane	13,300	1,500	--	--	50	1,750	--	480	B2
1,2-Dichloro- propane	--	90	--	--	--	--	--	111	B2
p-Dioxane	4,120	412	--	--	--	--	--	700	B2
2,3,7,8-TCDD Dioxin)	0.001	0.0001	0.00001	$3.5x10^{-5}$	$1x10^{-6}$	$3.5x10^{-5}$	--	$2.2x10^{-5}$	B2
Endrin	20	5	4.5	16	0.045	1.6	0.32	NA	E
Epichloro- hydrin	140	140	70	70	2	70	--	354	B2
Ethylbenzene	32,000	3,200	971	3,400	97	3,400	680	NA	D
Ethylene dibromide	8	8	--	--	--	--	--	0.05	B2

TABLE 2-5 (continued)
HA Summary Table

Cancer Chemical	10-kg Child One-day HA(ug/L)	10-kg Child Ten-day HA(ug/L)	10-kg Child Longer-term HA(ug/L)	70-kg Adult Longer-term HA(ug/L)	70-kg Adult RfD (ug/kg/day)	70-kg Adult DWEL (ug/L)	70-kg Adult Lifetime HA (ug/L)	70-kg Adult ug/L at 10^{-4} Cancer Risk	Group
Ethylene Glycol	19,100	5,500	5,500	19,250	1,000	35,000	7,000	NA	D
Heptachlor/	10	10	5	5	0.5	17.5	--	7.6	B2
Heptachlor-epoxide	10	--	0.13	0.13	0.013	0.4	--	3.8	B2
Hexachloro-benzene	50	50	50	175	0.8	28	--	2	B2
Hexane	13,000	4,000	4,000	14,000	--	--	--	NA	D
Legionella	--	--	--	--	--	--	--	NA	--
Lindane	1,200	1,200	33	120	0.3	10	0.2	2.65(CAG) 5.5(NAS)	B2/C
Mercury	1.58	1.58	1.58	5.5	0.158	5.5	1.1	NA	D
Methoxychlor	6,400	2,000	500	1,700	50	1,700	340	NA	D
Methyl ethyl ketone	75,000	7,500	2,500	8,600	24.7	860	170	NA	D
Nickel	1,000	1,000	150	150	10	350	150	NA	D
Nitrate/	10,000[a]	1,000[a]	10,000	10,000	--	10,000	10,000	NA	D
Nitrite	1,000[b]	1,000[b]	1,000	1,000	--	1,000	1,000	NA	D
Oxamyl	175	175	175	175	25	875	175	NA	E

a= Value given is for 4-kg infant; One-day and Ten-day HAs for all other populations is 111,000 ug/L.
b= Value given is for 4-kg infant; One-day and Ten-day HAs for all other populations is 11,000 ug/L.

TABLE 2-5 (continued)

HA Summary Table

Cancer Chemical	10-kg Child One-day HA(ug/L)	10-kg Child Ten-day HA(ug/L)	10-kg Child Longer-term HA(ug/L)	70-kg Adult Longer-term HA(ug/L)	70-kg Adult RfD (ug/kg/day)	70-kg Adult DWEL (ug/L)	70-kg Adult Lifetime HA (ug/L)	70-kg Adult ug/L at 10^{-4} Cancer Risk	70-kg Adult Group
Pentachloro-phenol	1,000	300	300	1,050	30	1,050	220	NA	D
Styrene	22,500	2,000	2,000	7,000	200	7,000	140	3	C
Tetrachloro-ethylene	2,000	2,000	1,400	5,000	14.3	500	10	68	B2
Toluene	21,500	3,460	3,460	12,100	346	12,100	2,420	--	D
Toxaphene	500	40	--	--	--	--	--	3.1	B2
1,1,1-Tri-chloroethane	140,000	35,000	35,000	125,000	35	1,000	200	NA	D
Trichloro-ethylene	--	--	--	--	7.35	260	--	280	B2
2,4,5-TP	200	200	70	260	7.5	260	52	NA	D
Vinyl chloride	2,600	2,600	13	46	--	--	--	1.5	A
Xylenes	12,000	7,800	7,800	27,300	62	2,200	400	NA	D

On the other hand, some dangerous compounds are not included in health advisories. PCBs, chloroform, tetrachloroethylene, phenol and methylene chloride are all carcinogens and recommended safe levels for these compounds in drinking water are as follows: 12.6 ng/l; 0.10 mg/l (total trihalomethanes); 0.88 ug/l; 3.5 mg/l and 0.15 mg/l (long-term Health Advisory), respectively (USEPA 1986).

An analytical investigation may be structured according to known information regarding sources of the waste. Hazard identification should be followed by quantification and an exposure commitment calculation. If these procedures indicate a possible human health risk, then it becomes necessary to measure exposure levels. Biological monitoring of the exposed population is the preferred method as this quantifies the actual intake of the toxic agent. If this is not feasible, intake can be estimated from measured exposure levels in drinking water, food, or air.

Exposure to Man and Animals

Hazardous waste can affect human and animal health through different mechanisms and routes of exposure. The most obvious route is direct contact with the hazardous agent during handling of the waste, or waste adsorbed to oil matter or via empty containers, jars or bags left at disposal sites, dropped during transportation or reused without proper cleaning. This could also be a source of disease as well as chemical contamination. Children are an especially vulnerable group as they are likely to play around waste bins etc., and may put fingers or contaminated articles in their mouths. Inhalation of dust from waste storage and dumping sites may also constitute a hazard. This is, for example, the case for asbestos-containing material. Inhalation of vaporized chemical waste is also a potential exposure pathway, but is only likely to be of significance to the on-site workforce.

Groundwater can be contaminated from dumping sites and landfills. Hazardous agents, such as bacteria, viruses, and chemicals can be transferred to drinking water wells in this way. Certain viruses and bacteria may survive for weeks to months in soil and/or inadequately treated sewage sludge, thus increasing the risk of such agents being transferred to drinking water supplies.

The transport of contaminants in surface waters results in a rapid and extensive dispersion which can greatly increase the size of the exposed population. Drinking water can also be contaminated by direct transfers from disposal sites or by animals (e.g., birds) to surface reservoirs. Seabirds can also transfer bacteria from coastal sewage outlets and treatment plants to drinking water reservoirs. Other animals (e.g., rates and insects) may also transfer contagious diseases or dangerous chemicals from dumping sites to households in the community.

Chemicals from hazardous waste may be taken up by crops from soil-bound particles or contaminated surface- or groundwaters, or if contaminated water is used for irrigation purposes. The spreading of wastes on agricultural land and deposition of air emissions from smoke stacks and a variety of industrial point sources constitute other pathways for chemical contamination of vegetation and crops. Consumption of contaminated vegetation by animals can result in the tropic transfer of hazardous chemicals. Livestock may ingest large quantities of soil when feeding on pasture and this is often a significant source of exposure in areas with contaminated soils.

Finally, release of waste materials into the sea and via freshwater sources leaching from disposal sites and treatment plants as well as atmospheric deposition, may lead to the uptake of chemicals by aquatic organisms. Those compounds with high partition coefficients tend to bioaccumulate in aquatic food chains. This is of particular significance for compounds which are persistent in the environment as these show marked accumulation in fish. Consumption of contaminated seafood can be a significant source of human exposure, particularly for fishing communities. Figure 2-2 summarizes the different exposure pathways of hazardous wastes back to human populations.

Assessment of Health Risks

With identification of a hazard, accessing health effects data-including dose-response information on the particular contaminant(s)--and determination of public exposure to the hazard, a risk assessment can then be made. The risk of adverse effects on human health and the environment from the presence of hazardous chemicals or pathogenic organisms present in waste is fully assessed by quantifying target organism exposure. This will determine whether there is a potential adverse health risk and whether there is a sufficient safety margin between exposure levels and levels known to cause adverse health effects. The safety margin required varies between a factor of 2 to an order of magnitude greater, depending on factors such as the type of effect induced, the number of people at risk, or the extent of environmental damage. A substance causing irreversible injury and/or death will require a larger safety margin than a substance which may induce mild skin irritation, for example. Similarly, if thousands of people are at risk, the safety margin has to be larger than if just a few individuals are at risk. If the risk assessment reveals that the hazardous waste will impose an unacceptable risk to human health or the environment, then measures must be taken to limit the risk to an acceptable level.

During the period 1964-1972 an estimated 300,000 barrels of liquid and solid wastes were buried in shallow trenches at a 200 acre dump site in Hardeman County, Tennessee (U.S.A.). In 1972, a nearby test well was found to be contaminated with hazardous chemicals, and the site was closed. An analysis of water from private wells close to the dump showed no contamination. However, five years later, in 1977, the situation changed dramatically. Residents in the area of the dump became alarmed by the unusual and unpleasant odor and taste of their well water. Some people experienced skin and eye irritation, weakness in the upper and lower extremities, severe gastrointestinal symptoms including nausea, diarrhea, and abdominal cramps. The local authorities launched an investigation. Analysis of the well water revealed high concentrations of carbon tetrachloride and small amounts of other organic compounds known to have been dumped at the site by a pesticide manufacturer. The highest concentration of carbon tetrachloride found in one well was 18.7 mg/l. As no method for biological monitoring of carbon tetrachloride was available, it was decided to look for effects on liver function, as this is the main target organ in carbon tetrachloride toxicity. Liver function tests were performed on 36 exposed individuals and compared to a reference population of 56 people. A higher prevalence of enlarged liver and impaired function tests was observed in the exposed group. All signs returned to normal after cessation of exposure when examined a year later in a follow-up study.

It is important that in any case where potential exposure is discovered from hazardous wastes, the public is informed immediately about the source of exposure and the potential health risks involved. Such risks should then be compared with other risks, such as those associated with smoking, traffic accidents, alcohol consumption, and other estimable risk factors. An information system should be set up to ensure that the progress of ongoing investigations is being reported adequately. Such information is necessary in order to prevent the public from over-reacting and falling victim to political exploitation.

2.8 Degree of Hazard Concept

In identifying and classifying hazardous wastes, it is important to recognize that there are varying degrees of hazard associated with different waste streams. To reflect these differences, regulations in a number of countries have examined methods of ranking wastes according to how great a hazard they present.

There are strong economic arguments for doing this: It enables resources to be allocated so that the most dangerous wastes can be tightly controlled. In a number of European countries, this type of approach has been adopted in national regulations using concentrations of constituents to indicate whether or not a waste should be subjected to a high degree of monitoring and control. Other "degrees of hazard" schemes have considered the mobility of wastes as a criterion for establishing the degree of hazard.

There are, however, a number of difficulties in implementing this type of quantitative approach to degree of hazard assessments. In the first place, the amount of information needed is daunting. For this reason (and others) an alternative approach is recommended here. Under this system, three main categories of waste are defined.

- The first category includes those wastes of priority concern (Category 1) known to contain significant concentrations of constituents that are highly toxic, mobile, persistent, or bioaccumulative. Examples of Category I wastes would include the following:

  - chlorinated solvent wastes from metal degreasing. These are included because of their toxicity, mobility, and--to some extent --persistence in the environment;
  - cyanide wastes are included because of their acute toxicity;
  - PCB wastes are on the list because of their persistence and bioaccumulative properties.

- o Most wastes not singled out for special attention would be designated as Category 2 wastes. These would include metal hydroxide sludges (excluding hexavalent chromium) for which the toxic metals are in a relatively insoluble physical form with low mobility.

- o Category 3 includes primary large volume, low hazard wastes and some putrescible wastes, for which the cut-off between a 'hazardous' and 'non-hazardous' waste is least clear-cut.

It is emphasized, however, that this scheme is not intended to diminish the concern for the proper handling of Category 2, or even Category 3 wastes. Rather, it is an attempt to identify those waste streams for which a consensus has been reached that a particularly high degree of hazard is present, and accordingly for which a high degree of attention is warranted. It also allows certain related low hazard (Category 3) wastes to be brought under scrutiny, since in some local circumstances their control may assume high priority.

In Annex 2, an attempt has been made to categorize various types of waste. However, in some cases more specific information on concentrations and on properties--such as flashpoint--is required. These factors should be taken into account in assigning a waste to a particular category of hazard.

As new substances of concern surface and the need for additional health/environmental effects information develops, please consult your local/national health department. If necessary, they will in turn contact their local UNEP/WHO representative for assistance.

2.9 Environmental Effects of Hazardous Waste Disposal

Adverse effects on biota can arise at disposal sites as a result of construction activities and the subsequent release of toxic chemicals to the environment. In addition, the plants and animals living in the vicinity of such sites can be used to evaluate the geographical extent and intensity of contamination resulting from hazardous waste release. This activity, termed biological monitoring, generally relies on measurement of the concentration of the contaminant(s) in the species selected for examination. The presence of sub-lethal effects may also be investigated, but these are often difficult to relate in a causal manner to a specific chemical. Biological monitoring offers the advantage that containment levels in biota are often much higher than in the physical environment. This is of particular importance in the aquatic environment, where pronounced bioaccumulation results in markedly elevated levels of certain organics in fish, even in waters which contain low levels of these compounds. In the case of food crops or livestock, measurement of the pollutant concentration will not only provide an insight into the extent of environmental contamination, but will also allow an estimation of the potential exposure resulting from the consumption of such food items.

Increased mortality of biota, particularly large animals, can provide an early warning of contaminant release from a disposal site. An example is the numerous cases of fish deaths resulting from episodic inputs of chemicals to surface waters. Such events can be caused by surface run-off from disposal sites--landfills and impoundments--during periods of heavy rainfall or due to dike failure. Adverse effects can also extend from the individual or population level to effects on the functioning of the ecosystem itself. This may result in changes in nutrient cycling or reduced primary production in the impacted area.

2.9.1 Effects on the Terrestial Environment

Effects on the terrestial environment at disposal sites tend to be of a localized nature. One effect of importance, however, is that the production of landfill gas depletes the oxygen supply in the upper layer of the landfill, causing vegetation to die off. This effect can produce problems when re-vegetation of the site is being carried out. Metal-rich wastes can also inhibit the re-vegetation of disposal sites. Those areas of the site lacking vegetation will be susceptible to erosion; wind-blown dispersal, and episodic flooding can result in the environmental release of contaminants. Land spreading of certain industrial wastes can result in significant inputs of metals and organic chemicals to agricultural land. Certain metals are phytotoxic and if soil levels are sufficiently high these can reduce crop productivity. Other metals can accumulate in the edible portions of crops, which may lead to problems of exposure for human consumers.

2.9.2 Effects on the Aquatic Environment

The efficient dispersal which occurs when pollutants enter surface waters is an important feature of this environmental compartment. Thus, widespread contamination may arise from a single source of discharge, particularly in rivers, drainage canals, and coastal waters. As mentioned earlier, fish deaths resulting from contaminant inputs are often the most visible sign of an environmental impact. In addition, attention has recently focused on sub-lethal effects observed in button-dwelling commercial fish species caught near waste dump sites in coastal waters. The effects observed include epidermal lesions and liver neoplasms; in some coastal waters these effects have been related to elevated levels of aromatic hydrocarbons in the sediments.

2.10 Summary

A working definition for hazardous waste(s) is developed in this chapter and examples of such wastes are given. The range of possible industries for a country to have are listed together with the wastes they typically produce; and a classification is made. Movement of waste components in the environment is discussed together with their varied effects on human health and the environment. A scheme for classifying hazardous wastes by the degree of hazard they pose is proposed.

2.11 References 2.1 - 2.10

Federal Register. 1986. 51 (114) (Friday, June 13): 21685. Washington, D.C.: U.S. Government Printing Office.

Federal Register. 1986. 51 (216) (Friday, November 7): 40643, Washington, D.C.: U.S. Government Printing Office.

USEPA. 1986. Superfund Public Health Evaluation Manual, EPA/540/1-86/060 (October). Washington, D.C.: Office of Emergency and Remedial Response.

World Health Organization. 1984. Guidelines for Drinking-Water Quality, 3 Vols. Geneva.

ANNEX 2 - Waste Types for Proposed Classification Scheme

I INORGANIC WASTES

ACIDS AND ALKALIS

Waste Streams	Industry/Process	Industrial Groups
Acid		
Spent sulphuric acid	Galvanizing	D
Spent ferrous pickle liquor	Steel pickling	D
Acid strip solution	Metal finishing	D
Spent nitrating acid	Organic synthesis	F
Spent chromic acid	Anodising	D
Spent brightener for stainless steel	Metal finishing	D
Acid tars	Coking	C
Spent reagents	Pesticide manufacture	F
Alkalis		
Alkaline cleaning agents	Metal degreasing	D
Spent ammoniacal etchants	Electronics	G
Spent caustic baths	Metal finishing	D
Waste ammonia	Photocopying shops, chemical synthesis	F/L
Caustic sludge	Oil re-refining	F
Spent caustic	Oil refining	C
Ammonia still lime sludge	Coking operations/gas works	C

CYANIDE WASTES

Untreated rinse water	Electroplating	D
Spent electro-plating process solutions		D
Heat treatment wastes	Steel production	D
Spent concentrates and semi-concentrates	Hydrometallurgy	D
	Chemical synthesis	F
	Fumigation	L

HEAVY METAL SLUDGES AND SOLUTIONS

Lead sludges from diaphragm cell process	Chlorine production	F
Wastewater treatment sludge from the mercury cell process		
Brine purification muds from the mercury cell process		
Wastewater treatment sludges	Chrome pigments	F
	Wood preserving (1)	H
Surface impoundment dredged solids	Lead smelting (2)	D
Emission control sludge	Lead smelting (3)	D
Treatment process wastewater sludges	Zinc production	D
Acid plant blowdown		

Waste Streams	Industry/Process	Industrial Groups
Electrolic anode sleeves and sludges		
Cadmium plant leachate residue		
Lead sludges	Battery production	G
Sludge	Tin plating mill operations	D
	Galvanizing mill operations	
Acid plant blowdown slurry sludges	Copper production (2)	D
Wastewater treatment sludges	Copper rolling and drawing	D
Spent pickle liquor and sludge	Copper production	D
Zinc and other heavy metal sludges	Textiles industry	H
Emission control sludge	Production of steel in electric furnace (2)	D
Spent pickle liquor	Steel finishing operations	D
Untreated wastewater	Manufacture of explosives	F
Wastewater treatment sludges	Manufacture/processing of explosives	F
Mixed metal sludges	Paint production	F
	Ink formulation	F
Waste sludges	Photographic processing	F
Spent reagents	Electronics industry	G
Etching solutions/rinse waters	Plastic plating	G
Grinding and polishing residues	Metal finishing	D
Lead sludge	Glassmaking	E
ASBESTOS WASTES		
Asbestos powder	Preparation and processing of asbestos	E
Lagging materials	Power stations, industrial manufacturing, gasworks dockyards, hospitals and educational establishments	Various
Asbestos diaphragms	Chlorine production	F
SOLID RESIDUES N.O.S.		
Emission control dust	Production of steel in electric furnaces (2)	D
Dust and sludge	Ferromanganese furnaces	D
	Silicomanganese electric furnaces	D
	Ferrochrome electric furnaces	D
	Iron and steel foundries	D
Waste sand	Iron and steel foundries	D

Waste Streams	Industry/Process	Industry/ Group
Emission control dust	Lead smelting (3)	D
Blast furnace slag	Copper smelting (3)	D
Spent catalysts	Chemical synthesis	F
Solid residues	Rubber production	F
Spent activated carbon wastes	Manufacture of sulphuric acid, chemical synthesis	F
Scrap batteries	Miscellaneous sources	Various
Spent iron oxide	Gas purification/coking	C

Notes: (1) using chromated copper arsenate
(2) Primary
(3) Secondary

II OILY WASTES

OILY WASTES

Waste Streams	Industry/Process	Industry/ Group
Used oil wastes	Vehicle repair shops, petrol stations	G/L
Acid waste oils	Textiles	H
Contaminated fuel oils	Oil tanks and reservoirs	Various
Compressor condensates	Compressors	Various
Sand trap and interceptor wastes	Manufacture of building materials	E
	Chemical synthesis	F
	Sand traps, storage tanks	Various
Oily sludges containing cyanide	Surface treatment of metals	G
Oily sludges	Oil recovery/cleansing	F
	Oil prospecting and mining	C
	Petroleum refining	C
Bottom sludges from tanks		
API separator sludge		
Heat exchanger sludge		
Dissolved air floatation float		
Silt/storm water runoff		
Oily sludges	Coking plants and gasworks	C
Caustic sludge	Oil re-refining	F
Drilling and cutting emulsions	Metal working	G
Waste vegetable oils	Production of vegetable oils	A

III ORGANIC WASTES

ORGANIC CHEMICAL RESIDUES N.O.S.

Waste Streams	Industry/Process	Industrial Group
Halogenated		
Propylene dichloride in admixture with lime slurry	Propylene Oxide/ Propylene Glycol	F
Distillation residues containing 1-10% chlorinated hydrocarbons (e.g., chlorinated toluenes from manufacture of benzaldehyde)	Ethers and Aldehydes	F
Residue with low concentration of o-dichlorobenzene	Isocyanates	F
Phosphoric acid contaminated with brominated hydrocarbons	Alkylated Bromides	F
Tarry residue (m.p. 60°C) containing chlorinated aromatic compounds	Dyestuff intermidieates and Dyestuffs	F
Aqueous waste containing low concentrations of mono-and tri-chlorobenzene		
Tarry residues of 1-2% halogen (chlorine, fluorine, bromine) content	Pharmaceuticals and Fine Chemicals	F
Spent filter cake of approximately 0.1% chlorine content		
Chlorinated hydrocarbon in admixture with toluene and dissolved solids (chlorine content 1%)		
Contaminated mixtures of chlorinated solvents (e.g., methylene chloride, chloroform, ethylene dichloride, chlorobenzene, with non-halogenated hydrocarbon solvents)		
Solvent waste containing small amounts of methylene chloride and and alkyl chloride		
Aqueous streams of about 0.1% chlorinated xylenes and terpene alcohols		
Still residues containing up to 2% films and disposables		
Aqueous stream containing about 40 ppm chlorinated hydrocarbons with traces of brominated and iodated compounds		
PVC (with or without additives) off-cuts, films and disposables: waste from machining of PTFE/Graphite products	Plastics and Rubbers	F
PVC granules from processing operations		
Slurry of chlorinated rubber and rubber in carbon tetrachloride		
Waste stream containing chlorinated hydrocarbons (10% chlorine content)	Dyeline intermediate products	F

Waste Streams	Industry/Process	Industrial Group
Epichlorohydrin wastes	Epoxy and phenolic resin	F
Contaminated chlorinated hydrocarbon solvents (e.g., methylene chloride, chloroform)	Products (research)	F
Ethylene dichloride tars	Chlorocarbon production	F

Source: Her Majesty's Stationary Office. 1979. Halogenated Organic Wastes, Waste Management Paper No. 15, Annex 2. London.

III ORGANIC WASTES

ORGANIC CHEMICAL RESIDUES N.O.S.

Waste Streams	Industry/Process	Industrial Groups
Non-halogenated		
Spent aqueous caustic soda solution	Oil refining operations	C
Distillation residues containing 45 per cent aromatic hydrocarbons (xylene to methyl naphthalene)	Petroleum refining	C
Still bottoms containing octyl phenyl naphthylamine and polyisobutylene		
Tars containing polymerized methyl-methacrylate, alkylated phenols, cyanovaleramide and condensation products, hexamethylene triamine	Heavy organic chemicals manufacture	F
Filter press cake containing 8 per cent naphthenates, 4 per cent naphthenic acid and metallic oxides	Chemical manufacture	F
Still residues containing: diphenylamine, aromatic amines, inorganic compounds, 2-naphthol and oxidation products, phenol decomposition products and amine decomposition products	Dyestuffs and inter-mediates manufacture	F
Distillation residues containing phenylamines, nitrated phenylamines and phenyl ethers	Production of chemical intermediates	F
Glycol and glycol ether residues in admixture with hydrocarbon sludge, plastic powder and water	Petrochemicals manufacture	F
Liquid cyclopentadiene residue	Petrochemicals manufacture	F
Dimethylformamide residues	Pharmaceuticals manufacture	F
Residue containing up to 20 per cent organic amines		
Liquid comprising 70 per cent toluene, 6 per cent chlorphenol + 20 per cent by-products		
Distillation residues - terpene hydrocarbons and weak acid stabilizers	Fine chemicals manufacture	F
Waste from hydroquinone processing, containing 0.2 per cent insoluble tars and 35 per cent soluble tars		
Caprolactam residues	Fibers manufacturing	F
Still bottoms containing spent caustic, alcohols	Lube oil additive manufacture	F
Tar slurry (1 per cent coal tar + water)	Aluminum smelting	D

Waste Streams	Industry/Process	Industrial Groups
Phenol-formaldehyde and epoxy resins, varnish blends and solvent	Plastics fabrication	F
Propylene polymerization residues; polymerized ethylene granules	Plastics manufacture	F
Tar emulsions	Town gas manufacture (coal carbonization)	C
Acid tar washing of BTX fraction	(coal carbonization)	C
Distillation bottom tars	Phenol production	F
Centrifuge and distillation residues	Toluene diisocyanate production	F

Source: Her Majesty's Stationary Office. 1977. Tarry and Distillation Wastes and Other Chemical-Based Residues, Waste Management Paper No. 13, Annex 3. London.

III ORGANIC WASTES

HALOGENATED SOLVENTS

Waste Streams	Industry/Process	Industry/ Group
1,1,2 - trichloro - 1,2,2, -trifluoroethane	Dry cleaning	L
Perchlorethylene, Perchloroethylene, trichloroethylene	Textiles and leather	H
Trichloroethylene, 1,1,1, - trichloroethane 1,1,2 - trichloro -, 1,2,2, - trifluoroethane	Metal cleaning	G
Dichloromethane	Paint stripping	L
Chloroform, carbon tetrachloride	Industrial and domestic cleaning	L
Chlrobenzene; 1,2 - dichlorobenzene	Chemical synthesis	F

NON-HALOGENATED SOLVENTS

Waste Streams	Industry/Process	Industry/ Group
Methyl ethyl ketone, "Special Boiling Point" aliphatic hydrocarbons toluene	Adhesive manufacture	F
"Special Boiling Point" aliphatic hydrocarbons, xylene, toluene, white spirit, kerosene, esters	Motor vehicle manufacture	G
White spirit, kerosene, refined paraffin, "Special Distillates"	Cleaning materials and polishes	F
Kerosene and white spirit (with significantly greater quantities of chlorinated hydrocarbon solvents).	Engineering industries	G
n-Hexane, ethanol, methanol, isopropanol	Extractive industries (essential oils, etc.)	F
Propylene glycol, isopropanol, diacetin, glycerol triacetate	Food flavorings, essences, perfumes cosmetics and toiletries manufacture	
"Special Boiling Point" solvents, paraffin, glycerol triacetate	Industries where large fleets of vehicles require maintenance - including road, rail and air transport	G
White spirit, kerosene	Leather industry	H
Petroleum fractions of the white spirit type	Organic wood preservatives	H
Methanol, Industrial Methylated Spirit, acetone, various glycols, ethanol, ethyl acetate, cyclohexane	Photographic industry	J
White spirit, "Special Boiling Point" solvents, kerosene, ethanol, isopropanol, ethyl acetate, butyl acetates, acetone, methyl ethyl ketone, toleuene, xylene, methyl isobutyl ketone	Printing industry	J

Waste Streams	Industry/Process	Industry Group
Toluene, xylene, white spirit, cellosolves, isobutanol, methyl ethyl ketone, methyl isobutyl ketone	Shipbuilding and refitting	G
Petroleum hydrocarbons	Tyre manufacture	F

Source: Adapted from Department of the Environment. 1977. Waste Management Paper No. 14, Annex 1. London: Her Majesty's Stationary Office.

POLYCHLORINATED BIPHENYL WASTES

Solid and liquid wastes	Manufacture of PCBs	F
Dielectric fluid/solid wastes	Scrap transformers	G
Dielectric fluid/solid wastes	Scrap capacitors	G
Hydraulic fluids	Mining equipment, aircraft	G
Heat transfer fluids	Chemical industry	F
Plasticiser residues	Chemical processing	F
	Plastics processing	F

III ORGANIC WASTES

BIOCIDE WASTES

Chemical Classes	Waste Types	Industry/Process	Industrial Groups
Insecticides	Still bottoms	Manufacture of biocides	F
o Organophosphorus compounds	Filter media	Biodice formulaltors	F
	Extraction units	packers	F
o Organochloride compounds	Packaging	importers	F
	Clothing	wholesalers	F
o Carbamates	Effluent treatment sludge	distributor	F
Herbicides	Sweepings		
o Phenolics	Spill clean ups		
o Phenoxyacids	Washings		
o Substituted ureas			
o Triazines			
o Benzoic acids			
o Dinitroanilines	Empty containers	Agriculture users	A
o Anilides	Unused products	Animal husbandry users (dips)	A
o Others	Spills	Horticulture users	A
Fungicides		Industrial users	
o Dithiocarbamates		o wood preservation	H
o Phthalimides		o paint industry	F
		o paper and board	J
		o textiles (not wool)	H
		o electric cable	G
		o tobacco	A
		o adhesives	F
		o building industry	E
		Public sector users	L
		Home and garden users	L
		Drum reconditions	G
		Service companies (rodent/bird control)	L

BIOCIDE WASTES

Waste Streams (1)	Industry/Process	Industrial Groups
Lacquering residues	Lacquering shops	G/H
Old lacquers	Paint/lacquer shops (trade)	G/H
Old paints	Paint/lacquer shops	G/H
Lacquer sludge		
Paint sludge		
Coating material residues	Manufacturing of coating mats	F
Printing ink residues	Manufacturing of printing inks	F
	Printing works	J
Resin residues	Plastics processing	F
	Manufacturing of coating mats	F
	Manufacturing of synthetic resin	F
Resin oil residues		F
	Manufacture of resin	H
Paint residues	Paint production	F

(1) Wastes typically contain mixtures of aliphatic solvents, resins and may also include heavy metals.

IV PUTRESCIBLE ORGANIC WASTES

Waste Streams	Industry/Process	Industrial Groups
Spoiled vegetable oils	Production of edible oils	A
	Production of edible fats	A
Esterified oil residues	Production of pharmaceuticals	F
	Production of articles of personal hygiene	F
Butchering wastes; including blood, offal and intestines	Slaughter houses,	A
	meat processing	A
	meat packing	A
	fish processing	A
Poultry	Poultry and feather processing	A
Fish wastes	Fish processing	A
Animal carcasses	Livestock raising	A
	Pharmaceutical industry	F
Hideglue	Tanyards and fur industry	H
Fleshings		
Residues		
Hide liming sludge		
Tanyard sludge		
Sludge and residues	Processing of natural gut	A
Boiling out residues	Processing of animal products	A

V HIGH VOLUME/LOW HAZARD WASTES

Waste Streams	Industry/Process	Industrial Groups
Drilling muds	Petroleum/gas extraction	C
Fly ash	Power generation	C
Mine tailings	Mineral extraction	B
Contaminated soil	Miscellaneous	Various
Flue gas desulphurization sludges	Power generation	C
Phosphogypksum sludges	Fertilizer production	F
Titanium dioxide wastes	Pigment production	F

VI MISCELLANEOUS WASTES

Waste Streams	Industry/Process	Industrial Groups
INFECTIOUS WASTES		
Special faeces	Livestock raising	A
	Veterinary quarantine	K
Contagious wastes Animal and human tissue	Human and animal health institutes	K
	Microbiological laboratories	K
	Contagious hospitals	K
	Microbiological industries	K
	Microbiological institutions	K
Dressing wastes Disposable linen Disposable hospital wastes	Hospitals	K
	Therapeutic institutions	K
LABORATORY WASTES		
Waste pharmaceuticals	Pharmacies	L
Laboratory chemical residues	Manufacture of pharmaceuticals/ fine chemicals	F
	Research institutes	Various
	Factory laboratories	Various
EXPLOSIVE WASTES		
Waste munitions	Armaments	F/G
TNT, azides	Manufacture of explosives	F
Nitrated organic chemical wastes	Chemical synthesis	F

CHAPTER 3 - Planning for Hazardous Waste Management

3.1 Introduction

Once the problems of hazardous waste within a particular country have been recognized, it will be necessary to formulate policies and strategies to tackle them. Legislation and regulations must be developed and plans for facilities to recycle, treat and dispose of the waste need to be drawn up.

A coherent and well thought out plan is essential before one begins to construct facilities for hazardous waste management. A hurried decision can result in an inappropriate or overly expensive facility or in serious environmental pollution.

3.2 A Framework for Planning

Preparation of a plan for hazardous waste management is made easier if undertaken within a systematic framework. The processes involved in deriving a plan have been discussed in depth by Wilson (1981 and 1985), and this general approach to planning for waste management can be easily adapted for hazardous waste.

The systematic framework is perhaps most appropriate to planning at a regional or national level, but it can also be applied at a local level to a group of industrial plants or even to a single plant. However, effective planning must be based on a good inventory of the types and volumes of hazardous wastes presently being generated as well as good projections of future waste production.

At its simplest, a long=term plan for hazardous waste management should specify:

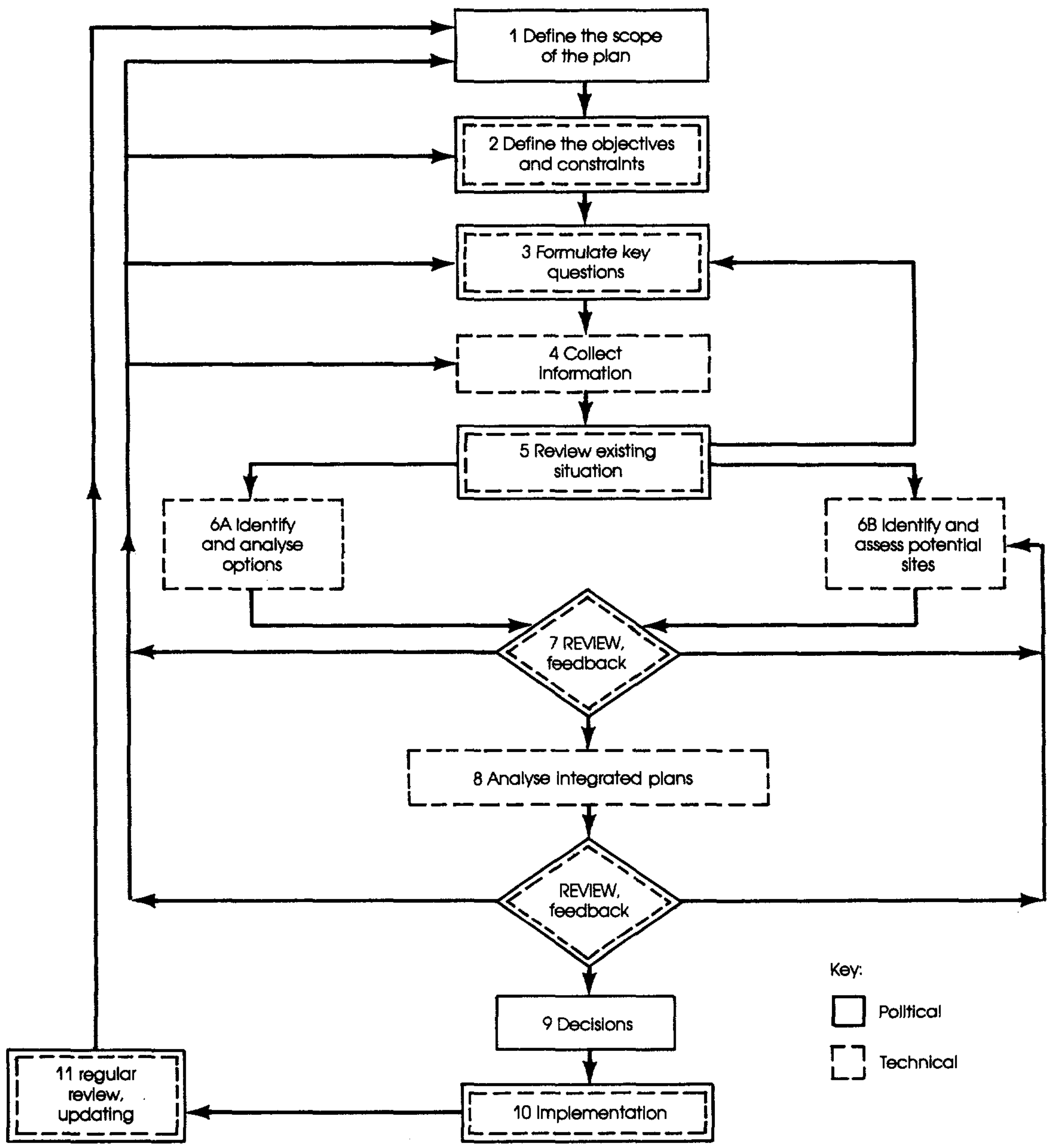
- what facilities are to be provided for the recycling, treatment or disposal of wastes;
- where and when those facilities are to be built,
- and the capacity of the planned facilities.

It will always be possible to think of a number of alternative plans, and these require technical evaluation based on a number of often conflicting criteria. Political considerations, cost, environmental impact, technical reliability and flexibility to deal with an uncertain future must be taken into account. Once all the options have been evaluated, the final choice is often a political decision.

The steps involved in deriving a plan for hazardous waste management are shown schematically in Figure 3-1. This step-by-step approach includes both strictly political decisions based on good technical analysis as well as steps involving both political and technical aspects. (See Figure 3-1.)

FIGURE 3-1

Steps in the Development of a Plan for Hazardous Waste Management



Steps in Development of a Plan for Hazardous Waste Management

- **Step 1.** At the outset it is necessary to define the scope of the plan. This is perhaps the most important step in the whole planning process. The plan must focus on the essentials of the problem, but must not be so narrowly focused that it only solves a part of the overall problem.

- **Step 2.** The next important preliminary step is to determine both the objectives to be achieved by the plan and the constraints within which it must operate.

- **Step 3.** At this point it is possible to formulate the key questions which need to be answered. These will initially be posed in fairly general terms, but will gradually become more specific as the planning process develops.

- **Step 4.** Having formulated the key questions, it is necessary to collect the information required to answer them, for example on the types and quantities of waste and on the options for waste treatment and disposal.

- **Step 5.** The next step is the preliminary evaluation and assessment of available technologies. Each option must be assessed as to how well it meets the specified objectives. Some, such as cost, can be measured in quantitative terms, while other considerations like technical reliability must be evaluated in more qualitative terms.

- **Step 6.** At this point, it will be possible to draw up a preliminary appraisal of the critical problems facing the area, region or country, and a short-list of technical options for solving them. It will be necessary to repeat some of the previous steps in the planning process, such as reviewing the scope of the plan and re-examining the objectives. When the most critical problems have been identified, effort can be devoted to refining the estimates of the quantity of particular wastes or reconsidering the basis of initial assumptions.

- **Step 7.** Once a short list of options has been drawn up, various combinations of those options should be looked at in order to generate a number of alternative integrated waste management plans. These plans are then evaluated in light of the specified objectives and constraints.

- **Step 8.** This short list of alternative plans is then subjected to another round of review and feedback. The final selection of a preferred plan will generally be a political decision.

- **Steps 9 and 10.** The selection of a plan is not the end of the process but rather the beginning. The plan must be implemented and it will require regular review and updating.

This represents a simplification of the total planning process. However, the main purposes of presenting such a framework are to demonstrate the advantages of a systematic approach, and to emphasize that planning is not a simple, once-through exercise, but rather an interactive process involving both political decision makers and technical specialists.

The remainder of this chapter expands on important aspects of each of the above steps.

3.3 Scope of the Plan (Step 1)

3.3.1 Basic Elements to be Considered

There are a number of basic elements which need to be considered at the outset in order to fully define the scope of the plan. These include:

- the quantities and types of wastes to be covered;
- the components of the waste management system (e.g. storage, collection, transport, treatment, and disposal) to be included within the plan;
- the geographical area for which the plan should be prepared;
- the time horizon;
- the responsibilities of government versus those of industry.

3.3.2 Types of Waste

It is difficult and inappropriate to plan for the management of hazardous wastes in isolation from other wastes. A proper system for hazardous waste management must exist alongside that for non-hazardous municipal, commercial and industrial wastes. If such wastes are not properly managed, for example by tipping at a municipal work dump, then it will be rather more difficult to enforce the use of proper facilities for hazardous wastes.

If a proper system and plan already exist for dealing with ordinary wastes, then it makes sense to develop a complementary plan for hazardous wastes. If, however, such a system does not exist, then it is necessary to develop plans for both non-hazardous and hazardous wastes in parallel. This will include systems for determining sources, quantities and classifications of hazardous wastes, and means for tracking wastes during transportation, treatment and disposal etc. as well as an assessment of current practices.

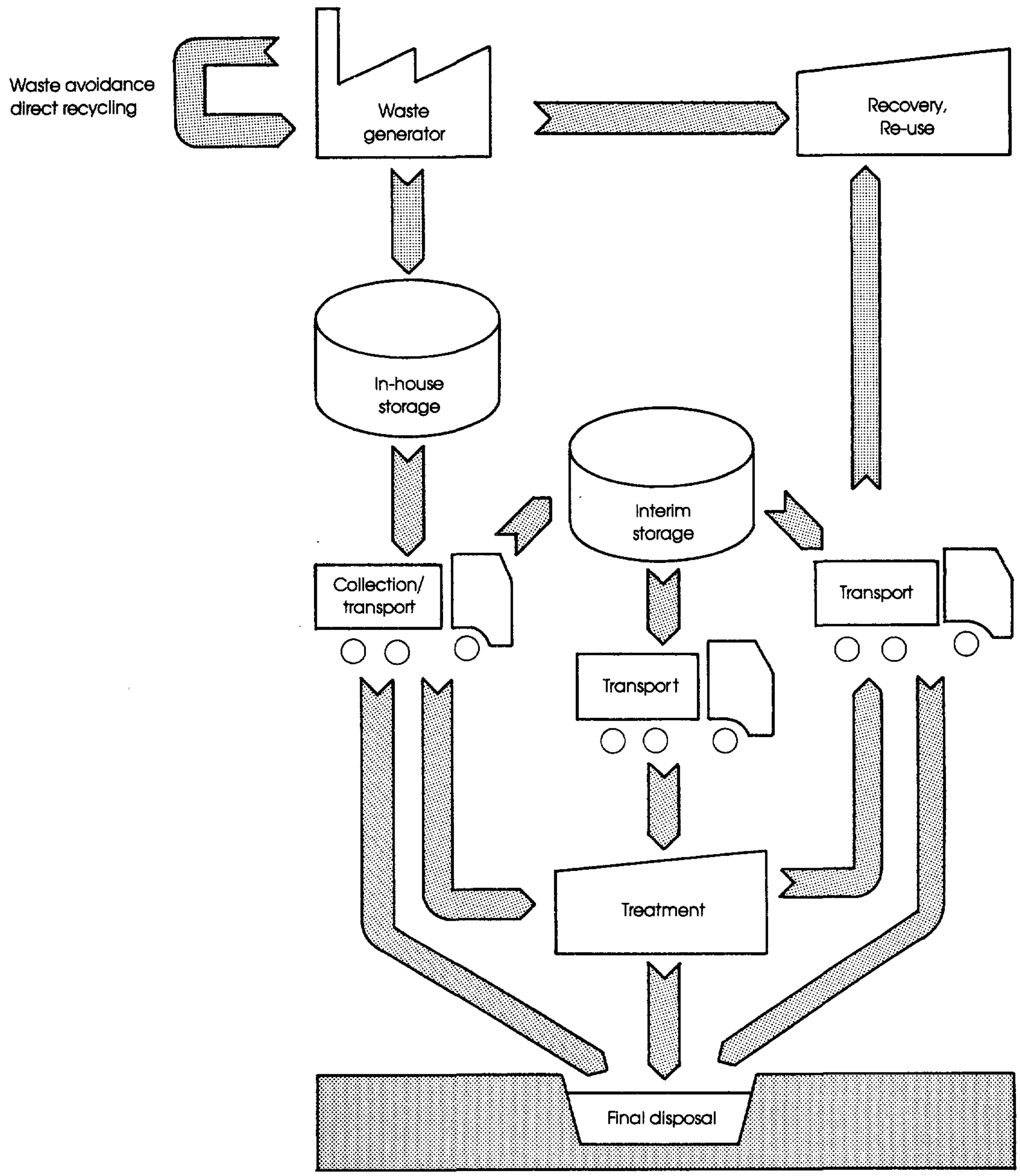
3.3.3 Components of the System to be Included Within the Plan

A simplified overview of the stages which may be involved in hazardous waste management is shown in Figure 3-2. These stages include:

- waste avoidance, reuse or recycling;
- in-house storage of waste on the producer's premises;

FIGURE 3-2

Components of the Hazardous Waste System



- collection of the waste from those premises and its subsequent transport;

- interim storage, which may include a collection or transfer station which accumulates wastes until sufficient quantity is available for economic transport;

- secondary transport;

- treatment or recycling; and

- final disposal.

A comprehensive plan for hazardous waste management in a region or country must encompass all of these stages. The plan must not be restricted to what happens to waste once it leaves the producers' premises. Facilities for on-site storage within the factory grounds and treatment and disposal by the producer himself must also be considered. See Figure 3-2.

3.3.4 Geographical Limits

The choice of the geographical area for which a waste management plan is to be produced is important and often requires cooperation between several regional or local government bodies and industry. For example, in the case of municipal waste, each autonomous municipality may wish or be required to take responsibility for its own waste. The question of regional cooperation becomes important for large metropolitan areas with a rural hinterland.

For hazardous waste, the waste quantities tend to be relatively small and the level of expertise required to deal with the wastes is relatively high. Thus, in the majority of developing countries planning at either a regional or a national level makes the most sense. Individual industries or local groups of industries also need to make their own plans, perhaps in cooperation with the authorities.

If local or regional planning is to be adopted, then coordination of those plans at a regional and national level is essential. International cooperation in the provision and use of specialized facilities may also be necessary. For example, there is insufficient hazardous waste to justify the provision of a high temperature incinerator in each of the States on the Arabian Gulf, but a regional facility serving some or all of the States could prove viable. In Europe, international cooperation may continue to be necessary to support specialized facilities such as those for PCB incineration, mercury recycling or secure, long-term storage in a salt mine.

3.3.5 Choice of Timescale for Planning

One cannot be dogmatic about the time horizon for waste management planning. It will depend very much on local circumstances and needs. There may be an immediate need to separate a short-term action program, intended to provide substantial improvements in the standard of operations over one, two or three years, from a long-term plan.

In longer term planning for new treatment and disposal facilities the appropriate timescale is determined by the anticipated lifetime of those facilities.

The time scale is also related to the types and quantities of waste being generated, and to the planner's ability to forecast the future. If it is difficult to see further than one or two years ahead, then a key factor in developing and assessing a plan must be its flexibility to handle future changes as they occur. In that case, when the quantity of hazardous waste that will need to be in handled in the future is uncertain, it may be appropriate to consider a phased implementation plan.

In general, a reasonable timeframe for which a hazardous waste management plan should be developed is between 5-20 years, perhaps most commonly between 10-15 years.

3.3.6 Government and Industry Responsibilities

Hazardous wastes are produced mainly by the manufacturing industry, and in many countries industries themselves are responsible for arranging the disposal of their wastes. Where it is possible and reasonably economic for a company to treat or dispose of its waste on its own property, government involvement is limited to monitoring the situation and ensuring that the facilities meet standards.

Where an industry does not generate a sufficient quantity of waste to justify its own treatment or disposal facility, then facilities to treat or dispose of the waste from a number of industries are required. Such facilities can be provided:

- by an independent company;
- by producer companies acting in cooperation;
- directly by Government; or
- by a combination of the above, perhaps with the participation of an international or foreign agency to provide technology, training or financing.

In countries with existing hazardous waste management systems all of the first three alternatives or combinations of them exist. Public authorities may be involved either directly, for example as partners in a joint venture with producing industries, or indirectly, for example providing low-cost finance for capital investment.

In addition the Government has responsibility for:

- setting environmental standards, regulations, or objectives;

- o ensuring that waste treatment and disposal facilities meet those requirements;
- o monitoring environmental quality;
- o maintaining inventories of waste generation; and
- o enforcing compliance with laws, regulations, etc. governing the building and operating of treatment and disposal facilities.

3.4 Objectives and Constraints (Step 2)

3.4.1 Objectives and Technical Assessment Criteria

It is important at the beginning of the planning process to have a clear idea of the objectives to be achieved by a plan for hazardous waste management. These objectives then need to be translated into clear and simple criteria which can be used for the assessment of alternative options and plans.

The principal objective of any plan for hazardous waste management is to ensure safe, efficient and economical collection, treatment and disposal of wastes; and to ensure that the system is reliable now and for the foreseeable future.

This broad statement encompasses a number of objectives, which need to be expanded to reflect particular local conditions. For each objective a number of assessment criteria can be specified. Some of these objectives are elaborated below.

o **Health Effects**

To reduce health risks and nuisance associated with the storage, collection, treatment and disposal of hazardous wastes.

o **Environmental Impact**

To reduce environmental pollution risks associated with hazardous waste treatment and disposal.

o **Technical Reliability**

To ensure that any hazardous waste technologies used are proven, safe, flexible, and maintainable under local conditions.

o **Political Acceptability**

Depending on local conditions, important objectives may include:

- maximizing the number of jobs created
- public acceptability of the facilities.

- **Resource Recovery**

  To maximize the utilization of both the material and fuel value of wastes. There may also be a requirement to minimize land usage, or to restore poor quality land.

- **Economic Viability**

  To minimize costs, subject to other (often conflicting) objectives and constraints.

- **Resource Conservation**

  To minimize the amount of hazardous wastes generated and ensure that all such wastes are collected, treated and disposed of properly.

  With so many possible objectives to be achieved by a plan, it is clear that no single plan will be best measured against all of the criteria. However, by explicitly setting out the criteria by which each of the options and plans are to be assessed, it is possible to achieve a much more systematic approach to the process of comparison.

3.4.2 Constraints

One way to simplify the evaluation process is to prioritize the objectives, perhaps reducing the number of objectives to be met by substituting instead a number of constraints. For example, instead of stating that environmental impact must be reduced to a minimum, one could define instead environmental standards which must be met. These standards are then used to 'screen' out some alternatives, and the remaining alternatives are then measured against the other criteria.[1]
A variety of constraints are likely to require particular consideration in developing countries.

- **Financial Constraints**

  There may be limits imposed by the national government on total expenditure, or specific limits on capital expenditure, phasing of expenditures, cost recovery, or the imports required to implement a plant. The government may wish to avoid a negative impact on the balance of payments. The extent and rigidity of these constraints will depend on the financing arrangements for any facilities. If the financing is to be provided largely by international companies, then a different view may be taken than if the source is either the national government or local companies.

- **Manpower Constraints**

  Any local shortage of skilled manpower for management, supervision,

[1] 'screen' a process of selection or 'filtering' which may be likened to sorting physical material by passing through a mesh screen to separate large and small particles.

operation or maintenance of facilities must be taken into account. This constraint relates directly to the objective that facilities should be reliable under local operating conditions. It also identifies the need for training to enhance locally available skills.

- **Land Use Constraints**

  Most hazardous wastes are generated near urban areas, where there is often a shortage of land. Shanty towns and other unofficial housing developments often grow up in close proximity to industrial plants, on land which could otherwise be available for on-site treatment and disposal facilities. In preparing a plan for hazardous waste management, liaison with other planners who are providing facilities for housing, industry and services, is essential. Parks, wildlife areas, and public water supplies, etc. should be identified as constraints in identifying suitable land for all facilities.

- **Local Environmental Constraints**

  In many urban areas in developing countries there is a high groundwater table, and often groundwater is the main source for domestic and even industrial purposes. This is an example of a physical environmental constraint, in this case on land disposal options. Climate may also restrict the applicability of certain options, such as solar evaporation ponds.

- **Time Constraints**

  Long and complicated land purchase procedures or intense local opposition may lead to long delays and prove to be a time constraint at certain sites. In fact, this factor may be critical in deciding on a site.

3.5 <u>The Key Questions (Step 3)</u>

Having defined the scope of the plan, the objectives to be met and the principal constraints, it is possible to formulate a series of key questions that need to be addressed by the plan.

Some of these questions may be rather general in nature, as illustrated by the following examples.

- What are the existing quantities, composition and location of hazardous wastes requiring treatment and disposal? How are these likely to change?

- To what extent are different waste streams kept segregated?

- How are the wastes stored, collected and transported at present? What are the principal problems and difficulties?

- How are the wastes recycled, treated or disposed of? What are the principal problems and difficulties?

- What options for recycling, transfer, treatment or disposal are available for overcoming these problems? How do these options rate against the various objectives and constraints of the plan? Which of the available options would prove most appropriate to the local circumstances?

- How many facilities should be provided? Should these be within individual factories, serving a group of industries, or serving the whole country? Where should such facilities be located? Are there clear priorities as to which facilities should be developed first?

- Are the existing organizational and management arrangements adequate for implementing the selected plan? Is the existing legislation adequate? Are sufficient resources available for enforcement? How is the overall plan to be financed?

These general questions encompass most of the subsequent steps set out in Figure 3-1. Each individual planning study will require the formulation of a set of key questions.

Initially, this list of questions may be posed in fairly general terms. As the scope of the plan and the objectives and constraints are defined, some more specific questions will be apparent. As one proceeds through the subsequent steps in the planning process, particularly the review of the existing situation and the initial identification and analysis of available options, it will be possible to focus the study more precisely by redefining the key questions in more specific terms.

3.6 Information Requirements (Step 4)

3.6.1 Introduction

Information is required at all stages in the preparation of a waste management plan. Information gathering should not be seen as a once-and-for-all exercise, but rather as a step-by-step process, beginning with preliminary information which is used for the initial screening of options. The results are then used to identify those key items of data to which the evaluation is most sensitive, and additional resources are put into obtaining better data on those particular aspects.

Five particular areas may be identified where information will be required:

- current sources, quantities and compositions of hazardous wastes;

- forecasts of future waste production;
- existing facilities and practices for hazardous waste management;

- information on the performance of alternative treatment and disposal management options measured against the various assessment criteria. An important element here will be information on existing industrial facilities (such as cement or lime kilns) which could be adapted for hazardous waste treatment; and

- current and potential markets for materials or energy recovered from hazardous wastes.

In the short term, considerable ingenuity is often required to collect the data necessary to review the existing situation and determine the need for immediate action; in the longer term, systems can be established through enactment of legislation and regulations that provide essential information on a regular basis.

3.6.2 Information on Waste Generators

There is often a shortage of information on the sources, quantities and types of hazardous wastes produced in an area. Here are four different approaches to data collection:

- a desk study may produce order of magnitude estimates based on international experience:

- wastes may be monitored at treatment and disposal facilities;

- a sample survey of waste generators may be conducted, using either a postal questionnaire, interviews or a combination of both; and

- a comprehensive survey of waste generators may be attempted. This is generally only possible in the long term, when comprehensive regulations to control hazardous waste have been implemented.

(i) Desk Study

In a desk study all existing information on potential waste generators, the type of industry, its size and location should be completed from existing government records.

The World Health Organization (1982) has published guidelines for the rapid assessment of quantities and types of pollution and waste sources, including discharges to air, water and land. The rapid assessment procedure is designed to utilize wherever possible data readily available in most countries, generally avoiding the need for extensive factory or source sampling surveys.

Here are some examples of the rapid assessment method:

- estimation of hazardous waste generation by multiplying the employment in a particular industrial sector by standard load factors.

- estimation of pollutant loads in effluents by multiplying a population figure, the production capacity of a particular type of industrial plant or the number of employees in a particular industrial sector by an appropriate load factor; and

- estimation of organic pollution load due to animal manure by multiplying the number of animals of a particular type by a standard load factor per animal.

The WHO report contains extensive tables of the necessary load factors for these calculations. Unfortunately, the extent of information available for hazardous wastes is comparatively limited.

Experience with carrying out detailed waste surveys in the UK and elsewhere has shown wide variations in waste-per-employee figures even within narrowly defined industry sectors. The use of locally derived factors (see iii below) is strongly recommended, because standard factors meant to be applicable in all countries are questionable. An example of this approach is given in Annex 3C.

At the present time, the extent of information which may be obtained from a preliminary desk study is limited. International experience is useful in identifying those types of industry which may be expected to produce hazardous waste (see Chapter 2). However, for quantification of the types and quantities of waste, there is no real substitute for specific local surveys.

(ii) Monitoring of Wastes Delivered for Treatment/Disposal

This approach attempts to measure the quantities of different types of waste currently being treated or disposed of, rather than measuring generation at source. The method can be applied either to all types of waste entering a site, or attention may be focused on specifically hazardous wastes. Quantities entering recognized disposal sites are likely to underestimate the total, because of losses at various stages en route to the disposal site (for example on-site disposal or temporary storage by the waste generator, intermediate salvaging of waste, unauthorized dumping, etc.).

Despite these limitation, this approach can give a reasonably reliable indication of the amounts and types of waste generated. The extent to which the results are affected by losses en route to the treatment or disposal site can usually be judged by observation, for example by looking for evidence of dumping elsewhere.

Information should be recorded on printed record sheets, including:

- date;

- time of arrival of deliveries;

- source of waste (e.g., local authority, hospital, name of firm, etc.); and

- the weight of each load, if a weighbridge is available.

If a weighbridge is not available, the type and approximate size (capacity) of vehicle (e.g., compression or non-compression, the approximate volume or qualified statement on vehicle size - "large four-axle tipper", "small two axle tipper," etc.) should be recorded. Where loads delivered are (e.g., quarter, half, three quarters, or completely full) should be recorded along with the appearance of the waste (e.g., mixed paper, metal slags and sludges, etc).

Ideally recording should take place continuously, but if continuous monitoring is not possible, entering loads should be recorded for at least two weeks (including weekends). Recording of loads entering a disposal site is likely to require additional manpower at the site to minimize delays for arriving vehicles.

(iii) Sample Survey of Waste Producers

Theoretically, a survey of waste generation at the sources should represent a more accurate way of estimating quantities of hazardous and other industrial wastes. Ideally, an initial survey should be carried out by contacting all firms in the area under consideration, but if the number of firms is too large, a representative sample should be chosen. A statistical analysis of the results will show how different factors (e.g., type of industry, number of employees, locality) effect the waste production of a firm. Subsequent surveys to update the information can then be carried out by sampling firms to see how the effect of these factors has changed.

In most areas, the cost and timescale of a complete survey is likely to be prohibitive, so a compromise must be reached between cost and accuracy. In a sample survey, a statistically selected sample of waste producers are approached for information. A number of comments can be made concerning the selection of a suitable sample.

- o Information is required on the number of premises within each industrial classification. Extrapolation from the sample to estimate the total waste production is generally on the basis of an assumed constant waste generation per employee within each industrial group. The industrial classifications used should thus be:
  - standard categories for which statistical information on the number of premises and number of employees is available; and
  - sufficiently narrow in scope so that it is reasonable to assume a constant waste generation per employee.
- o The sample should be stratified, for example identifying three groups which are expected to generate:
  - large quantities;
  - medium quantities; or
  - small quantities of industrial wastes.

This stratification could be based either on known waste production, or, more likely, on numbers of employees.

- The sample to be surveyed should be selected to include 100% of the first group, a large percentage of the second group and a smaller sample of the third group. Within each group, firms should be selected at random and care should be taken to ensure that prior knowledge or ease of access, etc. does not influence the selection.

- Statistical testing will be necessary to identify those cases where the assumption of a constant waste production per employee is not appropriate.

The survey may be carried out either by sending a questionnaire to waste producers for them to fill in and return or by conducting personal interviews or by some combination of the two. However, it is advisable that the person carrying out the survey goes around the sites with the factory employees responsible for process operation and waste disposal. Invariably, answers provided by companies to waste survey questionnaires are quite inaccurate and must be verified by a qualified hazardous waste specialist.

Experience from many parts of the world suggests that personal interviews are much more reliable than postal questionnaires, although the latter may be useful as a supplementary source of information. The use of well trained personnel is essential for interviews, so that the interviewer has a good idea of what types of waste to expect and is able to ask the right questions.

A particular advantage of carrying out a survey by personal interview is that it promotes information exchange, informing industry of the concerns and intentions of government and enabling the authorities to form a picture of the technical competence and expertise of the industries. The information gained through this exchange will assist in deciding whether treatment and disposal should be under the control of industry or under the control of government, or a combination of both.

In Annex 3A, an example is given of a typical waste generation questionnaire. This particular one was used as a basis for both interviews and a postal questionnaire in a recent waste production survey in England. The advantage of using a standard form to record the information is that it allows easy analysis, ideally by direct entry into a micro-computer. The UNDP/World Bank are developing a P.C. computer-based system for carrying out hazardous waste surveys in developing countries using the techniques discussed above. An example of the methodology is given in Annex 3C.

(iv) Comprehensive Survey

As discussed above, a comprehensive survey of waste producers is generally not feasible. However, the desirability of producing comprehensive information should be kept in mind when drafting national regulations for hazardous waste management.

There are at least three ways in which comprehensive data can be produced as a by-product of regulations to control hazardous wastes.

- o Perhaps the most comprehensive is the (annual) report by waste producers, which forms part of a registration scheme in a number of countries. The producer is required to make a regular report to the authorities on quantities, composition, and treatment and disposal methods. A number of countries view this as a vital part of the waste management system, providing good information and allowing government to learn more about waste production and so to check the data.

- o As discussed in Chapter 6, the manifest or trip-ticket system is used in many countries to ensure that waste arrives at its designated destination. If a central authority receives a copy of each manifest, this information can be used as a basis for compiling data on those wastes which are treated or disposed of outside the producing factory. However, such a system does not record information on wastes which are treated or disposed of on-site.

- o An (annual) report by treatment and disposal facility operators may also be required as part of a registration or licensing scheme. Compared to similar information reported by waste producers, data from treatment and disposal facilities give less insight into the origin of the waste and thus into the possibilities of alternative recycling, treatment or disposal methods.

3.6.3 Forecasts of Future Waste Generation

No matter how detailed the survey method, the results are only valid under the socio-political and economic conditions prevailing at the time of the survey. Any changes in government regulations, or in the political or economic conditions which directly or indirectly affect the cost or acceptability of current waste disposal practices will affect the hazardous waste inventory.

Forecasting future generation of industrial wastes is therefore notoriously difficult. In addition, many industries do not plan for more than two or three years ahead, and those plans tend to be confidential. The typical waste survey questionnaire shown in Annex 3A includes a question asking for information on changes in waste quantities or types. In many developing countries, the best source of information on which to base forecasts is likely to be the Ministry of Industry or the equivalent.

3.6.4 Information on Existing Treatment and Disposal Methods

The identification of existing treatment and disposal methods will be an important by-product of the surveys as described in Section 3.6.2 (ii) and (iii) above. For each method in use, the detailed information described in this section is required.

For any existing treatment plants, information should be readily available. For each plant it is necessary to know:

- its location;
- age;
- type (incinerator, chemical treatment, etc.);
- operating capacity;
- current throughout;
- remaining useful life;
- manpower requirements;
- percentages of recovered products, if any, and revenue received;
- operating cost; and
- ownership.

Figures for current throughout should be checked with those from elsewhere, weighbridge records, numbers of vehicles dispatched to the plant, etc. -- in order to obtain the most reliable figure. The experience has shown that waste transporters and handlers record waste by the size of the tanker vehicle or truck used and not based on the actual quantity of waste removed or disposed of. Data must be corrected by close examination of the figures and by multiplying by a correction factor for the type of waste.

It may be necessary to contact the manufacturer/plant supplier to advise on the scope for increasing plant throughout, future availability of spare parts, etc. If available, existing records may indicate the periods of breakdown and downtime and enable a measure of reliability to be determined. It may be necessary to obtain an expert engineering opinion on the remaining useful life of the plant and any modifications required.

For each existing disposal site, including on site storage and disposal at industrial sites and those receiving industrial or hazardous wastes along with other wastes, information is required on:

- its location;
- the daily/weekly amount and types of waste deposited there;
- the remaining capacity;
- facilities available on site (water, electricity, laboratory, sewer, telephone);
- its suitability (hydrogeologically, on amenity grounds, etc.);
- ownership;

- o planned future use, if any; and
- o methods of extending the life of the facility (e.g., by creating a new land form).

Determining the location of sites should generally present no problems, although unofficial sites may need to be sought out. The quantities of waste, if no weighbridge is on site, will require monitoring. The remaining capacity will require a detailed survey unless a visual inspection indicates that the amount is not of a sufficient order of magnitude to make a future contribution to waste disposal in the area. An assessment of the suitability of each site may require the use of specialist advisors, the drilling of boreholes and the testing of nearby streams and water sources.

3.6.5 Information on Potential Options for Recycling, Treatment and Disposal

In formulating a plan for hazardous waste management it will be necessary to consider many alternatives for recycling, treatment or disposal, including some not currently used in the area under study. One of the main purposes of this technical manual is to make available basic information on the various options, their technical and economic characteristics and their suitability for particular types of waste.

Some information on potential options can only be obtained locally.

- o Information is required on existing industrial facilities which could be adapted for hazardous waste treatment. For example, cement or lime kilns or industrial boilers could be adapted for the incineration of hazardous wastes.
- o Information on suitable sites for future waste treatment or disposal facilities must also be collected. This is a vital input to the process of site-selection, which is discussed in Section 3.9 below.

3.6.6 Market Survey

The viability of waste recycling resource recovery or energy recovery from wastes depends on the present or potential market for the recovered materials or energy. The economic incentive for waste recycling or recovery depends very much on government policies and regulations which affect the cost of disposal. A market survey is thus essential to assess the local situation.

The first step is to establish the base-line position, current market prices for the various materials, the specification of quality required and the pattern of demand for energy. Ideally, historical information should be sought in addition to current prices, since the markets for many recycled products can be rather unstable.

Some products recycled from hazardous wastes may not be direct substitutes for existing products. In such cases, establishing the acceptability of the product, the size of the market and the possible sale price may prove to be more problematical.

Often specific research will be required on a case-by-case basis in order to locate a market for a particular waste stream (see Section 6.4.3 on waste exchanges).

Recovered products from hazardous wastes will often take the form of energy, such as electricity or steam from incineration, or of fuel products, such as waste oil or contaminated solvents. A detailed study of the pattern of energy usage will be necessary, including the ability, both technical and financial, of medium-sized industrial users to switch to a novel energy source.

3.7 Review of the Existing Situation (Step 5)

After the preliminary collection of information, an objective review of the existing situation is required. One purpose of the review is to focus the planning on significant problems and inadequacies in the existing system. This review involves a repetition of proceeding steps, with the key questions being reformulated in more specific terms and additional information being collected where required.

The cyclical nature of the planning process is important. Collecting information is often very time-consuming and expensive. By examining initial information in order to identify specific problem areas, and then going back to collect more detailed information where it is required, one can be sure that the information being collected is going to be used. Data should never be collected without a clear purpose in mind. Improving hazardous waste management will usually require some increased costs. These include:

- capital costs for procurement of land, facilities and equipment;
- operating and maintenance costs associated with hazardous waste management systems -- including adequate manpower and training programs; and
- administrative and enforcement costs associated with the management system selected.

3.7.1 Economic Considerations

(A) Costs and Benefits

In theory, the total benefits in terms of improved public health, protection and conservation of land and other natural resources, and reduction of risk to future generations should always exceed the total costs of the hazardous waste management system. In practice it is very difficult to measure accurately the benefits and the costs because the necessary information is either not available or very difficult to develop.

In the absence of precise information government authorities must utilize more pragmatic decision-making techniques. In cases where careless handling and disposal of hazardous wastes pose imminent danger to public health, the government must move quickly to correct the problem. When the projected impacts are less severe, governments can be more cautious in trying to evaluate the costs of the proposed program in terms of its relative effectiveness. There is extensive literature on the use of environmental cost-benefit and cost-effectiveness analysis; references specifically related to hazardous wastes are included in the bibliography of this chapter.

(B) Who Pays?

There is no single answer for the question of who pays for the design and financing of a national hazardous waste management system. Usually either the polluter pays or society pays.

- Under the polluter-pays concept, government imposes direct regulations on generators and disposers of hazardous waste material. These regulations may restrict certain disposal options or specify the required treatment technology. This approach requires a well trained staff of technical experts and an effective enforcement program. Direct regulation is economically complex because the cost of complying with treatment facility standards varies greatly for different sources of hazardous waste. The possibility of having undesirable side-effects (e.g., plant closures and loss of employment) increases with the strictness and extent of the standards prescribed, although experience shows that in well run companies efficiency is enhanced through waste reduction. Alternatively government may impose a tax or charge system on the generation and disposal of hazardous wastes. This tax (or charge) could be designed to encourage less generation of hazardous materials and/or to produce the revenues needed to pay the costs of the hazardous waste management system.

- Under the society-pays concept, government may use general revenues to pay the costs of the hazardous waste management system or to provide subsidies, low interest loans or tax credits to generators and disposers of hazardous waste as incentives to improve their operations. Table 3-1 and 3-2 illustrate some of the pros and cons of taxes and subsidies. For uncontrolled dumping of hazardous waste society pays in the long term if not in the short term.

- More often than not a combination of "polluter-pays" and "society-pays" is adopted in practice, particularly in the early stages of developing a national hazardous waste management program.

The following section on financial considerations, provides more detailed guidance related to hazardous waste management systems and large projects which are key components of the system.

3.7.2 Financial Considerations

The construction, operation and maintenance of hazardous waste management

TABLE 3-1

Advantages and Disadvantages of Taxes

Advantage	Disadvantage
Minimizes control costs	Decreases corporate funds for R&D
Minimizes need for enforcement	Major administrative problem
Encourages cost-effectiveness	No precedents
Cost-benefit analyses performed by each polluter	Unforseen economic dislocation possible
Capable of rapid implementation	Encourages governmental control
Revenue raiser for social costs	If tax is too low, it could be construed as "license to pollute"
Tax continues during litigation	If tax is too high, is tantamount to fine
Creates incentive for process modifications	Quality standards absent, health protection not assured
	Precludes use of incentives
	Can be distorted into revenue collecting mechanism
	Inflation may reduce impact, as may economic growth
	No set goals

Source: Haas, Charles N. 1985. Incentive options for hazardous waste management. Journal of Environmental Systems 14(4).

TABLE 3-2

Advantages and Disadvantages of Subsidies

Factor	Advantage	Disadvantage
Establishment	Likely to be only weakly opposed	Rewards those who have yet to comply Encourages increase in discharges initially Subject to pork barrel treatment, on budget item Obtaining initial level of pollution is costly
Change	Can provide incentive for continued abatement. Encourages R&D Not biased to single technology Like to be more stable	Not effective in crises May be difficult to reduce
Administration	Spreads costs more diffusely than taxes	Can encourage entry of marginal firms May be construed as blackmail Does not discourage consumption of goods leading to pollution May need complex bureaucracy to administer
Enforcement	Likely to be lower	Will usually not be high enough to cover full cost, hence some standards may still be necessary

Source: Haas, Charles N. 1985. Incentive options for hazardous waste management. Journal of Environmental Systems 14(4).

systems represent a major financial undertaking and such considerations are an essential element of the planning process. The financial resources available from the public or private sector will necessarily influence the choice among proposed alternatives. Close attention must be paid to the cost of amortized capital, operation, and maintenance and to industry's willingness and ability to pay. It is also essential to identify and resolve the problems involved in raising the initial capital required for implementing planning decisions.

A thorough financial analysis of all the alternative technical solutions must be made. Among the issues to be addressed are the costs and benefits of each alternative, the methods and sources of funding, the allocation of costs on an equitable basis among the polluters and the beneficiaries of a project, and the willingness of government to contribute. Often governments are willing to contribute because of real concerns about public health.

This section presents (1) the framework within which financial issues are identified and analyzed; and (2) the essential elements which should be considered in allocating costs.

(A) The Financial Analysis

The financial analysis should include the following major elements:

- Preparation of cost data to compare costs of the available technical alternatives and select the most appropriate alternative.
- Identification of the responsibilities of the principal agency and the institutional arrangements that will influence financing of the collection and treatment system.
- A financing plan which identifies the various participating organizations, establishes the responsibilities of each, estimates the contribution of each organization to the annual capital and operating costs, and identifies potential sources of financing.

Identification and evaluation of the secondary impacts which could result from the proposed program, such as new employment or industrial development, etc.

(B) Developing Cost Data

Cost data are required for determining the share of costs to be assigned to each institution or agency involved in the proposed project. Estimates should be prepared jointly by the planning agency, prospective owner (if private sector) and the consulting engineer or firm. If most of the estimates are prepared by a consultant, then the other parties should be certain that all major cost categories have been identified and all assumptions are reasonable. Costs should be projected at least five years into the future, and preferably over the life of the facility, particularly if certain costs can be predicted to occur in later years. Costs which will be affected by inflation should be identified and properly adjusted as part of the projection process.

The basic costs associated with construction will include:

- o land, rights-of-way, and easements;
- o engineering, architectural, consultant, and legal fees;
- o actual construction costs, including the local agency's labor, freight, and storage charges; these should also include cost increases that could result from project delays;
- o equipment costs, including freight and storage charges;
- o financing charges (based on the financing method used), interest during construction, accounting and audit fees, taxes, and other related costs;
- o annual operation, maintenance, and replacement costs; and working capital and spare parts allowances should be made for the effects of inflation on these costs over the projected life of the project; and
- o administrative costs for the organization responsible for execution and long-term operation of the project.
- o identification of lease and foreign exchange cost component.

In many instances, data for estimating the costs for construction and operation may originate from a variety of reference sources and be based on different time periods. In order for the information to be useful it must be adjusted to a common base -- the prices that would prevail for the year in which the estimates are being prepared.

Data on costs can be adjusted to a common base by the use of annual costs indices. These indices represent the changes in price levels from year to year, based on the levels established for a specific year which is used as a reference point. The annual index reflects the changes due to inflation and other factors which influence price levels.

(C) Sources and Methods of Financing

In implementing pollution control plans provisions must be made to finance the capital costs of construction as well as long-term operation and maintenance, and future capital costs. Provisions should cover the complete system, including all its segments and phases. Funds may come from the private sector or one or more governmental levels (national, state and provincial, regional and municipal), and from industrial participants and traditional sources for financing (e.g., banks). International lending institutions may also provide financial assistance in the form of both grants, loans and equity. All these sources should be investigated during the planning process.

In some countries national and state governments may provide subsidies or loans or tax breaks for capital (including construction) costs. Within a country or state such funds may be available through several agencies, depending on such local factors as location, economic conditions, development needs, etc.

Local sources of capital funds include tax revenues loans, and bond issues of various types. Municipal governments generally have little or no surplus tax revenues, and hence are considered a poor source of funding. Usually the local government must resort to borrowing in order to furnish its share of the cost. However, in developing countries, loan funding, independent of government sources, may often be unavailable. The project must then be cut back in scope or else extended over time to facilitate financing from such annually allotted budget sources as are available.

Sources of capital at the local level include the following.

- **Bonds** - Although not frequently used in developing countries,they may take the form of:

  - special assessment bonds - issued to cover costs where specific private beneficiaries exist, and retrieved through payments from these private sources as opposed to general taxpayers;

  - general obligation bonds - backed by the credit of the issuing agency in contrast with revenue bonds which may not have the full faith and credit of the issuing agency but depend on revenues generated by project-financed income or from specified sources; and

  - industrial development bonds - issued by industry to finance capital costs for a variety of purposes, including pollution control. Government incurs no obligation since bonds are retrieved by payments received from industry.

- **Leasing/Installment Purchase** - local government acquires public facilities without initial capital expenditures for outright purchase. The lessor can be a private firm or a non-profit corporation.

- **Taxes** - this is a broad category in which part or all of the revenues generated are designated for a specific use. Types of taxes used include general sales, selective sales, use, ad valorem, property, and others.

- **Charges, Fees, and Permits** - refers to the form of assessment levied upon the beneficiaries of the public service. These may cover the capital costs, operating costs or both. For a self-supporting program the system should reflect the full cost of operation, maintenance, depreciation, and interest on debt. It should also cover a return on that portion of capital costs not financed by debt (e.g., government capital grants). In addition, funds generated from operations should be adequate to cover at least all operating costs and, if possible, all necessary requirements for debt service including sinking fund contributions for debt not redeemed by installments.

(D) Identifying Agency Responsibility

Institutional capability for assuring cost-effective management is critical. Proper management requires the execution of certain basic administrative functions, such as continuous planning and monitoring, operations and maintenance, regulation, and financial administration. These activities can be adversarial (such as operation and regulation), and when that is the case they should not be carried out by a single agency; however, responsibility for each function should be assigned so that inter-agency coordination is achieved. For example, a special district that owns and operates a hazardous waste management facility should work closely with the economic development agency in identifying future capacity needs.

(E) Preparing the Financial Plan

The purpose of the financial plan is to show in detail how the project is to be financed. It will determine whether or not the project is affordable with available resources. Who will pay? How much will each participant or beneficiary pay? When are payments to be made? These and related questions are not easily answered.

As a start, implementors and policy-makers involved should make a preliminary financial analysis, organizing and evaluating the information already assembled. The analysis should show the participating organizations, the responsibilities of each agency, and funding sources for each of the costs shown. Assumptions bearing on costs and funding should be clearly detailed.

The financial plan should include both a burden and risk analysis. The former identifies and attempts to predict the future financial burden on each of the affected institutions and on the host locales. The risk analysis shows the extent to which projected costs could vary in the event of unanticipated future changes in the proportion of external to local capital funding, and to changes in the costs for services, etc. As a planning tool, it is essential to have a fall-back position for financing if earlier assumptions do not materialize.

(F) Privatization

Privatization as an alternative method of financing various types of public works has been used frequently in some countries during the past ten years. Under privatization arrangements a private entity finances, designs, builds, owns, and operates the treatment facilities, and sells the services to industrial customers for disposal fees. Either the private entity or the community may assume responsibility for setting and collecting service charges, and for all other dealings with the customers served. Partial privatization has also been used successfully in some cases where a private contractor operates and maintains the system and provides services to customers for a fee.

Success of the privatization approach depends to a large degree on the effectiveness of enforcement of government pollution control regulations, the tax structure, tax treatment of private investments in these facilities, depreciation benefits and other tax benefits. In many instances, special legislation has been necessary to make the method a viable alternative, since the method may result in a transfer of national public revenues (i.e., government grants) to the local level via a private entity. Principal incentives for considering privatization may include:

- inability of the community to raise needed capital;
- tax advantages to the private operator;
- expected greater efficiency in the private sector due to fewer constraints than in the public sector, and
- transfer of risk for proper operation and maintenance.

A possible disadvantage of privatization is potential loss of control on the part of the public agency. Loss of control can be minimized by addressing the following issues in the agreement between private operator and public agency:

- level of service, especially with regard to reliability, safety, public health risks, and future expansions;
- future increases in costs resulting from factors which cannot initially be fully determined (change in hazardous waste characteristics, new treatment requirements due to new laws and regulations, etc);
- environmental concerns (pollution, aesthetics, noise, odors);
- future transfer of ownership of the facilities;
- resolution of disagreements between the parties;
- utilization of future financial assistance which might become available from outside sources; and
- regular inspections and regulatory control.

(G) Revenue Systems

A purpose of all charge systems - regardless of whether the charge is levied on the user or on the waste, - is to raise the revenues necessary to finance the facilities required to improve and protect the environment. Some type of pollution charge is currently imposed in many countries. All too frequently, public agencies make satisfactory financial arrangements for capital construction costs, but fail to plan for the funds needed for long-term operation and maintenance and debt servicing.

Local sources of operating income may take the form of either user charges or taxation, but user charges are the predominant method utilized. User charges can be designed to correspond to the amount of usage, or the extent of the pollution load, and are therefore considered to be more equitable than taxes.

To make the pollution control program self-supporting, charges should reflect the full cost of operations, maintenance, depreciation, debt amortization and interest. The inclusion of a depreciation factor assures the availability of funds for future plant and equipment replacements. If charges are not designed to recover all costs from those receiving the services, then the system will need to be subsidized and the financing plan prepared accordingly. All financing sources should be clearly identified.

Due to the chronic shortages of government funds in most developing countries, it is vital to find a way to retain the revenue generated by the hazardous waste management program for running and maintaining the program and not to let that revenue be put into a general fund.

(H) Revenue Requirements

The approach to determining annual revenue will vary according to ownership and regulatory requirements, as well as local policies and circumstances. For most facilities, rates are set so as to provide the annual income necessary to meet those operating and capital expenses (including debt service) not otherwise provided through subsidies, grants, or other sources. This is generally referred to as the cash basis. The following elements must be covered when determining income requirements, others may be included where necessary.

- Operation and maintenance, to cover:
  - collection system;
  - treatment facilities;
  - accounting and collection;
  - customer services;
  - administrative and general expenses; and
  - depreciation.
- Management and administration for capital projects.
- Materials and supplies for capital improvement and other projects.
- Routine capital purchases (e.g., office machines, computers, laboratory equipment, major machinery, spare parts, etc.).
- Payments for hazardous waste treatment obligations, (e.g., when part of a service area may be served by another facility or certain services are performed under contract).

- o Bond coverage requirements.
- o Debt service requirements.
- o Plant replacements.

Annual revenue requirements may also be established on a utility basis which means that a publicly owned entity is required or permitted by statute to follow rate-making practices employed by investor-owned utilities. The utility basis may be preferable for establishing the costs of serving customers outside service area boundaries. The method also has other benefits, such as recovery of cost over the life of the facility.

The four major components of the utility method are:

- o operation and maintenance expenses;
- o taxes and payments in lieu of taxes;
- o depreciation expenses; and
- o the rate base (often based on the total original cost value of facilities used or under construction) for providing services, and on which the financial rate of return is calculated.

The revenue structure should be subjected to a trial or test period of at least 12 months. The test period should be sufficiently long to be representative of the time during which the rates are expected to be in effect.

(I) Allocating Costs

As stated previously, the revenue structure should cover all of the expenses needed for capital costs and operations. Various approaches have been used. A common method is to base costs on the "cost-causative" operations performed by the hazardous waste treatment facility.

Under this method, costs are assigned according to the cost-causative agent or factor, which is defined as that characteristic or property of the hazardous waste or of the customers' requirements which predominantly influences the size and cost of the plant's components. Examples of cost-causative agents are average and peak waste generation, flammable agents, reactive agents, corrosive agents, and toxic agents. Certain basic data are required for determining the design and cost of needed facilities and the assignment of costs. As a minimum, the following factors, or cost-causative agents should be established:

- o number and type of customers;
- o average and peak hazardous generation rates;
- o waste characteristics;

- area and density of the collection system;

- contribution from other environmental protection activities (e.g., abandoned site cleanups, sludges from wastewater treatment);

- siting incentives to mitigate impact on the host community; and

- projected future potential customers and service needs.

Identifiable costs are assigned to each of these components for establishing charge rates. It is necessary to recognize seasonal or other use variations. For example, a refinery could generate large amounts of hazardous waste meeting demands for gasoline during the tourist season in the U.S. or Europe.

Once costs have been assigned to the cost-causative factors then the total service costs must be distributed according to the customers' classes. This can usually be done in three steps.

- The first step is to identify the types of services to be provided, classify the customers to be served, and assign services to each customer class. Classification should reflect groups of customers with similar service needs which can be satisfied at similar costs to the utility. Customer classification is based principally on waste generation rates and characteristics, type of service provided, whether the wastes accepted for final disposal are pre-treated or raw, and other similar considerations.

- The second step is to establish common bases for assigning cost responsibility. Each class of users is responsible for a specific number of service units which represent its share of the overall waste stream, capacity and customer costs. A service unit refers to the resources required to handle one unit, such as a cubic meter of waste, a kilogram of incineration capacity, etc.

Consideration should also be given to allocating the costs of sampling industrial waste and monitoring any required industrial pre-treatment measures. Each customer class might also be required to share in the cost of remedial handling of wastes from abandoned site cleanups.

- The final step is the establishment of costs per unit of service for each component, and the distribution of total costs per unit of service for customer classes. Responsibility for cost of service is assigned on the basis of projected waste quantity and quality, system capacity, and units of service assigned to each class.

(J) Alternative Cost Allocation Procedures

While the cost-causative procedure is most widely used, other approaches have also been successful. No one method can be considered universally applicable, since local circumstances will dictate the approach to be used. The underlying principles for all the methods are that ideally the total revenue collected should cover the total cost of the services provided, and that the distribution should be equitable and enable the utility to operate on a self-supporting basis.

3.7.3 Institutional Considerations

Hazardous waste management is a key element in preserving environmental quality. How effectively environmental goals are achieved will depend upon the degree to which a country's laws and policies are enforced.

As used in this section the term "institution" denotes the organizational forms responsible for management of various functions and programs. An "institution" could include the following:

- a national government agency or department;
- a state or provincial agency;
- a regional or river basin organization;
- a special district or authority;
- a county or municipal government; and
- a private entity, such as a public utility or an organization operating under a governmental contract.

Regardless of the levels to which individual functions are assigned the organizational structure must clearly delineate authority and responsibility for each of the political levels involved in order to assure successful development and implementation of control programs and projects.

(A) The National Organization

Responsibility for hazardous waste management in the smaller and less developed countries usually rests with the Ministry of Health, since pollution is thought of in terms of excreta disposal, which can have serious health consequences. The developed countries, on the other hand, have in most cases committed themselves politically to effective hazardous waste management through the establishment of an environmental agency under an administrator reporting directly to the head of government or to a cabinet minister. This agency is responsible for protection of all facets of the environment. Whatever the situation, it is extremely important that such an agency have a high enough governmental position to have access to the decision-making level of authority and to be readily responsive to presidential, executive, legislative, and public needs. The agency must also be provided with sufficient resources to accomplish its missions.

The national agency should concern itself with major policy and planning issues and with establishing the criteria to be applied by lower governmental levels in resolving major issues. Hazardous waste management involves many disciplines and interests. Other national agencies are also frequently involved, in particular the Ministries of Finance, Planning, and Industry. The Ministry of Education, for example, can play a role in establishing and implementing training programs. The interests and areas of responsibility of other agencies should be taken into consideration during the planning of a national hazardous waste management program.

Whatever the organizational structure, the responsible agency must be provided with sufficient staff, funds and other resources to enable it to carry out its assigned missions. It is essential that the agency is given full political and other government support on a continuing and long-term basis.

Although institutional and administrative arrangements for hazardous waste management can and do vary from country to country, there are a number of basic functions which are common to most situations. These are listed below and should be used for reference in establishing or modifying programs. Whatever the final organization, provision should be made for periodic assessment and for mechanisms to make any changes indicated as time passes.

The functions considered to be of major importance at the national level include the following:

- o Development and evaluation of national program policies, as well as appropriate recycling, treatment and disposal strategies. Establishment of procedures for updating and disseminating information about national programs and policies on a current basis.
- o Establishment of program planning criteria for application at the national, state, provincial and local levels.
- o Development of general criteria for siting hazardous waste facilities.
- o Identification of significant hazardous waste problems and organization of research on effects on human health and the environment.
- o Establishment and maintenance of demonstration programs for new technologies and applied research, emphasizing the use of low-cost and most appropriate technologies.
- o Establishment of criteria and guidelines for the use and disposal of known hazardous substances.
- o Establishment and maintenance of a nation-wide hazardous waste monitoring program with adequate laboratory, equipment and manpower resources. Promotion of complementary programs at state and local levels.
- o Establishment, maintenance, and enforcement of a manifest system

for generation, transportation and disposal of hazardous wastes.

- Establishment of criteria for resource allocation and cost recovery, as well as project selection criteria to be applied in deciding on investment alternatives.

- Provision of technical and financial assistance to states, provinces, municipalities and other pollution control agencies on planning, management, research and training, and on solving difficult or new types of problems.

- Establishment of criteria and programs for training hazardous waste control personnel.

- Compilation of scientific and technical information on hazardous waste, dissemination of this information to agencies, institutions, the general public and other segments of society.

- Coordination with other government agencies having an interest in or involvement with hazardous waste management efforts.

- Establishment and maintenance of a mechanism for citizen participation in resolving major issues and for public appeal of agency decisions.

- Establishing criteria possibly based on international agreements for transportation and movement of hazardous wastes.

(B) The State or Provincial Organization

An active interest in hazardous waste control on the part of state or provincial governments is often a key factor in effective management. The state government's responsibility is central, and progress toward solving problems and settling issues may be influenced to a high degree by the effectiveness of state action.

In larger countries, both developed and undeveloped, state or provincial governments have varying degrees of authority delegated by the national government. In smaller countries, however, all authority generally reposes in the national government. Where the latter is the case the functions as given below should be carefully examined and those which are applicable should be assumed by the national authority.

A number of conditions will affect productive use of economic and human resources -- the two vital ingredients of a successful program. These conditions include the legal basis for the program, the available resources, the administrative organization, the availability of reliable information for adequate planning, and a proper balance of program operations.

Organization for hazardous waste management must take into consideration the number and types of municipalities and other local units and the state's relationship to them, and the distribution of responsibilities within the state government structure itself.

The number of lower civil subdivisions having authority over hazardous wastes and autonomy in exercising such authority directly affects the demands on the responsible state agency and its program effectiveness. There is no single best organizational arrangement for hazardous wastes management. Whatever structure is adopted, it must ensure (as has already been stated) effective use of personnel and resources by all of the agencies involved - national, state, and local. An integrated approach by all agencies is essential.

A balance of activities is necessary for ensuring a successful program. Such activities should include provisions for:

- Securing adequate funding
- Updating the information on the nature and characteristics of the problem for program planning purposes
- Establishing the full scope of measures for securing compliance, such as information and education programs, administrative readiness, and the legal capability for positive enforcement action
- Continuing surveillance and technical study of hazardous wastes
- Technical review and assistance to municipalities, special districts, and industry. Along with personnel resources, the organization will also have other needs, such as well equipped laboratories and field facilities.

The following functions of the state, regional, or provincial government are vitally important.

- To establish and maintain on a current basis a clear definition of hazardous wastes and an inventory of hazardous waste production.
- To establish and maintain technical design standards for hazardous waste management systems.
- To establish and maintain a manifest system to cover the transportation of hazardous wastes.
- To conduct investigations and inspections to ensure compliance with standards, policies, regulations, permits, licenses, and other state statutory provisions. To carry out enforcement actions when violations occur.
- To provide technical assistance to other state agencies, local jurisdictions, industries, and the public in general covering:
    - laboratory services, through central or regional laboratories;
    - management information services;

- data collection, processing and evaluation aid; and

- environmental investigations on special problems.

- In cooperation with national agencies, to coordinate the financial and cost recovery policies in line with criteria established for resource allocation, sub-project selection, operation and enforcement.

- To disseminate technical advice and information on hazardous waste management to state and local agencies, committees, associations, and other segments of the general public.

- To coordinate emergency response capability at local levels.

- To devise a registration system for recording the location and relevant details of hazardous waste disposal sites on private property as well as for publicly operated facilities.

(C) The Local Organization

The local organization is usually a political and corporate entity established by law for the purpose of acquiring, constructing, improving, maintaining, and operating projects for the public's use, including hazardous waste collection and treatment facilities.
Many hazardous waste disposal problems can be reduced by proper regulation of collection system usage. Ineffective control of municipal waste use can result in uncontrolled industrial hazardous waste discharges.

In the urban areas the control functions may be vested in an independent municipal agency or assigned to another department (such as public health, public works, etc.) in the municipal government. The organization for managing the hazardous waste collection and disposal systems can take many forms and will depend upon local circumstances.

Major considerations for an effective state, regional, or local program include the size of the staff, occupational skills required, and the quality of administrative leadership and skills. The agency should also be provided with adequate legal services, either as part of its own staff or through state legal agencies.

Factors to be considered in organizing the staff include the total population, the population density and distribution, extent of urbanization, degree of industrialization, types of industries, and types and sizes of hazardous waste collection and disposal facilities.

At the local level, the staffs are the direct providers of many services to the public. Hence, local personnel must have the skills to establish and maintain the level of service desired by the national and state governments.

Responsibilities, authorities, levels of activities, and relationships among the agencies charged with management of hazardous wastes will change over time. The organizational structures need to be sensitive to major and significant changes, and be flexible enough to make adjustments when the need arises. At all levels, frequent retraining and upgrading of skills are essential to maintaining an efficient work force.

An effective hazardous waste management program will only be possible if air and water pollution control regulations are also effectively enforced and integrated into a fully coordinated environmental control program. If water pollution control is lax, hazardous materials will not be separated from polluted industrial effluents prior to discharge into the environment and quantities of hazardous wastes properly disposed of will be correspondingly less than under a strict enforcement regime.

Where a small community is adjacent or close to a larger one the smaller city may wish to utilize the facilities of the larger one through contract arrangements.

The use of a joint plant by several small communities in a region has proved effective in many cases. Because of economies of scale, one plant can be constructed and operated more economically than two or more smaller plants. The cost of transporting the hazardous wastes to a central treatment facility, however, will have a bearing on the economics of such arrangements. In addition, the risk of transportation accidents must be taken into account.

Whatever the organizational structure may be, the most important functions to be performed at the local level include the following:

- o To operate continously and maintain the hazardous collection and disposal systems in such a manner as to protect the interests and promote the well-being of the area served and its people. To initiate repair, replacement, expansion, and improvement projects as necessary. To review and approve designs and construction for all projects.
- o To establish and enforce standards for the control of industrial hazardous wastes.
- o To monitor, inspect and conduct laboratory testing to assure compliance with all applicable rules and regulations.
- o To coordinate hazardous waste collection and treatment activities with those of other agencies which may be involved at the national, state and regional level.
- o To coordinate the application of financial policies, project selection and resource allocation criteria with national, state and provincial levels.
- o To establish an emergency response capability to handle accidental spills of hazardous wastes through coordination of all public and medical services, etc.

- To establish community liaison and information programs to keep citizens informed on all aspects of the hazardous waste management program.

- Even if the disposal of hazardous waste is well planned and all necessary precautions are taken, continuous monitoring is required to check the adequacy of safety measures. Hazardous wastes tend to vary in composition and quantity to an extent which cannot always be anticipated. Environmental conditions may also be subject to changes which influence the effectiveness of safety measures. The monitoring strategy should therefore include regular analysis of the content of hazardous agents not only in waste but also in drainage water and ground water adjacent to landfills or dumps, as well as the content at the site of deposition. Similarly, levels of hazardous substances emitted from the stacks of incineration plants and in the surroundings of such plants should also be monitored.

3.7.4 Staffing and Training

The staffing structure must be based on the specific functions assigned to an agency, and will need to be established on an individual case-by-case basis. This section, therefore, will be limited to discussing a number of factors which should be considered in assembling a staff.

The shortage of adequately trained personnel at all levels of government has been a major obstacle to developing and implementing programs in both industrialized and developing countries. No one profession is dominant in control efforts. As problems become more complex multi-disciplinary teams with expertise in the following fields are required: civil, chemical, mechanical, and electrical engineering, the biological sciences, chemistry and the physical sciences, mathematics, operational research and systems analysis, financial analysis, economics, computer technology and applications, and others.

At all levels, but particularly at the national level, it is essential to have highly skilled professional capability, plus a comprehensive grasp of the hazardous waste management field. An adequate supporting technical and administrative staff is also essential.

3.8 Evaluation of Options (Step 6)

3.8.1 Introduction

Having identified and quantified the major types of hazardous wastes and the deficiencies in the available facilities, particularly for treatment and disposal, the next step is to identify and screen the available options for hazardous waste management.

Much of the detailed information in this manual is aimed at enabling the planner to identify a number of potential technologies for consideration in his country and to evaluate those options against his own particular objectives and constraints. It has been the sponsors' intention to provide sufficient information to allow a shortlist of appropriate solutions to be drawn up at a "pre-feasibility" level of detail. To go beyond that point more specific information relevant to the local circumstances will be required in order to determine the most appropriate and cost-effective solution.

3.8.2 The Hierarchy of Options

For any particular hazardous waste stream (i.e., type and quantity), it is possible to define a "hierarchy" of preferred management options, which should be considered in turn, the objective being to limit as far as possible the quantity of hazardous wastes requiring final disposal. In general, the sequence will be:

- waste avoidance or reduction at source;
- recycling or resource recovery;
- treatment by physical, chemical or biological means to destroy, convert or immobilize hazardous constituents;
- incineration to destroy organic wastes;
- disposal on land; and
- disposal at sea.

3.8.3 Practicable Options

Throughout this technical manual, efforts have been made to identify and discuss a number of relatively simple options which may be practicable where quantities of waste or financial resources are too small to justify conventional facilities.

Examples of such practicable options include the following:

- solar evaporation ponds as a means of sludge dewatering or drying;
- use of evaporation pits for very small quantities of solvents, where recovery or incineration is not practicable;
- encapsulation of very small quantities of difficult wastes in cement, prior to their burial in a landfill;
- adaptation of existing lime or cement kilns, or industrial boilers, to burn hazardous wastes;
- the use of engineered open-pit incinerators to burn small quantities of hazardous wastes in isolated areas; and
- "stabilization" of oily sludges by mixing with sand, or similar material, and weathering. The product may be used as a low-grow

asphalt substitute, for example to encourage rainfall run-off from the surface of a landfill site.

There is little information available on these and other options which may be of particular interest to some of the less developed countries where both financial resources and the quantities of hazardous wastes are limited.

3.8.4 Identifying Suitable Options for Particular Types of Waste

The first objective of any waste management program should be to minimize the amount of hazardous waste being generated and the amount requiring disposal. This objective can best be achieved through waste recovery and recycling.

The selection of appropriate treatment and disposal facilities will depend largely on the types and quantities of hazardous waste which are generated and on specific local factors. Not all options are suitable for all types of waste. Detailed consideration must always be given to the composition of the waste and other local factors.

As a general guide, Table 3-3 indicates treatment and disposal methods for 12 generic types of industrial waste, as recommended by the Environmental Protection Authority of Victoria in Australia (1985). Table 3-4 indicates both the hazardous properties and the recommended treatment or disposal methods for a large number of common industrial wastes. It should be emphasized that these recommendations are for the general situation as pertaining in the State of Victoria. In practice, choices will be influenced by the degree of pre-treatment carried out by the waste generator and/or by the availability of suitable facilities for treatment or disposal.

In a country with an established waste management system, it is possible to draw up a "decision tree" to provide guidance to generators on the appropriate treatment or disposal method for particular groups of wastes. Figures 3-3 and 3-4 provide examples of such decision diagrams as prepared in the United Kingdom for tarry wastes and pesticide wastes. Although some of the terminology in these diagrams is specific to the United Kingdom, they do provide useful examples of the sequence of questions which need to be asked in order to decide on the suitability of a particular option for a specific type of waste.

3.8.5 Evaluation of Options

The various options for providing waste treatment and disposal facilities must be compared and evaluated in terms of their performance as measured by the various objectives and constraints established at Step 2.

Many evaluation tools have been developed to assist the decision-maker in comparing alternatives. The most helpful is probably the use of a simple tabular or matrix presentation in which each option is compared directly against each evaluation criterion, with entries in the table being made in

TABLE 3-3

Recommended Disposal Methods in the State of Victoria, Australia

	Recovery	Incineration	Treatment Physical Chemical Bilogical	Immobilization Chemical fixation Encapsulation	Landfill
Effluents, Washwaters			xxx		
Acids, Alkalis			xxx		
Heavy Metals			xxx	xxx	residues
Toxic Inorganics			xxx	xxx	residues
Reactive Wastes			xxx		
Non-toxic Inorganics	xxx				xxx
Solvents, Oils	xxx	xxx			
Resins, Paints, Organic Sludge	xxx	xxx			
Organic Chemicals	xxx	xxx	xxx		
Pesticides		xxx	xxx		
PCBs, Chlorinated hydrocarbons		xxx			
Putrescible, Biodegradable Wastes		xxx	xxx		

Source: Environmental Protection Authority of Victoria. 1985. Draft Industrial Waste Strategy for Victoria. Melbourne.

TABLE 3-4

Properties and Disposal of Common Industrial Wastes

Waste Type	Code	Property					Recommended Disposal (items in ( ) refer to treatment residues)							
		S	F	R	P	Od	r	pc	s	l	l	b	i	d
Abattoirs residues	081				x	x				x		x	x	(x)
Acids and solutions (inorganic)														
Alkylation acid	029	x		x			x	x			(x)			(x)
Boric	029	x					x	x			(x)			(x)
Chromic	023	x		x			x	x			(x)			(x)
Fluosilic	029	x		x			x	x			(x)			(x)
Fluoboric	029	x		x			x	x			(x)			
Hydrochloric	021	x		x			x	x			(x)			
Hydrofluoric	023	x		x			x	x			(x)			
Nitric	022	x		x			x	x			(x)			
Perchloric	029	x		x			x	x			(x)			
Phosphoric	022	x		x			x	x			(x)			
Pickling acids	029	x		x			x	x			(x)			
Sulphurous	029	x		x			x	x			(x)			
Sulphuric	021	x		x			x	x			(x)			
Acids, organic														
Acetic	029	x	x	x		x	x	x			(x)			(x)
Benzoic	029						x	x			x		x	x
Butyric	029		x			x	x	x			(x)	x	x	(x)
Formic	029	x	x	x		x	x	x			(x)		x	(x)
Lactic	029					x	x	x			(x)	x		(x)
Oxalic	029	x		x			x	x			(x)			(x)
Sulphonic acids	029	x		x			x	x			(x)			(x)
Trichloacetic	029	x		x			x	x			(x)			(x)
Alkaline materials														
Ammoniacal solutions	031	x		x		x	x	x			(x)			(x)
Caustic soda or sodium hydroxide	031	x		x			x	x			(x)			(x)

TABLE 3-4 (continued)

Waste Type	Code	Property					Recommended Disposal (items in ( ) refer to treatment residues)							
		S	F	R	P	Od	r	pc	s	l	l	b	i	d
Lime Slurries	032			x			x	x		x				
Lime neutralized metal sludge	033	x							x		x			
Soda ash or sodium carbonate	031			x			x	x			(x)			(x)
Sodium phosphate or polyphosphates	031	x		x			x	x			(x)			(x)
Sodium silicate	031	x		x			x	x			(x)			(x)
Sodium sulphide	045	x				x	x	x			(x)			(x)
Sodium peroxide	051	x		x			x	x			(x)			(x)
Alkaline cleaners	031	x		x			x	x			(x)			(x)
Alkali metals	055	x	x	x			x	x			(x)			(x)
Animal residues	081				x	x	x			x		x	x	
Antimony compounds	045	x					x	x	(x)		(x)			
Arsenic compounds	045	x					x	x	(x)		(x)			
Asbestos wastes	181	x							x	x				
Bags-previously contained hazardous materials	121	x							x		x		x	
Barium salts	045	x					x	x	x		(x)			
Bleaching powders and solutions	051	x		x		x	x	x			x			
Boron (compounds of)	045	x					x	x			x			
Cadmium (compounds of)	045	x					x	x	(x)		(x)			
Cannery wastes	082				x	x				x		x		
Cattle dips and residues	049	x			x	x		x	x	(x)	(x)			
Carbonization liquors (wood or coal)	159					x		x					x	
Chlorinated hydrocarbons														
Chloroform	074	x				x	x						x	
Carbon tetrachloride	074	x				x	x						x	

TABLE 3-4 (continued)

Waste Type	Code	Property					Recommended Disposal (items in ( ) refer to treatment residues)							
		S	F	R	P	Od	r	pc	s	l	l	b	i	d
Ethylene dichloride	074	x				x	x						x	
Perchlorethylene	074	x				x	x						x	
Trichloroethane	074	x				x	x						x	
Trichloroethylene	074	x				x	x						x	
Chromium compounds	045	x					x	x	x		(x)			
Copper compounds	045	x					x	x	x		(x)			
Cyanides														
Plating residues	013	x					x	x			(x)			(x)
Heat treatment residues	014	x					x	x			(x)			(x)
Metal complexes	015	x					x	x			(x)			(x)
Organo-cyanides	159	x	x	x			x	x			(x)			
Detergents	155	x					x	x			x			(x)
Disinfectants	159						x	x			(x)			(x)
Drugs (see Pharmaceuticals and residues														
Dyestuffs	061/9	x									x		x	
Explosives	053	x	x	x				x						
Fats, grease	104				x	x	x			x		x	x	
Fish residues	081				x	x				x		x	x	
Fluorides and compounds containing fluorine	042	x					x	x	x		x			
Fruit residues	082				x	x				x		x		(x)
Fungicides (see Pesticides)														
Grease trap residues														
domestic	083				x	x				x		x		
commercial	084				x	x					x	x		
Hydrocarbons														
Lubricating oil	101		x				x						x	
Light oils	101		x				x						x	

TABLE 3-4 (continued)

Waste Type	Code	Property					Recommended Disposal (items in ( ) refer to treatment residues)							
		S	F	R	P	Od	r	pc	s	l	l	b	i	d
Solvents (low flash-point)	072		x				x						x	
Insecticides and contaminated containers (see Pesticides)														
Isocyanates	159	x	x	x			x	x			(x)			(x)
Lead compounds	045	x					x	x	(x)		(x)			
Lime slurries	032			x			x	x		x				
Lime neutralized metal sludges	033	x							x		x			
Manganese compounds	047	x					x	x	(x)		(x)			
Mercaptans	153	x	x			x		x					x	
Mercury and compounds	045	x					x	x	(x)		(x)			
Methacrylates	153	x	x			x	x	x					x	
Motor fuel additives and residues	071	x	x								x		x	
Nickel compounds	045	x					x	x	x		(x)			
Nitrates	051	x		x			x	x			(x)			(x)
Oils														
Cutting oils	101		x				x				x		x	
Cutting emulsions	103					x		x			x		(x)	(x)
Hydrocarbon	101		x				x				x		x	
Lubricating	101		x				x				x		x	
Organo-Nitrates	159	x	x	x			x	x						
Oxidizing agents														
Chlorates	051	x		x			x	x			(x)			(x)
Chromates	051	x					x	x			(x)			(x)
Nitrates	051	x		x			x	x			(x)			(x)
Permanganates	051	x		x			x	x			(x)			(x)
Peroxides	051	x		x			x	x			(x)			(x)
Paint thinners (low flashpoint)	072		x				x						x	
Pesticides	161/9						x	x	(x)		(x)		x	

TABLE 3-4 (continued)

Waste Type	Code	Property					Recommended Disposal (items in ( ) refer to treatment residues)							
		S	F	R	P	Od	r	pc	s	l	l	b	i	d
Peroxides	051	x		x			x	x			(x)			(x)
Pharmaceuticals and residues	154	x						x	x	(x)	x		x	
Phenol and phenolic compounds	152	x				x							x	
Phosphorus residues	054	x	x	x		x		x	x		(x)		x	
Pickling acids/ solutions	029	x		x			x	x			(x)			(x)
Poisons (any material which would be labelled under Schedules 1-7 of the Poisons Act)	045	x							x		x			x
Polychlorinated Biphenyls (PCBs)	156	x						x					x	
Radioactive materials (controlled under other Acts)	171/2	x						x	(x)		(x)			
Scallop shells	081				x	x				x				
Selenium compounds	045	x					x	x	x		(x)			
Sheep dips and residues	049	x						x	x	(x)	(x)			
Solvents, low flash-point	072		x				x						x	
Sulphides	045	x				x	x	x			(x)			(x)
Sulphites	045	x				x	x	x			(x)			(x)
Surfactants	155	x					x				x		x	
Tetraethyl lead residues	151	x	x						x		(x)		x	
Timber preservatives	049	x						x	(x)		(x)			
Thallium compounds	045	x					x	x	(x)		(x)			
Triple Interceptor Trap residues (T.I.T.)	103					x		x		x				x
Turpentine residues	071	x	x				x						x	

TABLE 3-4 (continued)

Waste Type	Code	Property					Recommended Disposal (items in ( ) refer to treatment residues)							
		S	F	R	P	Od	r	pc	s	l	l	b	i	d
Vanadium compounds	045	x					x		x		(x)			
Vegetable wastes	082				x	x	x			x		x		
Waxes-animal & plant	182		x			x	x			x			x	
Weedicides (see Pesticides)														
White spirits	072		x				x						x	
Zinc compounds	045	x					x	x			x			

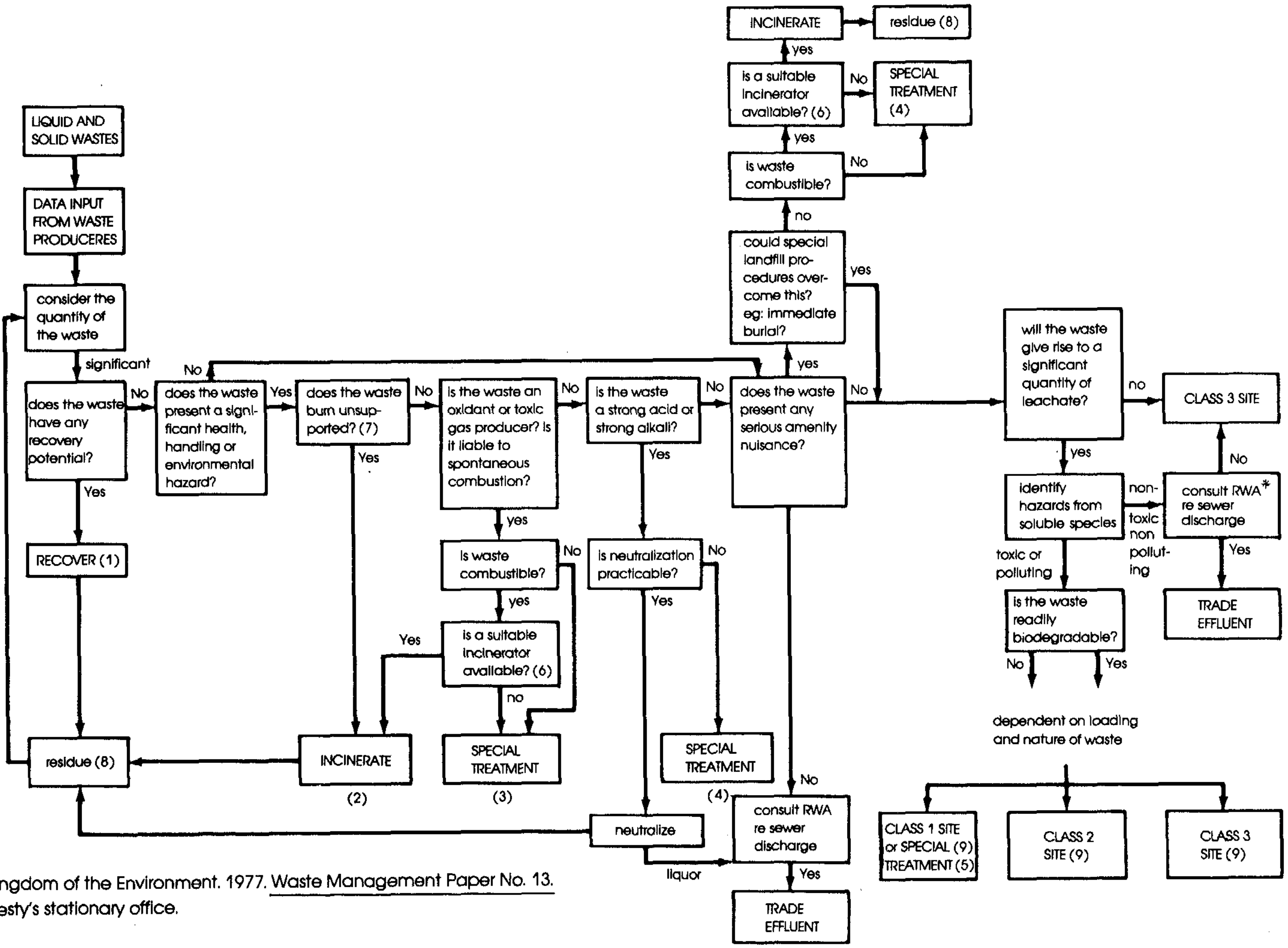
Recommendations are those for general situations. Practical choices will be influenced by appropriate pre-treatment and/or availability of suitable facilities. Disposal to sewers watercourses and landfill is subject to acceptance criteria of relevant authorities.

S - toxic, carcenogenic
F - flammable
R - corrosive, highly reactive
P - putrescible
Od - odorous

r - recovery, recycle
pc - physical/chemical treatment
s - solidification
l - landfill (normal) (licensed)
l* - landfill (impervious) (licensed)
b - bilogical treatment
i - incineration
d - water/sewer discharge subject to agreement or license

Source: Environmental Protection Authority for Victoria. 1985.
Draft Industrial Waste Strategy for Victoria.

FIGURE 3-3 Tarry Wastes, etc. Technical Memorandum: Liquid and Solid Waste



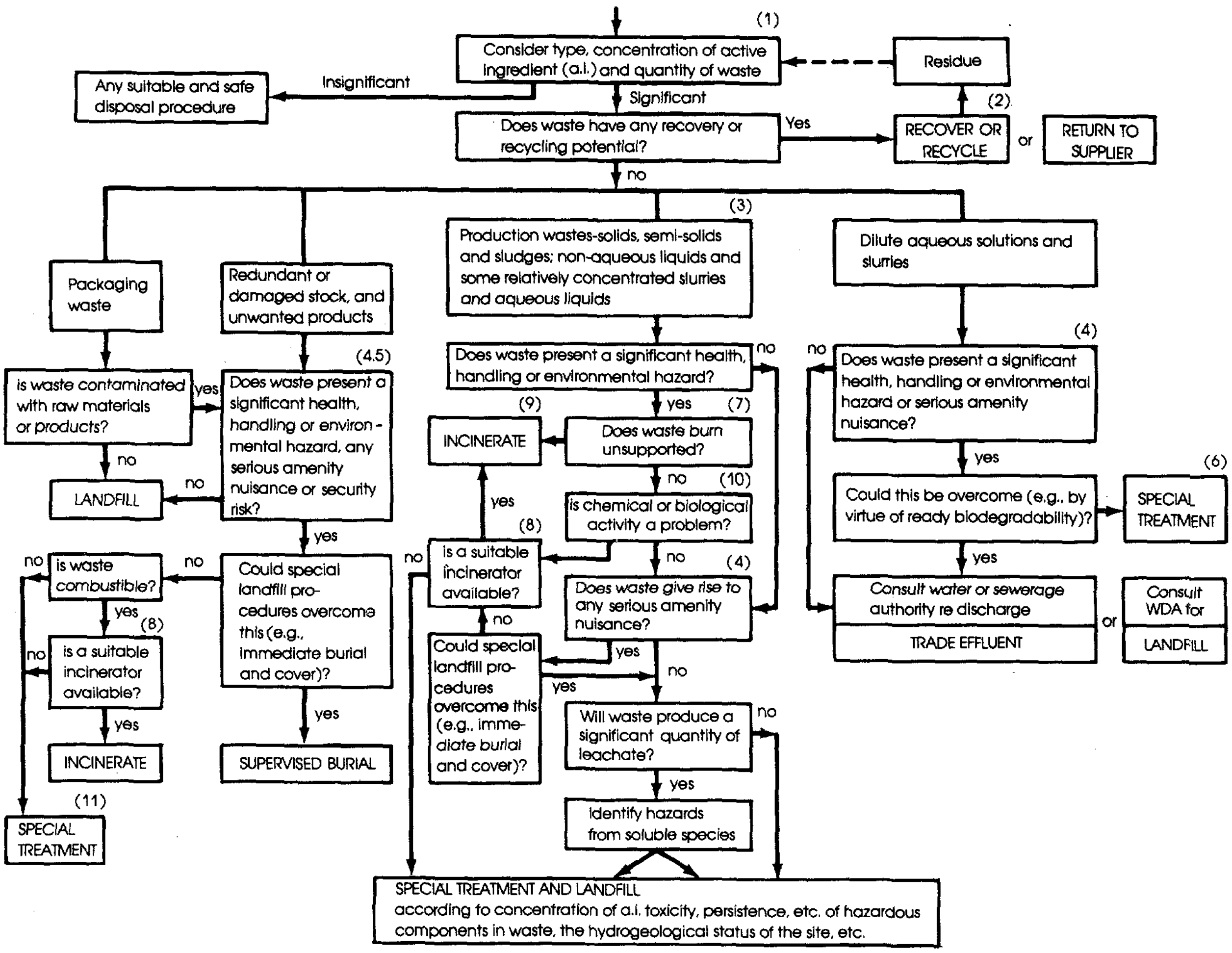
Source: United Kingdom of the Environment. 1977. Waste Management Paper No. 13. London: Her Majesty's stationary office.

*Note: The above landfill disposal routes represent an idealized situation. It is recognized that site suitability cannot be determined remotely, since such considerations as local conditions, degree of loading, the relative toxicities and rates of biodegradation of wastes will influence site selection. In practice, the mutual suitability of sites and wastes must be assessed by local consultation between the Waste Disposal Authorities, the Regional Authorities (River Purification Board in Scotland) and other relevant bodies.

Notes: 1. Recovery is taken to include the recovery of potential heat values. 2. No option is given for this incineration step, subject to its technical feasibility. All other incineration recommendations are preferred options, to prolong the life of limited landfill capacity, and to minimize landfill site hydraulic load in the case of liquids. 3. In this context, special treatment will encompass chemical treatment (which may include neutralization), chemical solidification or mineshaft disposal. 4. In addition to (3) above, this could include submission to Ministry of Agriculture, Fisheries and Food for consideration or sea-disposal. 5. In addition to (3) and (4) above, special treatment in this context should include incineration. 6. This is less likely for solid wastes than for liquid wastes, although suitable facilities do exist within the private waste disposal sector. In addition, municipal refuse incinerators may be suitable for some solid materials subject to the constraints imposed by design considerations, except where a waste's aggessive or otherwise hazardous properties exclude this from aspects of safety. 7. A simple widely applicable test procedure is recommended whereby 5 ml of a liquid waste in a shallow dish maintained at 40°C are subjected to a naked flame (applied remotely - i.e., a taper is preferable to a match or cigarette lighter). All liquids which ignite and sustain combustion are deemed to be capable of burning unsupported. 8. Neutralization, recovery and incineration operations may produce residues which should be considered as wastes for disposal. 9. Class I, II and III sites refer to sites providing a significant element of containment (I), sites allowing slow leachate migration (II)) and sites allowing rapid leachate migration (III).

FIGURE 3-4

Decision Diagram of Disposal Guidelines for Pestice Wastes



The waste producer (if necessary by finding out from the supplier) should be the primary source of information on the properties of a particular waste. 1.The quantities of both current and future arisings of specific wastes and the handling capacity and loading of potential disposal sites are factors to be considered when deciding on a disposal route. The disposal of a particular waste as a one-off arising may require a totally different solution as opposed to a similar material arising on a regular basis in quantities which may be orders of magnitude greater or smaller. The overall properties of a waste should be taken into account, as well as the properties of the active ingredient(s). 2. Recovery includes reuse as a fuel, and selling clean empty containers as scrap. 3. Some aqueous wastes containing relatively high concentrations of organic and/or inorganic chemicals may not be readily amenable to treatment or discharge as liquid effluent. 4. *The generation of offensive odours is likely to be the main amenity nuisance.* 5. Secure disposal is of importance for all branded products and for all materials attractive to children or which could be subject to misuse. 6. In this context special treatment could include chemical and/or biological treatment, or the use of physical methods such as settlement of aqueous suspensions, sometimes by lagooning within the factory curtilage. 7. A simple widely-applicable test procedure is recommended whereby 5 ml of a liquid waste in a shallow dish are subject to a naked flame (applied remotely;-ie a taper is preferable to a match or cigarette lighter) and the temperature slowly raised to 40°C, with frequent application of the naked flame. All liquids which ignite and sustain combustion are deemed to be capable of burning unsupported. 8. Incineration facilities exist within the private waste disposal sector. Municipal incinerators may be suitable for small arisings of some solid materials (particularly packaging wastes, reject products and returned goods) after taking into account handling, safety and plant design considerations. 9. Liquids that burn unsupported should be incinerated where technically feasible. 10. Chemical properties of consequence might include pH value, reactivity of wastes with acids to produce toxic gases, liability to spontaneous combustion, or oxidizing potential towards organic materials. Undesirable biological activity might result from the presence of certain microbiological pesticide active ingredients in significant quantity. 11. Special treatment in this context could include chemical treatment, fixation for inorganic (or mainly inorganic) wastes, or physical methods such as puncturing or crushing of empty containers. The hydrogeological status of a landfill site will take account of its ability to contain leachate or otherwise allow of dilution and attenuation by natural processes in the underlying strata.

Source: United Kingdom Department of the Environment. 1980. Pesticide Waste Management Paper No. 21. London: Her Majesty's Stationary Office.

a mixture of quantitative and qualitative terms. This ensures that all of the relevant information is available to the decision-maker in a systematic framework. A multi-criteria comparison of this kind requires careful judgement, and will generally result in the selection of a short-list of options for further consideration. The use of a more mechanistic approach, for example ranking and weighting, tends to miss the multi-dimensional nature of the decision and is not, in general, to be recommended (Wilson 1981).

3.9 Site Selection (Step 7)

3.9.1 General Principles

In parallel to the analysis of treatment and disposal options, it is necessary to identify and assess potential sites for new facilities. Major waste handling facilities should be sited in accordance with planning criteria which incorporate safety, environmental, social, political and technical constraints. Consistent with the overall planning process, the goals of site selection should be:

- to minimize health risks;
- to maximize public acceptability;
- to minimize environmental impacts; and
- to minimize costs.

Risks to human health, environmental impacts and public acceptability are important factors to be considered in the site selection process. There may even be instances where they overlap in significance. For example, there may be situations where relatively minor health risk-related concerns are superseded by major environmental impacts. Similarly a major cost consideration might supersede a minor risk or environmental impact consideration.

To meet the siting goals, two basic tasks must be undertaken:

- the definition of factors and criteria for site selection; and
- the establishing of methods to apply the criteria in a rational way.

3.9.2 Siting Factors

Listings of selection criteria have been developed over the years in a large number of siting studies. While there is general agreement on the basic types of siting factors to be used for hazardous waste facilities, the manner of their classification and presentation varies widely. Table 3-5 is a listing of siting factors prepared for hazardous waste facilities in Victoria, Australia (Environment Protection Authority of Victoria 1985).

TABLE 3-5

Siting Factors

Physical Constraints

- Surface soils
- Subsurface geology and aquifers
- Topography
- Surface water and streams, flooding
- Seismic stability
- Land stability
- Wind direction

Ecological Constraints

- Flora and fauna
- Conservation value
- Habitat value

Human Values

- Landscape
- Recreation value
- Historical/archaeological/cultural
- Population density
- Employment opportunities

Land Use

- Agricultural value
- Extractive industry/mining
- Water supply (surface and subsurface)
- Development potential
- Transportation corridor or utility use
- Land use designation (residential/industrial, etc.)

Waste Disposal Suitability

- Proximity to users
- Transport access
- Availability to utilities and services
- Adjacent land use; zoning
- Site modifications

Source: Environmental Protection Authority of Victoria. 1985. Draft Industrial Waste Strategy for Victoria. Melbourne.

The factors are presented here as points for consideration rather than the basis for absolute exclusion criteria. Not all the factors listed are equally applicable to each type of hazardous waste treatment and disposal facility.

For example, for landfills and storage or evaporation ponds, the physical characteristics of the site should be more important than for other types of facilities where the wastes do not remain on the site and do not normally come into contact with the soil. Special attention should be given to the hydrogeologic suitability of the site (e.g., subsurface geology and aquifers and permeability of soils). To some extent these constraints can be overcome by site modification (e.g., by the use of liners to provide artificial barriers to waste migration). The strategy recommended here, however, is to select, wherever possible, sites with a high degree of natural containment. Careful attention to the hydrogeologic conditions can reduce the site preparation cost considerably and can substantially increase the safety of these facilities.

Special physical constraints also apply in the case of incineration. Consideration should be given to the prevailing wind direction and air dispersion characteristics of the site. Avoid areas prone to atmospheric inversion conditions or upwind of and in close proximity to residential areas.

Ecological constraints cannot readily be overcome by plant design changes and in some cases may be treated as exclusion criteria in identifying suitable sites.

The construction and operation of all hazardous waste treatment and disposal facilities will have a disruptive influence on human values, (e.g., landscape, recreation) as a result of traffic, noise, possible odors, etc. To some extent, these can be mitigated by inclusion of a buffer zone or other measures. In other cases, mitigation will be only partially successful or will not be possible at all.

The importance of existing land use is determined to some extent by the pattern of future development, both urban and rural. The extent to which a waste disposal facility would compete with agricultural or mining interests for example will vary from place to place. Water supply catchments and future development zones are best avoided to eliminate any potential conflicts, and to give some assurance of long term environmental security.

The suitability of a site for waste disposal must also be assessed so that the facility can effectively serve its intended customers and can itself draw on utilities such as sewerage, drainage and power.

In general, the relative importance of the various siting factors depends very much on the local physical, social and economic conditions. Certain critical choices, or "trade-offs", may have to be made, for example:

- the preservation of agricultural land versus the potential for local environmental impacts;

- the minimizing of transportation distance versus optimizing site hydrogeologic suitability; and

- the use of vacant land near existing urban development versus a site in a remote rural area.

Such trade-offs require careful consideration, and should be made with the participation of the communities and organizations potentially effected. Public participation is an important step in obtaining public acceptance. The need for public input has been clearly illustrated in many siting efforts for hazardous waste treatment and disposal facilities (Centaur Associates Inc. 1979). The reader is referred to a handbook prepared by the United States Environmental Protection Agency which discusses in detail the techniques that can be used to address local concerns (U.S. Environmental Protection Agency 1982).

3.9.3 A Phased Approach to Site Selection

The site selection process should be a step-by-step evolution involving the evaluation of alternatives and the narrowing of geographic focus. A case study is presented in Annex 3B.

During each phase of site selection, the size of the study area is reduced by identifying issues, developing criteria appropriate to the scale of investigation and applying the criteria in a structured format. This phased approach offers the advantage of reducing the total amount of data to be handled and restricts detailed evaluation to relatively few sites. The number of phases and their complexity can be varied to suit the nature of the facilities, the study area and the preferences of the waste controlling authority. Typically however, a project siting exercise might be carried out in four phases:

- **Phase 1** - Definition of study areas and site requirements, including land area.

- **Phase 2** - Identification of areas for potential sites by application of exclusion criteria to the study area.

- **Phase 3** - Identification of candidate sites by 'screening' of areas identified in Phase 2.

- **Phase 4** - Comparative evaluation of candidate sites using detailed site evaluation criteria.

Providing that the criteria for each phase of the site selection process are chosen appropriately, the phased approach should result in an environmentally and economically sound selection of sites.

3.10 Review and Feedback (Step 8)

It has been emphasized throughout this discussion that the planning process is not a linear sequence of steps, but rather a complex structure where one gradually learns from experience and uses that information to re-evaluate preceding steps.

At this point in the procedure, it will be possible to draw up a preliminary appraisal of the critical problems facing the area, region or country, and a short list of technical options for solving those problems. Feedback will be necessary:

- o to check the scope of the plan;
- o to re-examine the objectives and constraints; and
- o to obtain better information on certain key aspects.

In the initial screening of available technologies and options one should consider as many alternatives as possible. The analysis should be sufficiently detailed to identify the most critical assumptions or items of input data (for example particular waste quantities, particular items in a cost estimate or particular environmental impacts of a facility), so that more effort can be devoted to obtaining better information on those aspects.

3.11 Generating and Evaluating Alternative Plans (Step 9)

Following any necessary review and feedback, the planner will have produced a short-list of technologies for hazardous waste management which are potentially attractive in terms of local needs and circumstances. If the quantities of waste are relatively small, or the waste sources are relatively concentrated, then perhaps the planner has enough information at this point on which to base the choice of an appropriate plan. However, in some cases, it may be necessary to take into account the geographical distribution of waste generators, and also a number of possible locations for each of the alternative treatment or disposal facilities. A relatively concise short-list of alternative technologies may thus give rise to a much longer list of feasible alternative plans, taking into account the various combinations of alternatives for collection and transport and for the location of facilities.

In evaluating alternative plans, it is important to consider how easy it will be to implement the different schemes. Particular questions which need to be considered include:

- o what regulations will be required to ensure that the system is used?
- o how easy will it be to enforce the use of the system?
- o are there significant differences in the organizational arrangements required?
- o how able is the overall system to cope with a failure in any one part?
- o how is the scheme going to be financed?

Alternative plans require systematic evaluation and assessment against the various objectives and constraints. For example, a careful trade-off is required between the benefits of concentrating all the wastes at a central facility, with increased safety and security of the operation and decreased treatment/disposal cost, as against two or more local facilities, which have the counterbalancing advantage of reducing both the risks and the costs associated with transportation.

The evaluation of alternative regional plans for waste management including use of collection and transfer stations may be attempted using computer models. These models generally utilize linear programming or similar techniques to produce an "optimal" solution for a given situation. A number of comments should be made (Wilson 1981 and 1985):

- mathematical models can, in general, focus only on one criterion, which is usually that of least cost;
- to be useful, a model should incorporate sensitivity analysis, to identify both critical assumptions and key items of uncertain data;
- the most useful type of model is not a "black box" to produce the optimum solution, but rather an "interactive", user-friendly model which can be used by the waste manager himself to construct and evaluate alternative plans; and
- most "black box" models, and those interactive models as exist, are designed for regional planning of solid waste management, usually in developed countries.

In the longer term, computer models are likely to play an increasing role in developing countries in planning for waste management, including hazardous wastes, and planning authorities may wish to develop their own capability in this field.

3.12 Selecting and Implementing the Preferred Plan (Steps 10 and 11)

In principle, once the alternative plans have been evaluated, it is possible for the decision-makers to assess the advantages and disadvantages and to select the preferred plan. However, in practice another review and feedback exercise similar to that described in Section 3.10 is required.

The implementation of a plan for hazardous waste management does not simply depend upon the mandate of the authorities. It must be a cooperative exercise between the authorities, the waste producers and those who operate the disposal facilities, possibly also including the general public.

Coordination and consultation with all of these interested parties is essential for successful implementation of the selected scheme.

A plan for hazardous waste management is not an end in itself, it represents merely the first step. It must be implemented, its progress monitored and it must be regularly reviewed to identify the need for change. Among the aspects which require particular attention are the following:

- adequate regulations;
- effective enforcement;
- coordination with, and cooperation from, waste producers;
- professional management of facilities; and
- proper training of staff.

3.13 References 3.1 - 3.12

Centaur Associates, Inc. 1979. Siting of Hazardous Waste Management Facilities and Public Opposition. Prepared for United States Environmental Protection Agency. Washington, D.C.

Environment Protection Authority of Victoria. 1985. Draft Industrial Waste Strategy for Victoria. Melbourne.

United Kingdom Department of the Environment. 1976. Waste Management Paper No.2; 1977. Waste Management Paper No.13; and 1980. Pesticide Waste Management Paper No.21. London: Her Majesty's Stationary Office.

United States Environmental Protection Agency. 1982. Using Compensation and Incentives when Siting Hazardous Waste Management Facilities. A Handbook. Washington, D.C.

Wilson D.C. 1981. Waste Management - Planning Evaluation, Technologies. Oxford: Oxford University Press.

Wilson D.C. 1985. Long-term planning for solid waste management. Waste Management & Research, 3: 203-216.

World Health Organization. (WHO) 1982. Rapid Assessment of Sources of Air, Water and Land Pollution. Offset Publication No. 62. Geneva: WHO.

3.14 Bibliography 3.1 - 3.12

Anderson, Fredick R., et al. 1977. Environmental Improvement through Economic Incentives. Baltimore: The Johns Hopkins University Press.

Bernstein, Corrine S. 1985. Private funds, public project. Civil Engineering 55 (9).

Haas, Charles N. 1985. Incentive options for hazardous waste management. Journal of Environmental Systems 14 (4).

Hufschmidt, Maynard M., et al. 1983. Environment, Natural Systems, and Development -- An Economic Valuation Guide. Baltimore: The Johns HopkinsUniversity Press.

Jones, David C. 1984. Municipal Accounting for Developing Countries. CIPFA-World Bank Publication. Washington, D.C.: The World Bank.

Kalbermatten, John M., et al. 1982. Appropriate Sanitation Alternatives - A Technical and Economic Appraisal. World Bank Studies in Water Supply and Sanitation 1. Baltimore: The Johns Hopkins University Press.

M. M. Dillon, Ltd. 1985. Site Selection Process, Phase 4, Selection of a Preferred Site. Prepared for Ontario Waste Management Corporation. Toronto.

Monet, M. P. 1985. Financing resource recovery projects. World Wastes 28 (6).

Organization for Economic Cooperation and Development. 1986. The Costs and Benefits of Hazardous Waste Management. Paris.

Peskin, Henry M., and Eugene P. Seskin (eds). 1985. Cost Benefit Analysis and Water Pollution Policy. Washington, D.C.: The Urban Institute.

UN Economic Commission for Europe-Committee on Water Problems. 1984. Principles and Methods of Economic Incentives including the Fixing of Fees and Charges in Water Supply and Waste Water Disposal Systems. Vol. 1. Geneva.

U.S. Environmental Protection Agency. 1983. Benefit-Cost Assessment Handbook for Water Programs. Vol. 1. Research Triangle Park, North Carolina: Research Triangle Institute.

U.S. Environmental Protection Agency. 1984. Financing Capability Summary Foldout - A Simplified Approach. Washington, D.C.

Ray, Anadarup. 1975. Cost Benefit Analysis -- Issues and Methodologies. A World Bank Publication. Baltimore: The Johns Hopkins University Press.

Shubnell, Lawrence. 1982. Project Structure and Financial Risk Sharing: Financing the Bresco Project. Maryland: Government Finance Association, Inc.

Watson, Douglas J., and W. Johnson Gerald. 1985. Privatization fills the funding gap. In Public Works. Ridgewood, New Jersey: Public Works Journal Corporation.

ANNEX 3A - A Typical Wastes Generation Questionnaire for Use as Part of a Waste Disposal Survey

Notes on the Waste Generation Questionnaire

This questionnaire is designed for use both in personal interviews and in a postal survey. It allows direct entry of the data into a computer for processing.

The questionnaire is designed to obtain information on a wide variety of waste types, primarily those produced by industry and commerce.

The first page comprises general information on the firm, its products or services and the number of employees. For computerization the firm is given a unique serial number and assigned to an MLH group (the minimum list heading which is a subdivision of the UK standard industrial classification) and a local authority area, which allows the information from the survey to be sub-divided on a geological basis.

Question 1 contains information on the types of waste produced. Part (A) distinguishes 10 broad waste types while Part (B) sub-divides industrial wastes into some 20 types. Both of these categorizations are based on those of the UK Department of the Environment (1976). It will be noted that an additional six waste categories are allowed under category (B), in order that the waste producer can describe this waste in his own words if he is un-sure as to which category it should come under. These wastes can then be re-classified by the survey team.

Questions 2 to 8 are answered for each type of waste separately. Typically, a firm might fill in four columns for, say, waste types I, IIIA, and VIII.

Question 2 categorizes each waste stream by its physical form: solid, semi-solid or liquid.

Questions 3 asks the producer to categorize his waste according to its hazardous properties. The quality of this information from postal returns is generally poor.

Questions 4 to 7 concern the quantity of waste. Most producers do not measure or weigh the waste quantities, so the aim of these questions is to enable an estimate of the volume to be derived from their size and the frequency with which they are emptied. In order to manipulate the information from the survey in tons, the computer program also requires the survey team to assign a typical waste density to each type of waste.

Question 8 concerns the treatment or disposal arrangements for each type of waste. In the particular area for which this questionnaire was designed, the predominant disposal methods are by landfill, operated either by the local authority or by a private contractor, or by the producer himself. For general use, other disposal options should be added to the list on the questionnaire.

Question 9 concerns by-products which are sold to other companies for recovery, recycling or reuse. Information is requested both on the type of waste and on the quantities.

Question 10 invites the respondent to provide any information on likely changes in the quantities or type of waste to be generated in the future.

WASTE DISPOSAL SURVEY
WASTE ARISING QUESTIONNAIRE

Name of firm

Products/Services

No. of employees

Address

Tel. No./Ext. No.

Name of contact | Position

Date

OFFICE USE ONLY

Serial No. | Code

MLH Group | L.A. Area

Postal survey (Dates of despatch) 1. 2.

Interview (Personal) Y/N on by whom

Interview (Telephone) Y/N on by

NOTES:

1. Waste type (classification)
Please identify the types of waste produced by your premises by ticking one or more of the primary categories listed below:

a)

Category	Waste Type	
I	Household and commercial (inc. waste from offices, shops, etc.)	______
II	Medical, surgical and veterinary wastes.	______
III	Industrial waste (see below for details)	______
IV	Mine and quarry waste	______
V	Radioactive waste	______
VI	Farm waste	______
VII	Construction and demolition waste	______
VIII	Sewage sludge, gully and cesspit emptyings	______
IX	Old cars, vehicles, etc.	______
X	Ash (from incinerators), etc..	______

If you have ticked category 'III' above, please specify the waste type produced by ticking one or more of the categories listed below:

b)

Category	Waste Type	Examples	
A	Inorganic acid.........	(sulphur acid, etc.)......	______
B	Organic acids....................................		______
C	Alkalis................	(Ammonia, caustic, etc.)..	______
D	Toxic metal compounds..	(Lead, zinc compounds, etc.)	______
E	Non-toxic metal compounds	(Iron, etc.)..............	______
F	Metals (elemental).....	(Mercury, aluminium)......	______
G	Metal oxides.....................................		______
H	Inorganic compounds....	(Cyanides, sulphides).....	______
J	Other inorganics.......	(Asbestos, slug, silt, etc.)	______
K	Organic compounds......	(PCB's cleaning solvents, etc.)	______
L	Polymeric materials....	(Epoxy resin, latex rubber, etc.)	______
M	Fuel, oil and greases..	(Fats, waxes, kerosene, etc.)	______
N	Fine chemicals and biocides............	(Pesticides, cosmetics, drugs, etc.)	______
P	Misc. chemicals wastes............................		______
Q	Filter materials, treatment........................ sludge and contaminated rubbish		______
R	Interceptor waste, tars.	(From pits and traps, etc.)	______
S	Miscellaneous waste.....	(Soaps, paper, glass, etc.)	______
T	Animal and food waste...	(Slaughter and processing waste, etc.)	______

Please describe any industrial wastes not falling within the above waste types.

U ____
V ____
W ____
X ____
Y ____
Z ____

Please respond to the following questions for each waste category (and sub-category for industrial waste) ticked in question one (1). Should further space be needed, please photocopy relevant pages.

Waste category

	________	________	________	________	________

2. (a) What is the nature of the waste?

o solid	________	________	________	________	________
o semi/solid	________	________	________	________	________
o liquid	________	________	________	________	________

(b) Do you have any information on the chemical composition of the waste (yes/no)?
If yes, please attach details on a separate sheet.

3. In your experience, is the waste:

o flammable	________	________	________	________	________
o toxic	________	________	________	________	________
o corrosive	________	________	________	________	________
o odorous	________	________	________	________	________
o non-hazardous	________	________	________	________	________

4. Please state the numbers of units of each of the following types used for temporary waste storage:

o dustbin/sack	________	________	________	________	________
o bulk bin	________	________	________	________	________
o skip	________	________	________	________	________
o tank	________	________	________	________	________
o drum	________	________	________	________	________
o other (specify)	________	________	________	________	________

5. What is the size of each of the units described in (4) above?

o dustbin/ sack	________	________	________	________	________
o bulk bin	________	________	________	________	________
o skip	________	________	________	________	________
o tank	________	________	________	________	________
o drum	________	________	________	________	________
o other (specify)	________	________	________	________	________

NB. Please give approx. sizes in litres or m^3 (cubic metres).
For example standard dustbin = 70 litres, a standard paladin (industrial dustbin) = 950 litres ($0.95m^3$)

6. How often are the units emptied per week?

o dustbin/ sack	________	________	________	________	________
o bulk bin	________	________	________	________	________
o skip	________	________	________	________	________
o tank	________	________	________	________	________
o drum	________	________	________	________	________
o other (specify)	________	________	________	________	________

7. What is the weekly waste total calculated from 4-6 above (m^3)?

________ ________ ________ ________ ________

8. What are your current disposal arrangements for each waste category?

o Local authority	________	________	________	________	________
o Contractor (name)	________	________	________	________	________
o Self (specify: e.g. burn, bury or transport else-where)	________	________	________	________	________
o Other (specify)	________	________	________	________	________

9. Does your company produce any 'waste' by-products which are sold to other companies (i.e., scrap, metal, plastics, paper, oil, solvents, tires)?

If yes, please specify:

____
____
____

10. Are there likely to be any changes in the facilities operated by your company which are likely to increase or decrease the volumes of waste generated (i.e., due to an expansion or retraction programme) or alter the type of waste generated (due to a process change) in the foreseeable future?

If yes, please specify:

____
____
____

Thank you for your cooperation.
Please return the above forms in the SAE provided at your earliest convenience.
Please do not hesitate to telephone for additional information or assistance to complete the above.

Source: Environmental Resources Limited (ERL). 1987.

ANNEX 3B - The Siting of a Hazardous Waste Management Facility in the Province of Ontario, Canada - A Case Study

Introduction

This case study describes the siting of a hazardous waste management facility undertaken by the Ontario Waste Management Corporation (OWMC). Ontario Waste Management Corporation is a Provincial Crown Corporation in Toronto which was set up by the Ontario Government. The prime responsibility of OWMC is to establish and operate a hazardous waste management system for Ontario by properly treating and disposing of all hazardous wastes generated in Ontario that require special treatment and disposal.

As part of this mandate OWMC has undertaken a facilities development process of which site selection forms a major component. A preferred site was selected after exhaustive evaluation of possible options, and at the time of writing is undergoing more detailed evaluation to confirm its suitability. The summarized description of the siting process provided here is abstracted largely from reports prepared by OWMC (1983 a,b; 1984; and 1985).

This case study is presented as an example of how siting a hazardous waste management facility was undertaken in a particular situation. It is intended to demonstrate the principles that should be followed in the siting process rather than prescribe a detailed set of steps that must be taken in every case. This case may involve a more detailed and lengthy process than is appropriate in all situations. These considerations should be borne in mind when using the case study as a model for siting of facilities in developing countries.

Facilities Development Process

To understand the selection study, it is important to know something about the overall Facilities Development Process within which site selection is incorporated.

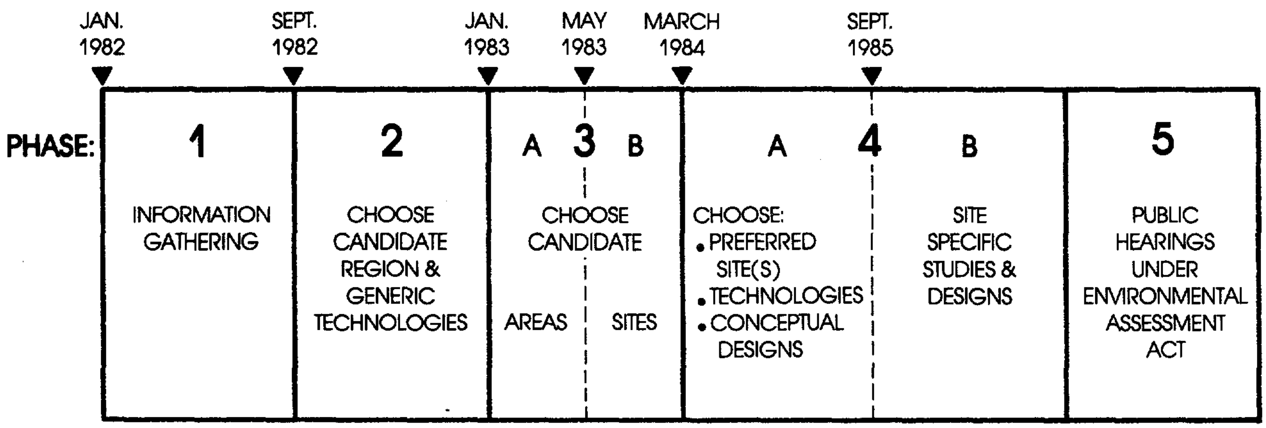
The Facilities Development Process was designed to move OWMC through the process of selecting a site hearing and approval processes required prior to construction. The process consists of five phases as shown in Figure 3B-1.

Phase 1 was completed in September, 1982. It defined the nature and size of the industrial waste problem in Ontario, as well as the principles, goals and objectives of the program. Phase I also outlined possible treatment technologies, described the hydrogeologic conditions throughout Southern Ontario (i.e., the underground rock and soil conditions and how they affect underground water movement) and identified the engineering, planning and environmental issues that should be considered in later phases. Preferred hydrogeologic conditions -- specifically, thick, uniform clay-textured soils -- were considered an important site requirement to provide natural containment and thereby avoid total reliance on engineered safety features to contain potentially toxic waste residues.

Phase 2 was completed in January, 1983. It resulted in the search for sites being narrowed to the Golden Horseshoe region of Southern Ontario where approximately 70% of Ontario's special waste is generated and where the risks

FIGURE 3B-1

Facilities Development Process



Source: Ontario Waste Management Corporation. 1985. Facilities Development Process. Phase 4A Report.

and costs associated with transporting these wastes are minimized. In addition, in Phase 2 it was determined treatment and disposal facilities should consist of three major components:

- o high temperature thermal destruction;
- o physical/chemical treatment processes, including solidification; and
- o engineered landfill,

and that only one installation of each major component should be constructed.

In Phase 3, OWMC identified 20 candidate areas within the Golden Horseshoe which were selected on the basis of environmental, transportation, airshed, and agricultural land use considerations.

Within these areas, OWMC then identified 152 potential sites by applying a series of 40 factors encompassing a range of physical, social, resource, biological, land use, transportation and agricultural considerations. By introducing more detailed information on these factors, these potential sites were then reduced to eight candidate sites.

Finally in Phase 4A, a preferred site was identified and the conceptual design of the facility developed. A perspective drawing of the proposed facility is shown in Figure 3B-2.

Within this Facilities Development Process, the site selection study was undertaken in five steps. The steps in the site selection study and their relationship to the overall Facilities Development Process can be summarized as follows:

- o Step 1 (Phase 2): Narrowing the Search to a Single Geographic Region in Ontario.
- o Step 2 (Phase 3): Identifying Candidate Areas within this Region.
- o Step 3 (Phase 3): Identifying Candidate Sites within Candidate Areas
- o Step 4 (Phase 4A): Comparison of Candidate Sites and Identification of a Preferred Site(s).
- o Step 5 (Phase 4B): Detailed Testing of Preferred Sites.

This step-by-step approach to site selection is illustrated schematically in Figure 3B-3. The principles, goals and objectives developed for site selection and each of the five steps themselves are outlined in the following sections.

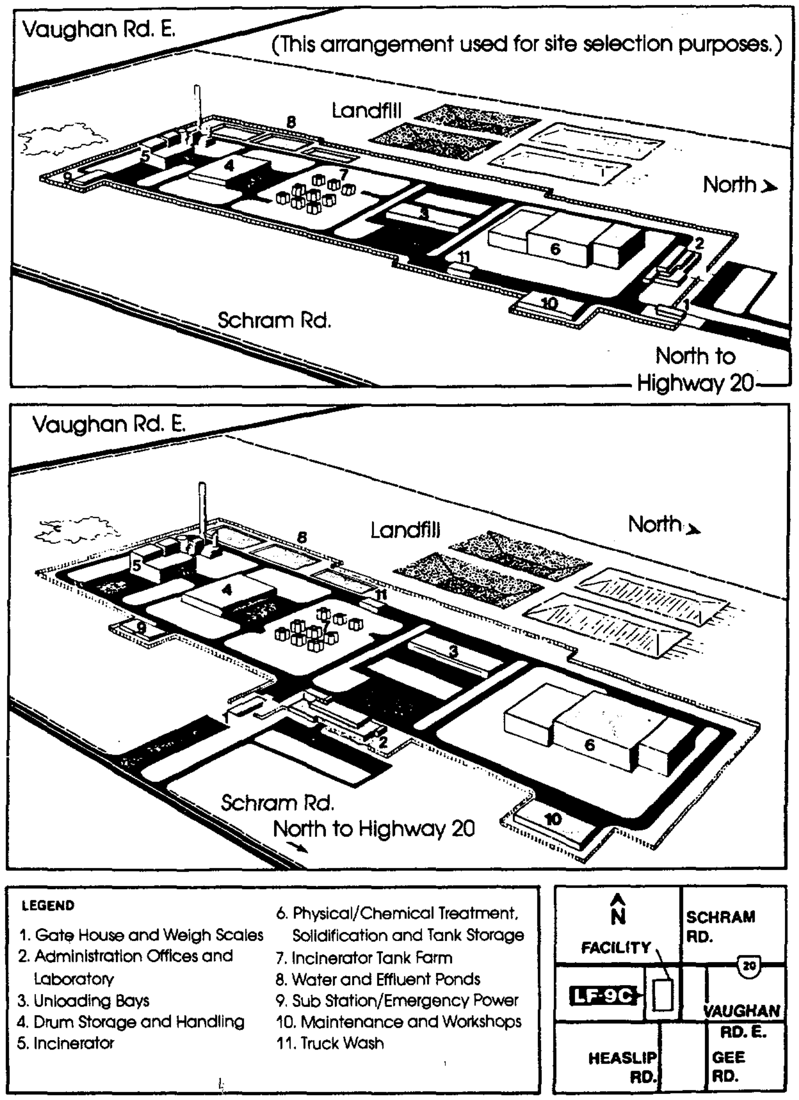
Principles and Goals of Site Selection

General Principles

The following general principles were identified in shaping the search process for sites:

FIGURE 3B-2

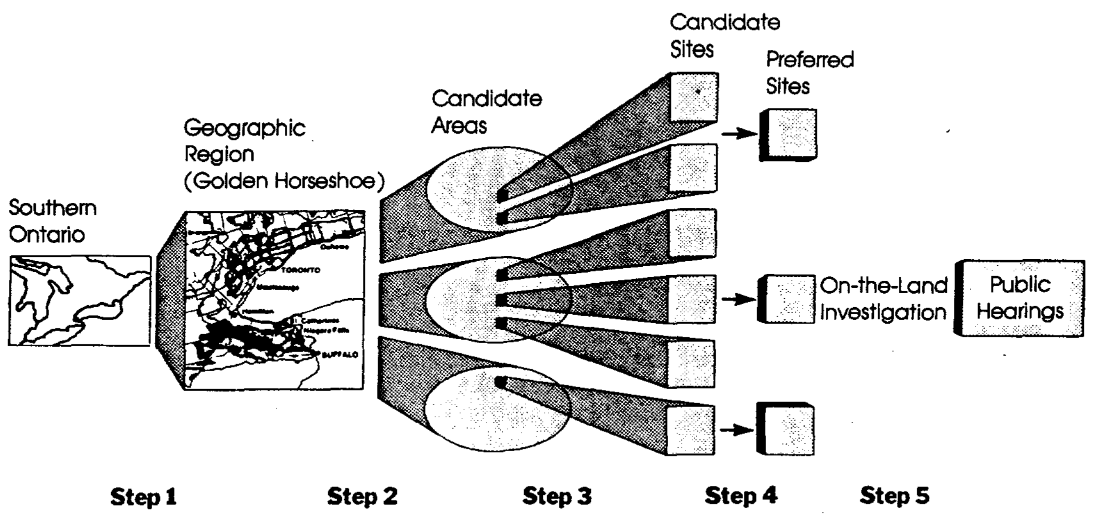
Perspective of Proposed Facility: Two Possible Conceptual Arrangements



Source: Ontario Waste Management Corporation. 1985. Facilities Development Process. Phase 4A Report.

FIGURE 3B-3

A Step-by-Step Approach to Site Selection



- **Progressive refinement of the search process:** The process must move through a series of steps, which involve the evaluation of alternatives and the narrowing of geographic focus.

- **Definition of the environment:** The very broad and inclusive definition of the environment used in the Ontario Environmental Assessment Act (1975) was adopted by OWMC. The environmental impact assessment process embodied in this Act also was adopted by OWMC.

- **Protection of human health and the environment:** The primary consideration must be protecting human health and the environment.

- **The involvement of those who might be affected:** Agencies, organizations and people who might be affected must be consulted at key decision points in the process (i.e., site selection must include a thorough consultation process).

- **Efficiency and effectiveness of the process:** The costs and time involved in conducting a detailed analysis and evaluation of every conceivable site across the entire province were considered prohibitive. The search and selection process must focus available resources systematically on critical concerns and reach definite conclusions as quickly as possible.

Goals and Objectives

Based on these principles, three site selection goals were adopted by OWMC, in the following order of importance.

- Minimize risk to human health.

- Minimize environmental impacts.

- Minimize financial costs to OWMC.

Although this ranking was assigned to reflect the general priorities of OWMC and the public, it was also recognized that there would be instances where these goals overlap in significance. For example, there may be instances where relatively minor risk-related concerns are overridden by major environmental impacts. Similarly, a major cost consideration might override a minor health risk or environmental impact consideration.

In addition to these three goals, specific objectives were also formulated. The objectives represent a refinement and elaboration of the goals. In the case of the goal of minimizing environmental impacts, for example, the objectives specify different elements of the environment to be protected. The goals and objectives were applied to the entire site selection process. For each step in the process specific factors were identified pertaining to the areas of concern being addressed in that step. A large number of objectives were developed to assist in shaping and directing the site selection process. These objectives are listed in Table 3B-1.

TABLE 3B-1

Site Selection Objectives

I. Goal

- To minimize risk to human health.

Objectives

(A) Site - "Pathways" into the Environment

(1) To site facility components in hydrogeologic settings that will restrict naturally the movement of contaminants and protect ground water resources, and to utilize engineering measures where required to ensure maximum environmental safety.

(2) To site facility components in hydrogeologic settings that will restrict naturally the movement of contaminants and protect human health, surface water resources and aquatic ecosystems.

(3) To site facility components in airsheds that have atmospheric dispersion characteristics which will protect air quality and aquatic and terrestrial ecosystems.

(4) To site facility components in settings that minimize the hazards to the site as a result of such conditions as flooding, potential susceptibility to seismic disturbance, and slope failures, and to utilize engineering measures where required to ensure maximum environmental safety.

(5) To site facility components in settings that facilitate environmental monitoring as well as the application of countermeasures, including back up emergency services.

(6) To site facility components to minimize potential contamination of food chains in the environment.

(7) To site facility components to minimize hazards to the site from other uses which might contribute to the likelihood or severity of a release of contaminants.

(8) To locate effluent discharge locations (if required) with dispersion characteristics that will protect human health, surface water resources and aquatic ecosystems.

(B) Site - Human Exposure

(1) To site facility components to minimize the number of people who might be exposed, as well as the duration of their exposure, to contaminants in the event of a release.

TABLE 3B-1 (continued)

(2) To site facility components to minimize the potential for the contamination of existing wells and other sources of water for human or animal consumption.

(3) To site facility components to minimize the potential for exposure of populations which are sensitive to exposure and/or are difficult to evacuate.

(C) Transportation and Discharge - "Pathways" into the Environment

(1) To select transportation routes and modes which minimize the likelihood of a release of contaminants during transit.

(2) To site facility components to that the physical settings along the access routes to the site(s) naturally restrict the movement of contaminants and protect human health, terrestrial and aquatic ecosystems.

(D) Transportation and Discharge - Human Exposure

(1) To site facility components to minimize the number of people who might be exposed and the duration of that exposure to contaminants along access routes to the site(s) in the event of a release.

(2) To site facility components to minimize the potential for exposure of populations who are sensitive to exposure and/or difficult to evacuate along access routes to the site(s).

II. **Goals**

- To minimize environmental impacts.

Objectives

(A) Physical and Biological

(1) To avoid destruction and minimize disruption of significant natural ecosystems.

(2) To avoid destruction and minimize disruption of significant vegetation or wildlife populations.

(3) To avoid destruction and minimize disruption of rare or uncommon species of plant and animal life.

(4) To avoid destruction and minimize disruption to significant landforms and other physical features.

(5) To minimize physical impacts on surface water such as sedimentation and changes in base flow.

TABLE 3B-1 (continued)

(6) To minimize impacts on surface water quality from emissions.

(B) Resources

(1) To minimize the amount of land required to safely construct and operate the facility component(s).

(2) To minimize displacement of prime agricultural soils.

(3) To minimize displacement and disruption of existing farm enteprises.

(4) To minimize disruption to productive agricultural areas and to stable agricultural communities.

(5) To minimize displacement and disruption to other natural resources uses such as mineral aggregates.

(6) To minimize disruption of economically and/or recreationally important biological resources.

(7) To minimize displacement of and disruption to heritage and archaelogical resources.

(8) To minimize displacement of areas with a potential for resource development.

(C) Land Uses and Land Ownership

(1) To minimize conflict with existing, committed, proposed and planned land uses.

(2) To minimize the potential for the establishment of the facility components in locations characterized by similar industrial uses.

(3) To minimize the amount of private property required and the disruption to land ownership patterns.

(4) To minimize conflict with Federal, Provincial, municipal and native communities, policies, programmes and plans.

(D) Social

(1) To minimize the displacement of people, particularly those groups and individuals vulnerable to change.

(2) To minimize conflict between the facility components, operations and the use and enjoyment of properties in the vicinity of the site(s), as a result of visual intrusion, noise, etc.

TABLE 3B-1 (continued)

(3) To minimize losses or impacts on buildings and features of archaeological, historical, symbolic, cultural or social significance.

(4) To maximize compatibility between the facility components and the character, image, traditions and lifestyle of the affected area.

(5) To establish the facility components, to the extent possible, in areas in which the local communities can adapt to the type of changes which might result from the project.

(6) To maximize community acceptance of the facility components.

(7) To maximize compatibility with the visual character and appearance of the landscape in the vicinity of the facility components.

(8) To minimize conflict between the transportation of hazardous wastes to the facility components and the use and enjoyment of properties along access routes to the site(s).

(9) To minimize conflict between facility-related traffic and local traffic by ensuring that access routes provide an acceptable level of service.

(E) Economics

(1) To maximize local employment opportunities.

(2) To minimize the displacement of businesses.

(3) To minimize property value depreciation.

(4) To minimize disruption to the operations of local businesses.

(5) To maximize compatibility with the local and regional economic character of the affected area.

(6) To minimize adverse effects upon the provision and use of public and private community services and facilities.

(7) To minimize the burden on municipal services and finance.

III. Goal

To minimize financial costs to OWMC.

Objectives

(A) To minimize capital and operating costs to the greatest extent possible without sacrificing environmental quality.

(1) To minimize approvals costs.

TABLE 3B-1 (continued)

(2) To minimize site acquisition costs.

(3) To minimize on-site development costs (e.g., clearing, drainage, grading, screening and other engineering modifications).

(4) To minimize off-site development (e.g., service extensions, road improvements).

(5) To minimize development and/or operations costs associated with the construction and operations of the facility component(s), e.g. (duplicate facility).

(6) To minimize development and/or operations costs necessitated by site or area characteristics (e.g., special remedial or monitoring measures to protect human health and the environment).

(7) To minimize on and off-site development and/or operations costs associated with effluent dispersion (e.g., pipelines).

(8) To minimize transportation operations costs associated with hauling hazardous wastes to and among facility components.

No one site can satisfy all the site selection objectives. With any given site or area under consideration, some objectives will be largely satisfied. Other objectives will not be satisfied or will only be partially satisfied. Thus, in the process of identifying and comparing potential sites, consideration was given to differences in the levels of satisfaction of various objectives. For example, trade-offs may have to be made between a facility location in an area of potential environmental significance versus a location on good agricultural land. The consideration of such "trade-offs" was crucial to decisions concerning the acceptability of the risks, impacts and costs associated with the preferred site(s).

Establishing the inventory of hazardous wastes was another important element of the information gathering exercise in Phase 1, but this is not described here. However, it was established that 30,000 tons per year of organic waste and 120,000 tons per year of inorganic waste were being generated in the region.

Step 1 - Narrowing the Search to a Single Geographic Region in Ontario

In selecting a single geographic region in Ontario as the area for further study, consideration was given principally to two factors:

- geological and hydrogeological conditions likely to offer higher probability of locating suitable sites, particularly with regard to landfilling; and

- proximity to the principal areas of hazardous waste generation in the Province.

Based on these considerations a number of zones of land within the geographic region of the Golden Horseshoe, an area at the west end of Lake Ontario where approximately 70% of Ontario's special waste is generated, were selected for further consideration. These zones were considered generally to have more suitable geological and hydrogeological conditions for the natural containment of hazardous wastes. By focusing on these zones, a second natural level of protection beyond that provided by the engineered design of the facilities would be built into the search and selection procedure.

Step - 2 Identifying Candidate Areas Within this Region

Siting Factors

In Step 2 of the siting process, consideration was given to siting factors for the individual components of the facilities as well as for the facilities as a whole (i.e., the option of having the facilities split between two locations was introduced). Siting factors were developed based on environmental, transportation and land use considerations and the following guiding principles:

- **Protection of the environment.** A second natural level of protection of the environment beyond that provided for by the design and operating procedures of the facility is essential.

- **Likelihood of suitability.** Because the factors addressed at this stage are at a broad regional scale, the suitability of a selected candidate area can be expressed at this stage only as a likelihood or probability of suitability, subject to later more detailed investigations.

- **The maintenance of choice.** As decisions on exclusion are made, there must be the assurance at each step of the process that no significant or unique alternatives are being discarded.

Using this approach, 19 candidate areas were identified within the Golden Horseshoe and, following further analysis, a twentieth candidate area was subsequently identified.

Estimation of Site Size

Concurrent with Step 2 of the siting process, a number of refinements were made to the facility design and operations concepts. Of particular relevance to siting were the issues of buffer zones and facility arrangement options, and their influence on site size.

(A) Buffer Zones

The size of any buffer zone will depend on the characteristics of the site and its surrounding area. OWMC's general approach was to consider sites that provided adequate space beyond the operating area of the treatment facilities. This extra space was necessary to monitor for any accidental releases of contaminants and to provide a zone where appropriate containment action would be possible if there were an accidental release. This area of space around the operating area is called the technical buffer zone.

Preliminary planning estimates suggested a minimum technical buffer zone of 400 m around treatment facilities, except in heavy industrial areas where the need might be less. This buffer zone was included in the estimated site size to minimize impacts on sensitive uses and features that might exist in close proximity to the facility.

(B) Facility Arrangement Options

The second issue that affected site size was how the three major waste treatment and disposal components could be grouped for siting purposes. The three facilities can be arranged in five variations:

Dispersed

1. separate incinerator
   separate physical/chemical plant
   separate landfill

Partially Integrated

2. incinerator
   and
   a physical/chemical plant — with separate landfill

3.	physical/chemical plant and landfill	with separate incinerator
4.	incinerator and landfill	with separate physical/chemical plant

Fully Integrated

5.	incinerator and physical/chemical plant and landfill	all at one location

Of these five major facility arrangement options two were preferred by OWMC: Option 5, the fully integrated facility on a single site; and Option 2, the incinerator and physical/chemical facilities on one site with the landfill on a second site. These two facility arrangements were found to minimize both transportation costs, risks and environmental impacts as well as capital and operational costs.

(C) Site Sizes

Based on an initial capacity of 150,000 tons/year of hazardous waste, waste quantity information indicated that about 30,000 tons would be organic waste and 120,000 tons inorganic waste. The physical/chemical treatment plant would be sized to process 50,000 tons/year of inorganic waste on a one-shift-per-day basis. Additional shifts would permit the plant to treat up to 120,000 tons/year of inorganic waste. The incineration plant would comprise one rotary kiln system sized to process 30,000 tons/year of organic waste on a three-shift-per-day basis.

Designing treatment facilities of this capacity, and a standard engineered landfill capable of receiving the treated residues from the incineration and physical/chemical treatment processes for two to three decades, was estimated to require the following minimum site sizes including a technical buffer zone:

- o for an incinerator and a physical/chemical treatment plant located together: 80 hectares (200 acres);
- o for an engineered landfill located separately: 110 hectares (275 acres);
- o for all three components located on one site (a physical/chemical treatment plant, an incinerator and an engineered landfill): 190 hectares (475 acres).

These estimates were used in the next step of the site selection process: identifying candidate sites within candidate areas.

Step 3 - Identifying Candidates Sites Within Candidate Areas

Step 3 in the selection process was itself subdivided into three basic narrowing stages, described below.

(A) The Identification of Site Areas: Constraint Mapping

In the first stage, smaller areas, called site areas, were identified with the larger candidate areas. To identify these site areas, data were first collected within the candidate areas on a long list of factors. Certain factors were then identified as "exclusionary" (i.e., factors which should rule out certain areas from further consideration at this time). The exclusionary factors are shown in Table 3B-2. These exclusionary factors were then mapped and certain areas excluded, and site areas free of those factors were identified. This technique, called constraint mapping, resulted in the identification of a large number of potentially suitable site areas (i.e., 152) for examination in greater detail.

(B) The Identification of Potential Sites: Site Screening

The second stage reduced the site areas in number and size to potential sites. It involved the collection of detailed data on each site area and the application of certain "screening" factors.

During the screening process, site areas were either dropped from further consideration or reduced in size. The screening factors addressed the following questions:

(i) Are there areas which are too small or unsuitably shaped to accommodate the size of facility required? (Site Size and Configuration Screen).

(ii) Are there areas which are crossed by major services? (Suitability Screen - Linear Facilities).

(iii) Are there areas which are less suitable because they contain a very sensitive environmental area? (Significant Environmental Units [SEUs] as identified by provincial and/or municipal agencies).

(iv) Are there areas which are unsuitable because they would result in severe environmental or social impacts? (Suitability Screen - Severe Impacts).

(v) Are there areas which have a number of constraints and no relative advantages over the site areas which could be retained? (Suitability Screen - Relative Suitability).

(vi) Are there areas for combined physical/chemical treatment plant and incinerator in particular that would mitigate potential impacts on agriculture and/or in industrially designated areas? (Compatibility Screen).

(vii) Are there site areas for a combined incinerator and physical/chemical treatment plant which should be eliminated because they are too far from selected landfills? (System Screen).

This stage in the process resulted in the identification of 16 potential sites: 10 landfill sites and six sites for a combined physical/chemical treatment plant and incinerator. Of the 10 landfill sites, two were considered as landfills only and eight were considered suitable as either landfills or as fully integrated sites.

TABLE 3B-2

Exclusionary Factors for Constraint Mapping

Physical Resources

- Surface granular soils
- Significant stream courses
- Flood plain areas
- Wetlands
- Drumlins
- Morainal features

Land Use

- Indian Reserves
- Residential built-on
- Residential, designated and serviced
- Commercial, designated and built-on
- Commercial, designated and vacant
- Existing rural residential

Recreation and Community Facilities

- Hospitals, homes for the aged, nursing homes
- Colleges and universities
- Special education facilities
- Police HQ
- Theme parks
- Regional shopping centres
- Correctional facilities
- Institutions for the handicapped

Transportation

- Airports

Agriculture

- Existing specialty crops
- High grade agricultural capability (typically Class 1 to 3)

Note: In practice, exclusion criteria were modified by further factors including public ownership, industrial zoning, effects of "urban shadow" and short haulage distance.

(C) From Potential Sites to a Short List of Candidate Sites: Initial Comparative Evaluation

The third stage in the review of candidate areas was an initial comparative evaluation of the 16 potential sites, using the factors identified in Table 3B-3. The factors encompass a range of physical, social, resource, biological, land use, transportation and cost considerations for each potential site, the area around each site and the access roads to the sites.

The comparative analysis of the potential sites addressed the following three questions:

(i) Did the additional investigations identify major constraints sufficient to remove some potential sites from further consideration at this time?

(ii) In comparing the differences among the potential sites, were there sites that were relatively less suitable which could be dropped from further consideration at this time without seriously limiting the diversity of siting choices for Phase 4?

(iii) Were there sites which possessed major disadvantages with respect to the top-ranked goal (i.e., minimizing risk to human health) such that the site could not be expected eventually to be the preferred site?

This analysis led to a reduction in the number of potential sites to eight candidate sites.

Step 4 - Comparison of Candidate Sites and Identification of a Preferred Site

Step 4, the process of evaluating each of the siting options was undertaken in three stages:

- the collection of more detailed data for each site and the development of more detailed factors for site comparison;
- the evaluation of the basic acceptability of the sites in the light of the more detailed data available; and
- the detailed comparative evaluation of the remaining siting options.

Each of these stages is described in the following.

Data Collection and Factor Identification

The first stage of the detailed comparative evaluation of siting options was the collection and compilation of detailed data both on and in the vicinity of each of the eight candidate sites on the subjects of hydrogeology, transportation, agriculture, biology, surface water, archaeology, land use, social and economic factors, air quality and dispersion characteristics, and costs. Information was obtained from a number of printed sources, as well as from interviews with area residents, farmers, businesses, municipalities and provincial agencies, and from field investigations and site testing, including

TABLE 3B-3

Initial Comparative Evaluation Factors

(A) Site

(1) Human Environment

- o Existing residences
- o Existing resources (agricultural, historical, archaeological, groundwater)
- o Existing community and recreational facilities (public, private)
- o Existing commercial and industrial uses
- o Future residents
- o Future resources
- o Future commercial and industrial uses

(2) Physical and Biological Environment (site and site vicinity)

- o Hydrogeology
- o Biology
- o Atmospheric dispersion

(3) Costs/Operations

- o Land acquisition
- o Site improvements
- o Utilities, roads, airports
- o Site size and configuration

(B) Site Vicinity

(1) Human Environment

- o Existing residences
- o Existing resources
- o Existing community and recreational facilities
- o Existing community character and lifestyle
- o Future residents
- o Future resources
- o Existing commercial and industrial uses
- o Future commercial and industrial uses

(2) Costs/Operations

- o Proximity to sewage treatment plants/receiving bodies
- o Proximity to rail access

TABLE 3B-3 (continued)

(C) Access Road - Local

(1) Human Environment

- o transportation safety
- o existing residents
- o existing resources
- o existing community and recreational facilities
- o future residents
- o future resources
- o existing commercial and industrial uses
- o future commercial and industrial uses

(2) Physical and Biological Environment

- o hydrogeology
- o stream crossings

(D) Access Road - Regional

(1) Human Environment

- o transportation safety
- o existing residents
- o existing resources

(2) Physical and Biological Environment

- o hydrogeology
- o stream crossings

(3) Costs/Operations

- o tonne kilometers of waste and solidification additives hauled a deep bore hole drilling program. OWMC then established a preliminary list of the factors to be used in evaluating the differences and similarities among the eight candidate sites. These factors were measures of the potential risks, impacts and costs of a waste management facility on each site.

The "risk" factors pertain to the potential effects on human health resulting from the operation of OWMC's proposed facilities. They encompass four potential means for exposure to toxic chemicals: transportation, air, surface water and groundwater. Risks to human health will be minimized through the use of the best proven technology, design, operations and monitoring procedures. The choice of a site can also reduce even further the very low levels of risk anticipated.

The "impact" factors pertain to the potential non-health effects on residents, agriculture, business, community facilities and services, land use, the natural environment and broader social and economic concerns.

Within each factor, a series of indicators was established to identify, measure, describe and predict these risks, impacts and costs. For example, within the risk factor grouping of hydrogeologic suitability (groundwater), one of the factors selected was capability of providing natural containment, for which the indicators were predictability of geologic condition and contaminant breakthrough line. Similarly, within impact grouping of agricultural resources, one of the factors selected was loss of farmland for which the indicators were soil capability and the drainage. The final list of factors and indicators was established after a series of meetings with government agencies and public working groups. The public working groups were asked to review and comment on the comprehensiveness of the factors and indicator s. The final list of the factors established during Step 4 is provided in Table 3B-3.

The Basic Acceptability Analysis

In the second stage of the comparative evaluation, each of the eight sites was assessed in light of the new data which had been collected during Step 4 to determine if there were any major constraints that would result automatically in the rejection of a site. This was called the basic acceptability analysis and all OWMC's site selection consultants were asked to consider whether or not a basic acceptability criterion existed for their discipline. In some disciplines, such as social impact analysis, no clear criterion of this kind could be established. For others, it was possible to establish such a criterion.

The site selection team concluded that if the hydrogeologic analysis of a candidate site revealed a strong likelihood of failure to provide natural containment, that site should be eliminated immediately from further consideration. This approach was considered preferable to continuing the analysis of a site that did not appear to meet basic acceptability. As a result of the analysis by the hydrogeologic and engineering consultants, two sites were dropped from consideration, leaving six siting options for further investigation.

The Detailed Comparative Evaluation of the Six Siting Options

The comparative evaluation of the remaining siting options began by ranking the risk and impact factors in order of importance Table 3B-4. This was followed by comparing each siting option with other siting options (i.e., a paired comparison).

(A) The Ranking of Factors

Some of the Phase 4A factors were considered to be more important than others in helping OWMC to determine the safety and suitability of the siting options.

In ranking "risk" factors, OWMC considered the potential severity of risk, the probable frequency of its occurrence, and the possibility of mitigating or reducing the potential risk. In ranking the "impact" factors, OWMC considered the likelihood of an impact occurring, the possible severity of that impact, the significance of the impact, the frequency and duration of a potential impact, its relationship to other factors, uncertainty of impact precondition, and the possibility of mitigating or reducing the impacts. "Cost" factors were established by totalling the estimated costs for each siting option and ranking the siting options according to them.

A preliminary ranking of factors was published in June, 1985 and comment was subsequently sought from the public at site selection workshops in July. Using the comments received at these workshops, OWMC refined and finalized the ranking of its factors. The final list of factors and their ranking appears in Appendix 2 to the OWMC Phase 4A report (OWMC 1985).

(B) Comparison of the Siting Options

The six remaining siting options were then compared on a factor-by-factor basis to identify the major differences or trade-offs between them. By reviewing these trade-offs, it became apparent that each of the options had its own set of strengths and weaknesses.

For example, in examining transportation, a siting option near the town of Milton (LF-4N/P1-1N) was favored over a siting option near the town of West Lincoln (LF-9C), mainly because the former was closer to where the majority of Ontario's special wastes are generated and to the major 400 series highways. But in examining hydrogeology, the West Lincoln siting option was favored over the Milton siting option, mainly because LF-9C has deeper and more uniform clay-textured soils offering a greater measure of natural containment. The resulting trade-off between transportation and hydrogeology, which were both ranked high as risk factors, was one of several trade-offs which were identified as the siting options were compared.

Based on this comparison of the siting options, two sites were agreed by all of OWMC's site selection consultants to be and the other a separate landfill and physical/chemical treatment-incinerator combination. The essential differences between the two options could be summarized in terms of lower risks for the integrated option, in particular greater natural containment and greater certainty of geological conditions, versus lower impacts for the separate facilities option.

TABLE 3B-4

Detailed Comparative Evaluation Factors

Factor Grouping	Factors
(A) Risk	
Transportation	o Annual province-wide hazard-based spill index of OWMC generated transport o Annual province-wide accident involvements of OWMC generated transport o Transportation risks on local and regional access roads due to accident involvements of OWMC generated transport o Transportation risks on local and regional access roads due to hazard-based spills of OWMC generated transport
Air Quality	o Risk from direct inhalation of emissions - chronic o Risk from direct inhalation of emissions - acute o Risks from ingestion of cistern and pond water o Risks from consumption of crops and livestock
Hydrogeologic Suitability	o Capability of providing natural containment o Ground water use
Surface Water Suitability	o Susceptibility of site to flooding o Potential for water use interference
Study Area: Site	
(B) Environmental Impacts	
Residents	o Displacement of residents
Businesses	o Displacement of businesses
Community and Recreation Features	o Displacement of historical, community and recreation features o Archaeological resources
Land Use	o Existing land use o Proposed and planned land uses o Land use stability

TABLE 3B-4 (continued)

Factor Grouping	Factors
Agricultural Resources	o Displacement of farms with on-site headquarters o Loss of farmland
Natural Environment	o Rare species o Natural vegetation displaced o Potential for occurence of other significant features
Site Area: Site Vicinity	
(B) Environmental Impacts	
Residents	o Economic stability of residents o Disruption of use and enjoyment of property and/or day-to-day activities (adjacent to site)
Businesses	o Business activities negatively affected by the presence of OWMC facilities o Business activities positively affected by the presence of OWMC facilities
Community and Recreation Features	o Disruption of operations of community and recreation features (adjacent to site) o Disruption of operations of community and recreation features (site vicinity)
Land Use	o Existing land use o Proposed and planned land use o Land use stability o Provincial policies and plans
Agricultural Resources	o Partial displacement of farms (off-site farms with on-site land) o Disruption of adjacent farm operations o Disruption of non-adjacent vicinity farm operations
Natural Environment	o Significant Environmental Units (SEUs) o Fish and wildlife features of significance o Other natural vegetation o Rare species
Air Dispersion/Air Quality	o Restraints to dispersion o Existing and anticipated air quality
Site Vicinity: Community and Regional	

TABLE 3B-4 (continued)

Factor Grouping	Factors
(B) Environmental Impacts	
Community and Regional	o Municipal finance and services o Social stability o Social cohesion o Community character o Regional and community economic base o Tourism economy o Tourism operations
Land Use	o Existing land use o Proposed and planned land use o Provincial policies and plans
Agricultural Resources	o Stability of farm population o Stability of agricultural land base o Disruption to the farm economy
Site Area: Access Roads	
(B) Environmental Impacts	
Residents	o Disruption of day-to-day activities and/or the use and enjoyment of property (adjacent) o Disruption of day-to-day activities and/or the use and enjoyment of property (vicinity)
Community and Recreation Features	o Disruption of operations of community and recreation features (adjacent) o Disruption of operations of community and recreation features (vicinity)
Land Use	o Existing land uses o Planned and proposed land uses
Agricultural Resources	o Disruption to farm traffic and cattle crossings o Disruption to crop livestock production
Natural Environment	o Fish communities
(C) Engineering Cost	
Cost	o Capital cost ($000) o Operating cost ($000)
Site Area for Facilities Placement	o Site area

Since protection of human health (as distinct from non-health related impacts on the environment) was the highest priority goal of OWMC's site selection process, the preferred site was the integrated siting option.

References Annex 3B

Ontario Waste Management Corporation (OWMC). 1983a. Facilities Development Process. Process Phase 2 Report.

Ontario Waste Management Corporation. 1983b. Facilities Development Process. Process Phase 3 Interim Report.

Ontario Waste Management Corporation. 1984. Facilities Development Process. Phase 4A Report.

Ontario Waste Management Corporation. 1985. Facilities Development Process. Phase 4A Report.

Note: For a more recent report, see OWMC. 1988. Environmental Assessment: For a Waste Management System. Toronto, Canada.

ANNEX 3C - **Development of Methodologies for Industrial Hazardous Waste Inventories - Experience in Mexico and Italy**

Written by Giancarlo Olivetti, Dagh Watson Spa, Italy and Richard Barnard, Ashact, UK.

Introduction

The preparation of an initial industrial hazardous waste inventory is not a difficult exercise; it is the subsequent identification and classification of hazardous wastes from that inventory that is difficult. This is not easy to achieve in developed countries where data on industry and their wastes are usually freely available. In developing countries the task is often much more difficult because local infrastructure probably does not permit access to up-to-date, accurate information on industrial activities and almost certainly does not facilitate identification or analysis of industrial wastes.

In this paper, we have shown how an industrial waste inventory with a hazardous waste identification and classification procedure was developed for Naples, Italy, and how the methodology is currently being developed, modified and used in a project covering the Metropolitan Area of Mexico City.

The Naples Experience

History

During the late sixties, pollution in the Gulf of Naples area of Italy was highlighted by several outbreaks of cholera which focused public attention on the problems of pollution. The Cassa per Il Mezzogirono (Italy's state- funded Development Agency for Southern Italy) committed itself to what is arguably one of the most ambitious pollution cleanup campaigns ever undertaken.

It was decided to study the problem, formulate pollution control plans and implement these plans so that the entire population of the Region of Campania (the county containing the Gulf of Naples) would be connected to the sewer system and the collected wastewater treated to standards sufficient to eliminate any public health risk. Coupled with this "liquid" cleanup campaign, a similar program for urban and industrial solid waste disposal (which, at the time, was haphazard and uncontrolled) was implemented. An idea of the magnitude of the problem can be gained from the size of the area covered (see Table 3C-1 Naples Study Area).

As part of this program, study of industrial waste production in Campania was undertaken in order to formulate a masterplan for its treatment and disposal. This in itself was a large task. Industry in the area under consideration varied from heavy steel mills -- like the one at Bagnoli, Naples, one of the largest and most modern in Europe -- to small, family-run businesses of which tanneries and shoe and leather goods industries are perhaps the most typical.

The objective of the part of the study which is described here was to identify and quantify industrial wastes requiring disposal (i.e., principally non-aqueous wastes). From this information, suitable disposal facilities were to be developed and hazardous or potentially hazardous materials requiring particular treatment and/or disposal methods were to be identified.

TABLE 3C-1

Naples Study Area

Area	2800 sq km
Coastal Length	260 km
Industrial Areas	17
Local Councils	195
Population - 1986	5.9 Million
- 2016	8.1 Million

Source: Borrelli, S., and L. Peccerillo. 1983. Planning and Development of the Gulf of Naples 'Clean-up' Project. Ingegneria Ambientale, No. 11: 558-567 in Italian.

The methodology that was developed to gather and interpret data on the types and quantities of waste being generated in the region is described below.

Initial Steps

The initial requirement was to gain an appreciation of the type, size and location of industry present. Background knowledge on industry in Campania showed that there was a general distribution of industry throughout the Region. It was also known that several major industrial areas existed at Caserta, Battipaglia (south the Salerno), along the coast between Naples and Pozzuoli, in the coastal area between Naples and Portici (the principal industrial area of Naples) and the area between Torre del Greco and Castellamare di Stabia.

Other areas were identified where there was a tendency for one particular type of industry to predominate; the most notable being Solofra with its tanning industry, Agro Nocerino with tomato production and canning, northern Naples with shoe and leather goods and Torre del Greco with coral and cameo factories. It soon became apparent that records giving information about industrial waste production in Campania did not exist in any useful form. It was therefore decided to produce a complete inventory of industry in Campania to provide a basis on which industrial waste production could be evaluated.

Identification of Industrial Presence

In any industrial waste management study the identification of industry present in the area under consideration may be considered to be the most critical aspect of the work -- clearly, if the existence of a factory is not known, then any waste it produces will not be identified. For the work in Campania, a detailed appraisal of industry was needed.

From information gathered by various Chambers of Commerce, Trade Associations and the Instituto Centrale do Statistica (ISTAT - National Census Information) it was found that there were over 25,000 industrial premises to be considered comprising numerous different types of industrial activity. In the ISTAT data, all industrial premises had been classified into a main industrial sector. Principal classes are shown in Table 3C-2.

Each of these classes was also subdivided into more distinct sub-categories. For example, class 3 11 is divided into the following sub-categories:

3 11 01	Bicycle manufacture
3 11 02	Vehicle manufacture (cars)
3 11 03	Two or three-wheeled vehicle construction
3 11 04	Lorry construction
3 11 05	Coachworks
3 11 06	Vehicle parts manufacture
3 11 07	Railway rolling stock and locomotive manufacture
3 11 08	Animal or hand-drawn cart manufacture
3 11 09	Aerospace industry
3 11 10	Boat construction and dockyards

This source also listed the number of factories in each sub-category and the total number of employees engaged in those factories for every local council.

TABLE 3C-2

Main Industrial Classification

ISTAT Class	Industrial Sector
3 01	Foodstuffs
3 02	Tobacco
3 03	Textiles
3 04	Clothing
3 05	Shoes
3 06	Leather Goods
3 07	Wood
3 08	Furniture
3 09	Metal
3 10	Mechanical
3 11	Construction
3 12	Minerals
3 13	Chemicals
3 14	Rubber
3 15	Cellulose
3 16	Paper
3 17	Publishing
3 18	Cinema/Music
3 19	Plastics
3 20	Various

Source: Instituto Centrale di Statistica. 1971. Classificazione delle Attivita Economiche. Serie C No.5 (in Italian).

It was decided to use this information as a basis for the inventory. This offered three distinct advantages:

(i) This source provided a ready-made industrial classification system.

(ii) It provided a means of extrapolating waste production data for any particular industrial sub-category (quantity of waste per employee).

(iii) It facilitated easy division of the whole area into 195 smaller areas (local councils) which could be examined independently or grouped together.

It was found that out of the 25,000 plus industrial premises in Campania the majority of them were engaged in small scale crafts or trades that produced wastes normally disposed of along with domestic garbage. Consequently, to make the project manageable, the remainder of the study was limited to industrial premises of 10 employees or greater, comprising some 3000 firms.

A data bank was constructed detailing, for each local council, the industrial premises of each industrial sub-category together with the total number of employees engaged in each.

The data bank on industrial presence took the following form:

Prog. Number	Local Council	Province	ISTAT Class	No. Employees
1	Castellammare	NA	3 01	35
2	Vesuviano	NA	3 01	15
3	Molinara	BN	3 04	36
.	.	.	.	.
.	.	.	.	.
		.	.	.
			.	.
				.
3276	Battipaglia	Sa	3 10	72

Inquiries showed that little or no information existed detailing the wastes produced by these industries. It was concluded that the necessary information would have to be obtained by a waste survey.

Approach to Waste Identification

It was impossible to visit all industrial premises with 10 employees or more -- over 3000 had been identified. Nor was it practicable to send them a questionnaire (this practice is best avoided since response is usually slow and inaccurate, often through willfulness rather than ignorance). A rational approach to the situation had to be found. It was decided that a representative sample of each type of industry would have to be visited, and the number of installations, the potential for waste production (if known) and the size of the industrial premises present in Campania, would have to be assessed. It was decided that at least one premise from each sub-category would be visited.

Data Collection

Between July 1983 and March 1984, over 185 industrial premises were visited and questions concerning administrative aspects of the factory and waste production were put to factory staff. It should be noted that the most obvious parameter by which unit waste production would normally be measured, quantity per unit volume of product or raw material used, was found to be unreliable as factories were often reluctant to disclose information regarding production. By contrast, data relating to the number of employees obtained from the local chamber of commerce or from social security records were more reliable. At the end of the survey, the quantity of wastes produced by that type of industry per employee were known for each industrial sub-category.

Another data bank was created containing this information. Where more than one premise from any industrial category was visited the average waste production was calculated. The data bank took the following form:

ISTAT Class	Description of Waste	Quantity Ton/Emp/ month	Months per Yr
3 01 A	Sludge	0.1125	11
3 01 A	Paper & Plastic	0.113	11
3 09 01	Sludge	0.00027	11
3 09 01	Refractory bricks	0.023	11
3 09 01	Slag	0.7	11
.	.	.	.
	.	. .	
		.	.
			.

Data Interpretation

By effectively combining one data bank with the other, the total amount of industrial waste produced in the area under consideration could be estimated. Similarly, applying selection procedures to the first data bank, waste production in a particular area (group of local councils or provinces) or industry type could be obtained.

Overall it was found that there were approximately 845,000 tons/year of industrial solid, liquid and sludge waste produced every year in Campania of which 60% originated in and around the City of Naples and 20% in and around the City of Salerno.

Even though a quantitative estimate of waste production had been made it was still necessary to assess the qualitative characteristics of the wastes to facilitate planning of a waste disposal strategy and the identification of hazardous wastes. It was evident that each waste identified would have to be classified so that suitable disposal routes could be identified and any hazard or potential hazard would automatically be recognized. The manner in which this is undertaken is the key to a successful industrial waste inventory. Some systems base qualitative interpretation on an inclusive list of chemical compounds. Although this may be considered ideal, it is invariably impracticable as the highly detailed analysis of each waste required to implement this system is rarely available. Also, unless a very complicated operating system is set up, hazards regarding the inter-mixing of chemicals will not be identified.

It was concluded that an easy to instigate, easy to operate, easy to understand system should be implemented for immediate short-term benefits but that the same system should readily allow future expansion and development. From the outset it was decided that whatever the methodology, it should be a computer-based, interactive system. The approach that was eventually adopted was to assign each type of waste a simple code based on simple physicochemical parameters that could be easily derived for each waste. The manner in which this has been accomplished has led to the development of a computer program which asks simple key questions about each particular waste. These questions were selected to progressively identify the waste, progressing on to its chemical constituents and, in this case, disposal possibilities.

It was decided that all wastes were to be included in the inventory even those which, because of certain circumstances, might not require disposal immediately. In this way, any future change could be easily accommodated. An identification system was therefore incorporated into the coding system to show that certain wastes currently do not enter the disposal pathway. The last three characters in the code indicate whether or not a waste requires disposal immediately.

The format of the coding methodology is represented in Table 3C-3; although on the VDU, communication techniques are improved with the use of moving cursor and highlighted areas, etc. The qualitative characteristics of the waste were thus eventually codified by assigning a letter or number to each the answer to each of the key questions. A twenty character code was assigned to each waste of the form LNLLLLL ____________________ LLL. For example, residual cutting oil may well have the code L10NNN ____________________ PNY. To allow the industrial waste inventory and classification system to be developed, space was left in the coding system for up to 20 characters.

The codes were then inserted into the waste data bank so the final data bank took the following form:

ISTAT Class	Description of Waste	Quantity Ton/Emp/ month	Months per Yr	Waste Code
3 01 A	Sludge	0.1125	11	F1BNNP____________NNS
3 01 A	Paper & Plastic	0.113	11	S3PNNC____________RSS
3 09 01	Sludge	0.102	11	F1IMBN____________NSS
3 09 01	Refractory bricks	0.023	11	S3INNN____________NSS
3 09 01	Slag	0.7	11	S2IXNN____________XXS
.	.	.	.	.
	.	.	.	.
		.	.	.
			.	.

TABLE 3C-3

Methodology for the Classification of Wastes

(1) Is waste is solid, liquid or sludge?

Solid (S)	Liquid (L)	Sludge (F)

(2) Is waste primarily:

Powder (1)	Emulsion (1)	Wet (1)
Small pieces (2)	Oil (2)	Dry (2)
Medium size (3)	Other hydrocarbon (3)	Non-aqueous (3)
Large size (4)	Waterbased (4)	Unknown (X)
Unknown (X)	Unknown (X)	

(3) Principal component of waste is?

Organic - chemical or petrochemical origin (O)
Organic - biological origin (B)
Metallic - (M)
Mix of organic materials (P)
Mix of inorganic and organic materials (V)
Mix of inorganic materials (I)
Unknown (X)

(4) Are any of the following present?

Heavy metals (M)
Phenols or their derivatives (F)
Cyanides or isocyanates (C)
Organic halogenated material (A)
Organic (non-halogenated) solvents (S)
Biocides or pharmaceuticals (B)
Tarry residues (R)
Asbestos (P)
Oxidising material (O)
Polycyclic organic materials (Y)
Metal carbonyls (D)
None (N)
Unknown (X)

(5) Is waste acid or basic?
Acid (A)
Basic (B)
Neutral (N)
Unknown (X)

TABLE 3C-3 (continued)

(6) Is the waste combustible?

Highly inflammable (S)
Combustible (C)
Combustible with other material or if dried (P)
No (N)
Unknown (X)

Space for questions 7-17 unused at present

(18) Is there a potential for direct reuse of the waste?

Possible with no processing (R)
Possible with processing (P)
Not possible nor probable (N)
Unknown (X)

(19) Can the waste be mixed with domestic refuse for disposal?

Yes (Y)
No (N)
Unknown (X)

(20) Is the waste to be considered?

Yes (Y)
No (N)
Unknown (X)

The qualitative characteristics of the waste were thus eventually represented by the answers to these questions -- one letter or number -- so that a nine character code was assigned to each waste of the form LNLLLLL ____________________ LLL.

On compiling these codes from gathered data, it was evident that not enough was known about the qualitative characteristics of many of the wastes. When the codes had been attributed as best as possible, a search of wastes with one or more Xs in the code was undertaken. This identified wastes with part or completely unknown qualitative characteristics. On the basis of this a series of visits were subsequently arranged to inspect and sample these wastes. From the results of these analyses the waste data bank was modified.

When any waste production is calculated by interaction of the main two data banks, with or without any selection procedures, the waste's code is retained alongside the quantity. So, when the calculation is complete, a selective search through the wastes can be made using the code to identify the presence of quantities and types of wastes of one or more code types.

For example, all potentially hazardous liquids would be identified by searching for wastes satisfying the following:

Code Character	Letter or Number
1	L
2	Any
3	Any
4	M F C A S B R P O Y D
5	Any
6	Any
7-17 Not Used	
18	Any
19	Any
20	Any

Identification of specific waste types is therefore possible. This can be improved, or tailored to particular circumstances, by modifying the code creation process or utilizing one or more of characters 7-17.

The Mexican Experience

Background

The United Nations Development Programme (UNDP) with the World Bank as executing agency, has undertaken a global Integrated Recovery Project to examine and promote the recycling of wastes and the recovery of resources. A part of the second stage of this project is the development and testing of survey and inventory methodologies for classifying, quantifying and characterizing industrial wastes in Mexico City. The initial part of this project, an evaluation of waste production and disposal practices in the Metropolitan Area of Mexico City, was completed two years ago.

Even during this initial phase of the work, difficulties were encountered owing to the sheer magnitude of the problem. An idea of the size of the problem can be gained from the area covered (see Table 3C-4). The Federal District of Mexico City is made up of sixteen 'delegaciones' (local authorities). Due to ever increasing urbanization, the Metropolitan Area of Mexico City today encompasses twelve municipalities of the neighboring State of Mexico.

Identification of Industrial Presence

During the past thirty years there has been a transition from an overwhelmingly agricultural and mining base to an industrial economy centered in Mexico City. Heavy industries have been established, notably manufacturing steel, glass, cars, tractors, railway, trucks, diesel engines, petrochemicals and a wide range of industrial machinery. Because of the rapid expansion of the city industrial areas are often intermixed with residential property making location and identification of industrial premises more difficult. This is shown in Figure 3C-1.

During the initial survey, information gathered showed that there are over 30,000 industrial premises in the Federal District alone. With the major industrial premises to the north of the city outside the Federal District, it is estimated that the number of industrial premises exceeds 50,000, including a 40,000 brl/d refinery.

At the outset of the second phase of the work, it was found that very little information on industrial waste existed. In fact, the situation was exactly as in Naples -- the only reliable reference was the census records on industrial presence and employment. Data on industry resulting from the census is stored by the Secretaria de Programacion y Presupesto (SPP), Instituto Nacional de Estadistica. Although the classification system used, Clasificacion Mexicana de Actividades y Productos (CMAP), is different from the ISTAT system it is possible to convert from one to the other.

Waste Identification

During the initial survey it was established that the quantities of industrial solid wastes collected and disposed of by the Departamento del Distrito Federal (DDF) was approximately 2900 t/d in 1983. For the whole of the Metropolitan Area the quantity is thought to be in the region of 5000 t/d.

The first phase of the study requires the implementation of an industrial hazardous waste inventory. However, as in Naples, little data on waste characteristics have so far been found to be available. Unlike the Naples project the scope of this phase of the study does not permit the execution of a waste survey in order to establish quantitative and qualitative data regarding waste production.

Planned Approach

To gain an appreciation of the potential wastes originating in Mexico City in order to set up an industrial waste inventory system (an inventory for solely hazardous wastes to be produced from this), it is proposed to create a data bank of industry in Mexico City (from SPP data), convert the industrial waste data bank derived from the Naples and other studies to the CMAP classification system and interact the resulting two data banks.

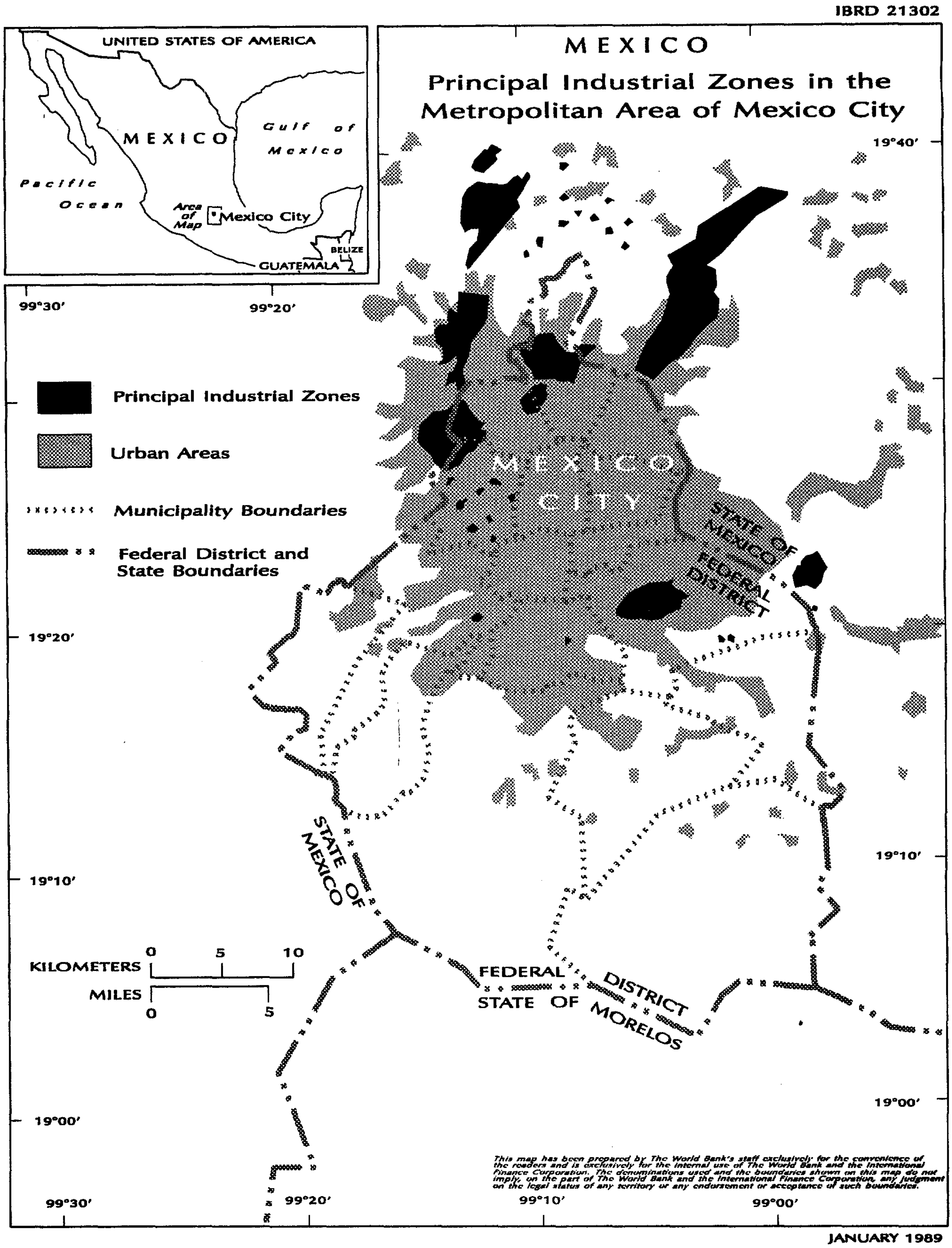
The information produced will be indicative of the likely waste production in Mexico City. By carrying out searches based on codes or groups of codes, a first attempt at evaluating the hazardous waste situation in Mexico City will be possible. It is realized that this approach will only be very approximate

TABLE 3C-4

Mexico City Study Area

Area	1200 sq km
Industrial	18
Local Authorities	28
Population - 1984	17.0 Million
- 2000	21.3 Million

FIGURE 3C-1


IBRD 21302
MEXICO
Principal Industrial Zones in the Metropolitan Area of Mexico City
UNITED STATES OF AMERICA
MEXICO
Gulf of Mexico
Pacific Ocean
Area of Map
Mexico City
BELIZE
GUATEMALA
Principal Industrial Zones
Urban Areas
Municipality Boundaries
Federal District and State Boundaries
MEXICO CITY
STATE OF MEXICO
FEDERAL DISTRICT
STATE OF MEXICO
FEDERAL DISTRICT
STATE OF MORELOS
KILOMETERS 0 5 10
MILES 0 5
99°30'
99°20'
99°10'
99°00'
19°40'
19°20'
19°10'
19°00'
This map has been prepared by The World Bank's staff exclusively for the convenience of the readers and is exclusively for the internal use of The World Bank and the International Finance Corporation. The denominations used and the boundaries shown on this map do not imply, on the part of The World Bank and the International Finance Corporation, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.
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but it does give a basis on which to work and develop. The most significant improvement will be the effective 'calibration' of the waste production data bank by modifying the production figures to those which are representative of the Mexican situation. To complete this, an industrial waste survey covering the most important industrial sectors will have to be undertaken.

Conclusion

The implementation of an industrial waste inventory has to be undertaken with a good appreciation of the information and facilities available and with an understanding of the capabilities and objectives of the people who are to use the inventory. It has been shown that the developed system can be used in other applications to provide a tool in assessing the potential waste disposal problems where little or no data on waste production exists.

An important factor to consider when developing these types of inventory is to keep them flexible and simple. It is always better to have a simple system that works and is used rather than an overly complex one which, although technically excellent, is rarely used or updated.

The system implemented in Naples as described above, modified on the basis of experience and now to be implemented in Mexico, gives a good basis on which waste management authorities can build a waste management system to the standard they desire. It is, of course, open to criticism but most of these criticisms can be overcome by accurate 'calibration' for a particular area or greater selectivity in the coding system. Further development of the system is underway to include a 'starter pack' for waste authorities suitable for IBM compatible personal computers.

The project in Mexico City is being sponsored by the UNDP/World Bank Integrated Resource Recovery and Waste Recycling Project (GLO/84/007) with co-financing provided by the Italian Department of Development Cooperation. The views expressed, however, are solely those of the authors and do not necessarily reflect the views of the sponsoring agencies. This methodology has been considerably improved for international application using UN ISIC industrial classification codes. The waste database has over 7,250 records.

CHAPTER 4 - Waste Minimization - A Key Strategy In Hazardous Waste Management

4.1 Introduction

Waste minimization is a very important hazardous waste management strategy in developing countries, as a recent example from a World Bank project in East Java, Indonesia shows. This example also illustrates the ability of engineers and technicians in developing countries to conceptualize and develop waste minimization technologies appropriate to local conditions. Prior to the commissioning of a new water treatment plant serving the city of Surabaya and financed by a World Bank loan, the government of Indonesia agreed to bring major polluting industries on Kali Surabaya, East Java into compliance with the government's liquid effluent standards. Since the government of Indonesia subscribes to the "polluter pays" principle, the Provincial Government of East Java placed the burden on the polluting industries to finance plant modifications or add-on pollution control measures necessary to meet effluent standards.

At one factory processing recycled paper into cardboard. The effluent discharge contains fine suspended paper pulp with a high BOD load, which was discharged directly to the Kali Surabaya. During low flow periods these suspended solids settle in the river bed creating anaerobic conditions and are re-suspended during periods of higher flow resulting in a high turbidity and a peak BOD at the inlet to the downstream water treatment works. This creates several operational difficulties and impairment of the quality of treated water.

Following laboratory investigations the company found that the fine suspended pulp fiber could be separated from the waste stream with polymeric flocculants using a diffused air floatation process. Moreover, it was found that the pulp fiber produced could be readily dewatered and was in a suitable condition for use as a low quality pulp. Following a market survey of low quality pulp processors in the region it was discovered that an egg carton manufacturer could utilize the pulp and had sufficient capacity to utilize all of the low quality pulp produced.

A one-third scale pilot plant was constructed to treat about a third of the waste stream. During a two year testing program which optimized the usage of polymer it was discovered that the floatation process could be effectively run even without compressed air. A full-sized plant has been constructed using locally available construction materials and methods and a local labor force. The recovered bulk is now being sold to the egg carton manufacturer at a price that covers operating costs as well as depreciation.

As a result of the government's directive to reduce pollution loads, the factory not only minimized waste through recovery and recycling, but also modified processes and procedures in the factory itself to reduce excessively high raw water and energy usage.

4.2 Waste Minimization Programs

4.2.1 Definition

The concept of waste minimization can best be illustrated by means of Figure 4-1 which subdivides the topic into three district headings: source reduction, recycling, and treatment. The definitions of the important terms utilized throughout this chapter are given in Table 4-1. Examples of successful waste minimization programs are given in Annex 4B, while Annex 4C relates the experience of a state wide program in waste minimization in North Carolina.

4.2.2 Source Reduction

Source reduction, the most prominent component of waste minimization, consists of product substitution and source control as shown in Figure 4-2. Product substitution means the replacement of an original product with another product suitable for the same end use, or the alteration of an original product use which results in a decrease or elimination of hazardous waste generation associated with the original product's manufacture. Examples include replacement of treated wood pilings with concrete pilings in marine construction, replacement of synthetic rubber with natural rubber, or replacement of paint coating with longer lasting plastic coating in certain applications. The definition can be broadened also to include research and development activity associated with seeking low-waste approaches to new products.

Source control means the reduction or elimination of hazardous waste generation within the process through input material alteration, technology alteration or procedural/institutional changes (good operating practices or good housekeeping).

(i) Input Material Alteration

The effectiveness of input material alteration as a source reduction technique generally differs according to the type of processing involved. Raw materials that are directly synthesized (converted) into a product can be purified prior to processing to reduce waste generation but, since most primary feed materials used in synthesis are already relatively pure, this technique generally results in minimal source reduction. For example, the use of a more costly, purer, propylene feed in the synthesis of acrylonitrile does not result in an appreciable decrease in the volume of waste that is generated.

Where a process is essentially a purification step, the use of a higher grade (more pure) material or ore yields less waste. The use of a higher grade crude in petroleum refining, for example, reduces the amount of impurities requiring removal during processing. Auxiliary raw materials, which are used in a process but are not converted into product, can sometimes be replaced with less toxic, more environmentally safe materials. Examples include the substitution of innocuous biodegradable detergents for toxic chlorinated solvents and the use of less toxic

FIGURE 4-1

Defining the Concept of Waste Minimization

ANY SOURCE REDUCTION, RECYCLING OR TREATMENT ACTIVITY THAT REDUCES THE VOLUME[(a)] AND/OR TOXICITY[(b)] OF ANY HAZARDOUS WASTE.

Source Reduction

ANY ACTIVITY THAT REDUCES OR ELIMINATES THE GENERATION OF HAZARDOUS WASTE *WITHIN* A PROCESS.

Recycling

ANY ACTIVITY THAT REDUCES VOLUME AND/OR TOXICITY OF HAZARDOUS WASTE *WITH* ATTENDANT GENERATION OF A VALUABLE MATERIAL WHICH IS SUBSEQUENTLY UTILIZED.

Treatment

ANY ACTIVITY THAT REDUCES VOLUME AND/OR TOXICITY OF HAZARDOUS WASTE *WITHOUT* ATTENDANT GENERATION OF A VALUABLE MATERIAL.

[(a)] VOLUME REDUCTION - PREFERABLY ACCOMPLISHED WITHOUT AN INCREASE OF TOXICITY.

[(b)] TOXICITY REDUCTION - PREFERABLY ACCOMPLISHED BY MEANS OTHER THAN DILUTION.

Source: Turman, C.E. Hazardous Waste Control Through Reduction.

TABLE 4-1

Working Definitions of Waste Minimization and Related Terms

Waste minimization:	The reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored, or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either (1) the reduction of total volume or quantity of hazardous waste or (2) the reduction of toxicity of hazardous waste, or both, so long as such reduction is consistent with the goal of minimizing present and future threats to human health and the environment.
Reduction of total volume or quantity:	The reduction in the total amount of hazardous waste generated, treated, stored, or disposed of, as defined by volume, weight, mass or some other appropriate measure.
Reduction in toxicity:	The reduction or elimination of the toxicity of a hazardous waste by (1) altering the toxic constituent(s) of the waste to less toxic or non-toxic form(s) or (2) lowering the concentration of toxic constituent(s) in the waste by means other than dilution.
Source reduction:	Any activity that reduces or eliminates the generation of a hazardous waste within a process.
Source control:	Any activity classifiable under source reduction with the notable exception of product substitution.
Product substitution:	The replacement of any product intended for an intermediate or final use with another product intended and suitable for the same intermediate or final use.
Recycled:	A material is "recycled" if it used, reused, or reclaimed (40 CFR 261.1 [b] [7]).
Used or reused:	A material is "used or reused" if it is either (1) employed as an ingredient (including its use as an intermediate) in an industrial process to make a product; however, a material will not satisfy this condition if distinct components of the material are recovered as separate end products (as when metals are recovered from metal-containing secondary materials) or (2) employed in a particular function or application as an effective substitute for a commercial product (40 CFR 261.1 [c] [5]).
Reclaimed:	A material is "reclaimed" if it is processed to recover a usable product or if it is regenerated. Examples are recovery of lead values for spent batteries and regeneration of spent solvents (40 CFR 261.1 [c] [4]).

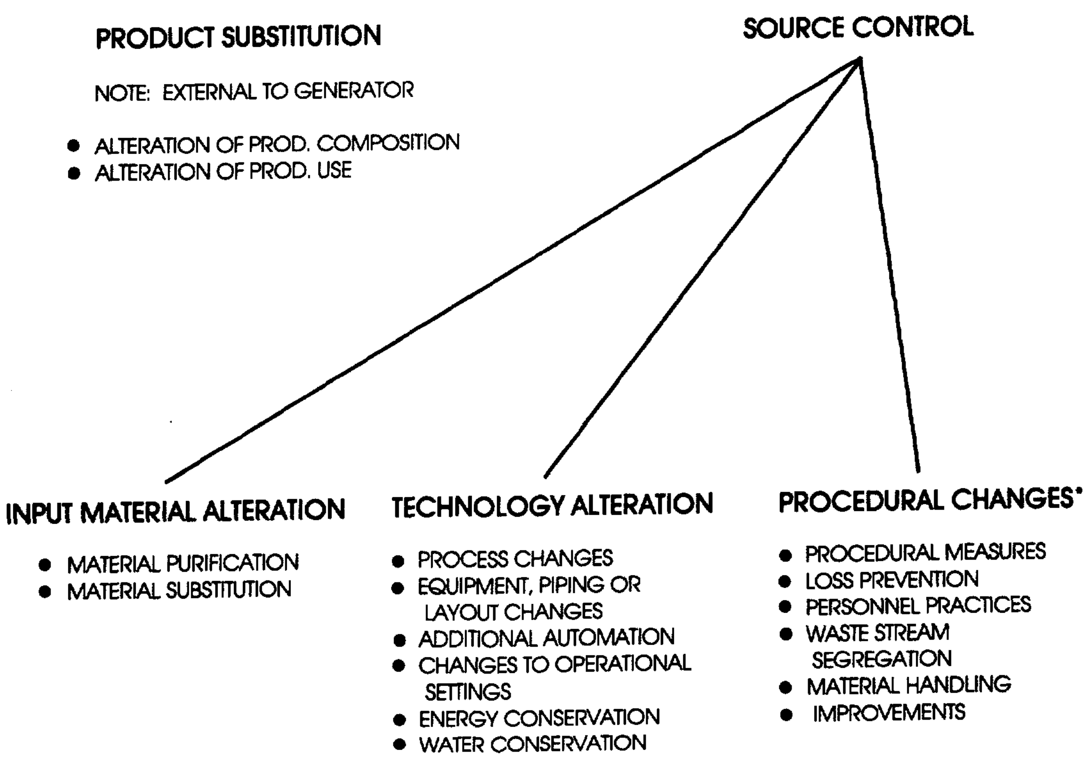
TABLE 4-1 (continued)

Treatment:	(as part of waste minimization) -- Any activity or a series of activities that reduces the volume and/or toxicity of hazardous waste <u>without</u> attendant recovery of valuable material that is subsequently employed in the manufacture of a commercial product (e.g., an incinerator for disposal of spent chlorinated solvent with scrubbing and neutralization of hydrogen chloride from the flue gas);

Source: U.S. Environmental Protection Office. 1986. <u>Minimization of Hazardous Waste</u>. No. 530-SW-86-033 (October). Washington, D.C.

FIGURE 4-2

Concept of Source Reduction As a Component of Waste Minimization



*ALSO REFERRED TO AS "GOOD OPERATING PRACTICES" OR "GOOD HOUSEKEEPING".

Source: Turman, C.E. Control Through Source Reduction.

compounds in lieu of chromate corrosion inhibitors in cooling towers. Sometimes, however, a manufacturer may substitute a material not because the waste would be less toxic but because the waste is simply not regulated.

(ii) Technology Alterations

In certain instances, technology substitutions are also effective in minimizing waste. A product can sometimes be manufactured by two or more distinct processes. Certain processes, such as the chloride process for producing titanium dioxide, generate considerably less waste than alternative processes, such as the sulfate process. Unfortunately, modification of existing facilities can involve considerable research and development and capital investments, and can require a lengthy implementation period.

Inefficient chemical reactions in a process are a major source of increased waste generation. Improving the efficiency of the process through modification of catalysts, reactor design, and operating parameters has been shown to reduce significantly the quantity of waste generated. For example, in the production of acrylonitrile by the catalytic ammoxidation of propylene, switching from an antimony-uranium catalyst to a ferrobismuth phosphomolybdate catalyst has boosted the conversion of acrylonitrile by 35 percent. In another instance, there has been a significant decrease in tar formation where changes in reactor design improved mixing for the manufacture of epichlorohydrin. Attaining zero waste generation, however, is currently beyond the technical capabilities of most chemical processors.

Modification of equipment is another way to reduce waste generation. The invention of mechanical wipers to scrape the sides of paint tanks, for example, reduces the exposed volume of waste paint that would otherwise produce fugitive volatile organic compound (VOC) emissions. Similarly, process automation, which helps optimize product yields by automatically adjusting process parameters, has in many cases minimized operator error, reduced the likelihood of spills, and discouraged the production of off-specification materials. As noted earlier, these off-specification materials can be highly toxic, albeit lower volume, wastes.

Water conservation can also result in significant waste reduction. Efficient product washing results in reduced sludge generation by minimizing the amount of product lost to the wash water and the quantity of wastewater that is generated.

Technology modification and development of low waste techonologies is currently a central focus of waste minimization. Generally these changes are most cost-effective when implemented during a plant's planning or design period or when a plant is retooling and replacing worn out equipment. Retrofitting plants that have already been designed and/or constructed is often expensive and difficult. Consequently, while technology modification may be of limited effectiveness in reducing waste generation and toxicity from existing sources, it can be effective in limiting future waste generation.

(iii) Procedural Changes

"Good operating practices" or "good housekeeping practices" involve the alteration of existing procedural, organizational, or institutional aspects of a manufacturing process. The goal is to limit unnecessary generation of waste attributable to human intervention (or the lack of it). Employee training, management initiatives, inventory control, waste stream segregation, improvements in materials handling, scheduling improvements, spill and leak prevention, and preventive maintenance are all examples of good operating practices. Others include the scheduling of batch operations to limit the frequency of equipment cleaning and, consequently, waste generation; the segregation of hazardous wastes from non-hazardous wastes to minimize the volume of contaminated wastes; and the reduction of overspray and runoff from spraying by the paint booth operator during paint application.

(iv) Product Substitution

Replacement of an original product with a different product that is intended for the identical use can be an effective method of source reduction. For example, integrated pest management, an alternative to pesticide use in certain applications, reduces pesticide production and, in turn, the waste generated during pesticide production and application. The substitution of concrete pilings for creosote-treated timbers eliminates wastes from the manufacture of the creosote-treated pilings. Substitution of less toxic solvents, such as petroleum solvents for more toxic solvents such as perchloroethylene or trichloroethylene, generates a spent solvent waste that is less toxic.

It is difficult to quantify the current status or effectiveness of these source reduction techniques. Each substitution needs to be evaluated on a case or application-specific basis. The viability of a substitute can be based on:

- o whether the substitute can function adequately as a replacement;
- o whether the economic cost of a substitute justifies its use as a replacement,
- o whether the manufacture and disposal of a substitute reduces environmental consequence;
- o whether the cost/environmental benefit of the substitute is sufficiently attractive; and
- o socio-political factors, such as government action (e.g., procurement policy) to promote the substitute.

Trade-offs have to be weighed prior to the selection of substitutes. For example, water-based inks, sometimes used for engraving and flexographic printing, have the advantage of being less toxic than solvent-based inks, but require more energy to dry, possess a low gloss, can cause paper to curl, and occasionally require brief process stoppages. Petroleum solvents can be used in dry cleaning, but they are much more flammable than the more commonly used but more toxic perchloroethylene.

Available data are insufficient to quantify the current effectiveness of source reduction practices in reducing volume or toxicity. In qualitative terms, data indicate that industry in developed countries have already considerably reduced the volume of their wastes. Most of these source control methods, however, have been employed (1) to reduce costs or improve product quality, and, in turn, increase profits and (2) to respond to existing environmental regulations. Rarely have these practices been used solely for the purpose of waste minimization. Current information suggests that further significant source reduction does appear feasible and practicable.

4.2.3 Recycling

Viewed generically, "recycling" encompasses both re-use and reclamation activities. The discussion in this section on recycling activities pertains to hazardous waste recycling for materials recovery as well as for energy recovery. A recycler's decisions as to how to treat a waste is principally determined by the character of specific waste streams or waste mixtures. Where treatment should take place (either onsite of offsite), however, is a function of a generator's management practices which include:

- o proximity to offsite recycling facilities,
- o economic costs related to the transportation of wastes,
- o the volume of wastes available for processing, and
- o costs related to storage of waste onsite compared to offsite.

Recycling is characterized by three major practices: (1) direct use or re-use of a waste in a process, (2) recovery of a secondary material for a separate end use such as the recovery of a metal from a sludge, and (3) removal of impurities from a waste to obtain a relatively pure re-usable substance.

(i) Materials Recovery

Although recycling of selected streams is practiced to a considerable degree by certain industries, only about 4 percent of the hazardous waste generated in the United States was recycled in 1981. Of the waste that was recycled, 81 percent by volume was recycled onsite. Offsite recycling, however, is becoming increasingly common with the advent of commercial recyclers and direct transfer of wastes from generators to others who can re-use the wastes. Table 4-2 summarizes these data for the ten highest volume waste generating industries.

TABLE 4-2
Ten Highest Volume Waste Generating Industries+
Generation and Recycling Volumes during 1981

SIC	Industry	Volume of Waste Generated M gals*	Total Volume Recycled M gals*	Percent**	Volume Recycled Onsite M gals*	Percent**	Volume Recycled Offsite M gals*	Percent**
28	Chemicals and Allied Products	28,000	340	1.2	300	1.1	32	0.1
35	Machinery, Except Electrical	4,200	26	0.6	18	0.4	7.9	0.2
37	Transportation Equipment	2,300	900	39.0	880	38.0	22	0.9
42	Motor Freight Transportation	1,700	NR		NR		NR	
29	Petroleum and Coal Products	1,300	36	2.8	32	2.5	4.2	0.3
33	Primary Metal Industries	1,000	170	17.0	18	1.8	150	15.0
17	Construction: Special Trade Contractors	870	0.2	<0.1	0.1	<0.1	0.1	<0.1
34	Fabricated Metal Products	820	24	2.9	14	1.7	9.6	1.2
36	Electric and Electronic Equipment	670	47	7.0	0.4	<0.1	46	6.9
49	Electric, Gas, and Sanitary Services (includes POTWs)	470	3.3	0.7	0.1	<0.1	3.2	0.7
Total:		40,000	1543.2		1262.5		271.8	

\+ These are wastes recycled at the end of the production process.
* Reporting error accounts for onsite and offsite volumes not equalling total volume recycled.
** Percent of total waste generated (by SIC).
NR: No Recycling of this type reported in RIA Generator Survey.
Source: U. S. Environmental Protection Agency. 1984. National Survey of Hazardous Waste Generators and Treatment, Storage, and Disposal Facilities Regulated Under RCRA in 1981. Washington, D.C.: Office of Solid Waste.

Recycled wastes are used as feedstocks in production processes or as substitutes for commercial chemical products. Examples include:

- o the re-use of solvents for equipment cleaning;
- o the recycling of collected pesticide dusts at pesticide formulators; and
- o the re-use of ferric chloride wastes from titanium dioxide manufacturing as a wastewater conditioner in water treatment.

The proportion of waste that is recycled is both industry and waste specific. In general, certain wastes, such as solvents, tend to be recycled more often than others, such as pesticides. Factors that influence whether an industry recycles its waste include (1) the type of waste generation process used; (2) the volume, composition, and uniformity of wastes; (3) whether uses and re-uses of the wastes have been identified, and (4) availability and price of virgin materials relative to the costs of recycling and storing the wastes. Toxicity of the waste does not appear to be a direct factor in the recyclability of a generated waste, although, as noted previously, high volume wastes, which are often less toxic, are more commonly recycled. Based on limited data, some industry-specific observations can be made. See Table 4-2.

Generally, the streams that are recycled in the greatest volumes are dilute waste streams containing a constituent that can be re-used in large-scale applications by a generator. For example, in the chemical and allied products sector, spent acids and alkaline solutions are recycled in the transportation equipment industry; wastewater treatment sludges from electroplating and chromium plating processes are recycled; and in the primary metals industry, spent pickle liquor is recycled. Chronium solutions can be reused and recovered in tanneries. These streams are of varying toxicity, and data are inconclusive as to whether toxicity plays a role in a stream's being recycled.

Solvents tend to be recovered in larger proportion than other wastes. This is because there is both an existing technology to allow recovery and because a market exists for the recycled solvent. The available technology (e.g., distillation) is relatively inexpensive to operate and can attain high purity levels (95 percent or higher). In other cases, however, production processes generate wastes that are not practical for recovery since the recovered wastes themselves would not be useful in production.

(ii) <u>Energy Recovery</u>

In the 1981 U.S. survey, data indicate that recycling for materials recovery and re-use appears to be more popular than fuel use or energy recovery. There are two reasons why this is so. First, some wastes that could be recycled for energy recovery can also be reclaimed and re-used over and over. Energy recovery in contrast destroys the inputs. Only when the waste is too "dirty" (contaminated from repeated re-use) do generators consider energy recovery a desirable option. The 1981 data may not, however, provide a completely accurate picture of current practices because of recent developments in energy recovery technology. Many technologies were not available in 1981, and others are only beginning to be commercially available today. Solvents tend to be used for energy recovery because they can possess high energy values. Increasing quantities of high calorific wastes are being used by cement plants and lime kilns.

(iii) Other recycling technologies

Wastes that have higher constituent concentrations are usually selected for recovery and reclamation. Data suggest that there are threshold levels that must be reached before wastes can be considered eligible for the recycling process. Halogenated solvent and nonsolvent wastes must be, on average, in the range of 35 to 40 percent before recovery or re-use technologies are practical. For other wastes, such as nonhalogenated solvents and corrosives, the threshold levels are lower for recovery or re-use practices. In any case, the average concentration level for the material being recovered using reclamation technologies is higher than that for any of the other management practices (such as onsite wastewater treatment, surface impoundments, wastewater discharge, land disposal, and treatment of organics).

A number of other typical characteristics are common to waste streams that are recycled. To be economically and technically viable for recycling, a stream usually must be uniform (i.e., it must not contain more than one contaminant). Other factors that must be met in order for recycling to be successful include:

- A market for the recycled material must exist within an economically viable distance; and
- The recycled waste must meet purity requirements for manufacturing processes.

Because recyclable wastes must be economically competitive with the virgin materials they are replacing, the wastes must often be processed prior to re-use. Reclamation processes include chemical, physical, and electrochemical separation. Some of the major technologies include the following:

- Distillation of solvent wastes;
- Dechlorination of halogenated, nonsolvent wastes; and
- Metal concentrating techniques such as leaching, solvents extraction, ion exchange, precipitation, crystallization, and evaporation to treat dilute metal-bearing waste streams.

While not as common as onsite recycling, commercial offsite recycling is becoming increasingly popular. It is, in fact, favored by some industries, most notably primary metals and small quantity generators of lead-acid battery wastes. Offsite recycling usually occurs at mobile plants, centralized recovery facilities, or other commercial recycling plants. An increasingly popular commercial recycling service called batch tolling accepts hazardous wastes from a generator only for treatment and returns the recovered product to the same generator for re-use. The recycler charges a fee to the generator for recovery of the reclaimed material. Some small volume generators have actually pooled their resources and now operate centralized facilities, thereby reducing their capital and operating costs.

Certain wastes that are not useful to a generator may be desired by another industry as a raw material. Waste exchanges are often helpful in facilitating the transfer and recycling of these wastes. They serve as information clearinghouses (listing wastes that are available or desired), and can also act as brokers; occasionally they actually transport wastes from one plant to another. Available information suggests that approximately 20 to 30 percent of all wastes listed by exchanges are eventually recycled. Some of the wastes that are most often recycled include acids, alkalis, solvents, metal wastes, and corrosives.

4.2.4 Treatment

This topic is treated in considerable depth in Chapter 6.

4.3 Incentives and Disincentives for Waste Minimization in Developing Countries

With very limited government enforcement of air and water pollution control regulations (if these have even been promulgated) and with no effective regulations to control hazardous wastes, the costs associated with the disposal of hazardous waste in developing countries tend to be negligible. If the wastes are transported off site the disposal cost may simply amount to the lowest bid received from the local waste hauler who dumps it on uncontrolled waste sites or into swamps, streams or ponds as close as possible to waste generators. Therefore, there is usually little or no economic incentive for the waste generator to engage in waste minimization practices unless the waste contains a valuable material which can be readily recovered, for example: gold and silver.

The most important requisite for waste minimization is active enforcement of air and water pollution control and hazardous waste management regulations. Even without specific regulations requiring waste minimization and utilization of low waste technologies, the increased cost of waste disposal and limitations on certain unacceptable disposal practices will provide some incentives for waste minimization.

Other barriers to an effective waste minimization program at a particular plant may include (Turman):

- o lack of awareness of the benefits of waste minimization;
- o lack of technical staff;

- a "hands-off-the-process" attitude caused by fear of upsetting a product's quality;

- organizational inertia, for example, an "if-it-isn't-broken-don't-fix--it" attitude;

- internal politics of the organization, for example, an innovator may feel inhibited by a fear of lack of management's support; and

- an "it-can't-be-done" attitude--people may reject an innovative approach merely because it is outside their range of experience.

4.4 Waste Minimization Audits

One procedure which can help overcome some of the above barriers to identification and implementation of waste reduction plans is a Waste Minimization Audit (Fromm and Callahan 1986). The objectives of the audit are:

- to generate a comprehensive list of waste minimization measures or options applicable to a specific industrial process, and

- to rank all identified waste reduction options and to allow management to focus on options deserving further in-depth consideration.

A typical wastes minimization audit may involve some or all of the following steps:

- selection of the audit team,

- compilation by the audit team of a waste stream list for the facility with the associated flowrates,

- generation by the audit team of waste reduction options for each waste stream,

- ranking by the audit team of each compiled option in three categories: effectiveness, extent of current use, and application potential,

- preparation by the audit team of documentation in support of selected options,

- presentation, discussion and joint review with plant personnel of options and their rankings,

- analysis by the audit team of revised rankings, and

- final report preparation.

The above procedure is applicable to all three categories of waste minimization (recycling, treatment and source reduction). However, it originally was developed and tested for source reduction options only. Source reduction measures should be considered even when recycling or treatment options are given priority, because reducing the quantities of waste that are recycled or treated often means an increase in revenues (e.g., due to an increase of product yield and lower cost of treatment). Tables 4-3, 4-4, 4-5 and 4-6 contain checklists of water reduction measures compiled based on many process analyses and on experiences gained with waste minimization audits in a number of industries. Annex 4A gives some examples of cost/benefit analyses of waste minimization projects.

4.5 Evaluating Waste Minimization Project Costs and Benefits

Ideally, the relative worth of any proposed capital project is developed by identifying and quantifying all project-related costs and savings. However, not all savings need be quantified in practice to demonstrate economic practicability.

In practice, the potential value of most capital projects has been established on the basis of savings in the following areas:

- raw materials costs
- utilities, labor, and maintenance costs, and
- enhanced revenues through creation of marketable by-products

Waste reduction projects can create savings in the same areas. However, the goal of reducing waste focuses attention on waste generation costs which were previously affected but not taken into consideration:

- disposal fees
- fees/taxes on generators per unit of waste(some states)
- transportation costs
- on-site waste storage and handling costs
- predisposal treatment costs
- permitting, reporting, and recordkeeping costs
- pollution and safety liabilities

For the purpose of evaluating a project to reduce waste quantities, some types of costs are larger and more easily quantified. These are disposal fees, transportation costs, predisposal treatment costs, raw materials costs, and operation and maintenance costs. It is suggested that savings in these costs be taken into consideration first because they will have a greater effect on project economics and will involve less effort to estimate reliably.

Disposal fees vary according to whether the wastes are solid or liquid, the type of container in which the waste arrives (drum or in bulk), and

TABLE 4-3

Waste Reduction Methodology Checklist: All Processes

All Waste Streams	1. Use higher purity materials 2. Use less toxic raw materials 3. Use non-corrosive materials 4. Convert from batch to continuous process 5. Tighter equipment inspection and maintenance 6. Better operator training 7. Closer supervision 8. Practice good housekeeping 9. Eliminate or reduce water use for spill cleanup 10. Implement proper equipment cleaning techniques 11. Use improved monitoring systems 12. Use pumps with double mechanical seals
Commodities Produced Continuously Examples:	Acrylonitrile, Epichlorophydrin, Petroleum Refining, 1,1,1 Trichloroethane, Trichloroethylene/Perchloroethylene, Vinyl Chloride Monomer
Heavy and Light Ends	1. Develop more selective catalyst 2. Optimize the reaction variables/reactor design 3. Use alternate process routes 4. Combust with heat (and HCI) recovery
Spent and Lost Catalyst	1. Develop tougher catalyst support 2. Use filter inside reactor freeboard 3. Regenerate and recycle spent catalyst
Equipment Cleaning Waste	1. Increase equipment drainage time 2. Use corrosion resistant materials 3. Agitate and/or insulate storage tanks 4. Re-examine need for chemical cleaning 5. Use nitrogen blanket to reduce oxidation 6. Use in-process HX cleaning devices
Leaks and Spills	1. Use bellow-sealed valves 2. Use canned (seal-less) pumps 3. Maximize use of welded vs. flanged pipe joints

TABLE 4-4

Waste Reduction Methodology Checklist: Commodities Produced in Batches

Examples:	Dyes, Inorganic Pigments, Paint, Agricultural Chemical formulation, Phenolic Resins, Wood Preserving
Material Handling	1. Segregate containers by prior contents 2. Use rinseable/recyclable drums 3. Purchase materials in bulk or in larger containers 4. Purchase materials in pre-weighed packages 5. Use pipeline for intermediate transfer
Reaction/Processing Step	1. Optimize the reaction variables/reactor design 2. Optimize the reaction addition method 3. Eliminate the use of toxic catalysts
Filtration and Washing	1. Employ efficient washing/rinsing methods 2. Eliminate the use of filter aids 3. Use countercurrent washing 4. Recycle spent washwater 5. Maximize sludge dewatering
Baghouse Fines	1. Increase use of dust suppression methods 2. Use wet instead of dry grinding 3. Schedule baghouse emptying
Off-Spec Product	1. Tighter control of reaction temperature 2. Reformulation of off-spec product
Equipment Cleaning	1. Install high pressure spray wash system 2. Alter production schedule 3. Use mechanical wipers on mix tanks 4. Clean mix tanks immediately after use 5. Use countercurrent rinse sequence 6. Recycle spent rinse water 7. Increase spent rinse settling time 8. Re-examine need for chemical cleaning 9. Dewater spent rinse sludge
Leaks and Spills	1. Use bellow-sealed valves 2. Install spill basins 3. Use canned (seal-less) pumps 4. Maximize use of welded vs. flanged pipe joints

TABLE 4-5

Waste Reduction Methodology Checklist: Manufacturing Operations

Examples:	Electroplating, Lithographic Printing, Metal Parts Cleaning, Metal Surface Treatment, Paint Application, Printed circuit Boards
Material Handling	1. Segregate containers by prior contents 2. Use rinseable/recyclable drum 3. Purchase materials in bulk or in larger containers 4. Purchase materials in pre-weighed packages
Solvent Cleaners	1. Install/operate cleaning tanks properly 2. Avoid cross-contamination of solvent 3. Avoid water contamination of solvent 4. Remove sludge continuously 5. Monitor solvent composition 6. Consolidate cold cleaning operations 7. Recycle spent solvent 8. Use plastic bead blasting for paint stripping
Alkaline/Acid Cleaners	1. Install/operate cleaning tanks properly 2. Avoid cross-contamination of solvent 3. Remove sludge frequently
Plating/Etching/ Surface Finishing Solution	1. Increase plating solution bath life 2. Use lower concentration plating bath 3. Use trivalent Cr in place of hexavalent: Cr 4. Use non-cyanide plating solutions 5. use in-line recovery techniques 6. Regenerate spent bath solutions 7. Segregate all waste streams 8. Inspect all parts for proper cleanliness
Rinse Water	1. Install/operate all rinse tanks properly 2. Use multiple rinse tanks 3. Install drain boards and drip tanks 4. Use fog nozzles and spray units 5. Agitate rinse bath 6. Use deionized water for rinsing 7. Recycle and reuse rinse water 8. Segregate all waste streams 9. Reclaim metal from rinse water
Paint Application	1. Use equipment with low overspray 2. Inspect all parts before painting
Leaks and Spills	1. Install splash guards and drip boards 2. Prevent tank overflow

TABLE 4-6

Replace Electroplating Chemicals

Electroplating is a common process used throughout the metals industry. Many electroplating process typically use chemicals containing high levels of cyanide, and hexavalent chromium which are highly toxic and pose disposal problems. Eletroplating chemicals are available which may replace chemicals containing chromium or cyanide.

Traditional Chemical	Substitute Chemical	Comments
Fire Dip (NaCN + H_2O_2)	Muriatic Acid with additives	Slower acting than fire dip.
Heavy copper	Copper Sulphate	Provides excellent throwing power with a bright, smooth, rapid finish. Requires good preplate cleaning. Eliminates carbonate build-up in tanks. Copper Cyanide likely still necessary for steel or tin-based metals.
Chromic Acid Cleaners	Sulphuric Acid and Hydrogen Peroxide	Non-chromium substitution. Non-fuming.
Chrome-based Anti-tarnish	Benzotriazole (0.1-1.0% solution in Methanol)	Non-chromium substitution. Extremely reactive, requires ventilation.
Cyanide Cleaner	Trisodium Phosphate or Ammonia	Good degreasing when hot and in an ultrasonic bath. Highly basic. May complex with soluble metals if used as an intermediate rinse between plating baths where metal ion may be dragged into the cleaner.
Tin cyanide	Acid tin chloride	Works faster and better

the quantity of waste disposed of. Table 4-7 gives some disposal fee ranges for solids and liquids in drum and bulk containers and for "lab packs." In the U.S., the drum prices shown are for larger quantities; disposal of small quantities of drums can cost up to three times as much per drum.

The cost of disposal site lab analysis of the waste is included as a disposal fee and appears in Table 4-7. Each shipment of waste to a management facility undergoes an analysis confirming the constituents of the waste shipment. Therefore, reducing the number of shipments will result in a savings.

Changes in raw materials cost, and operation and maintenance costs are process-specific. Maintenance cost may seem a minor item, but it may be quite substantial.

The remaining elements are usually secondary in their direct impact and should be included on an as-needed basis in fine-tuning the analysis. For example, calculating savings in waste storage and handling requires imputing a value for the waste inventory area and estimating the pre- and post-project costs of containerizing, labelling, and moving the waste. Changes in the administrative costs of regulatory compliance may occur only with a complete or near-complete reduction in waste volume.

Once cost savings have been calculated, the standard profitability measure can be computed. One of the more popular measures among engineers is the payback period. This measure has a strong intuitive appeal, especially for projects intended for reducing costs as opposed to increasing revenues. Capital funding for a project may well hinge on the ability of the project to generate positive margins long after payback and to realize an acceptable return on investment as measured by the internal rate of return.

One way of accounting for a reduction in an identified but not readily quantified risk is to ease the financial performance requirements for the project. The acceptable payback period may be lengthened to five years, or the required internal rate of return may be lowered. Such adjustments reflect recognition of elements which affect the risk exposure of the firm but which cannot be included in the analysis, such as lower potential liabilities. (These adjustments necessarily reflect the individual bias of the persons evaluating the project for capital funding.)

4.6 Requesting Approval for Funding of Waste Management Projects

Unfortunately, suggestions for process improvements are not always sold on their technical merits alone. As anyone involved in selling a product will say, presentation is the most important part of persuasion. A clear depiction of both tangible and intangible benefits may edge a project past its competitors for funding.

Persons willing to sponsor a waste reduction idea should exhibit a strong belief in their idea and confidence that it will work. In the interest of

TABLE 4-7

Typical Costs of Industrial Waste Management

Disposal	
Drum waste	
solids	\$50 - \$75/drum
liquids	\$75 - \$160/drum
Bulk waste	
solids	\$150/cubic yard
liquids	\$0.95 - \$2.50/gallon
Lab packs	\$100/drum
Analysis (at disposal site)	\$200 - \$300
Transportation	\$65 - \$85/hour @45 mph (round trip)

Source: Jacobs Engineering. 1986. Private Survey. Washington, D.C.

implementing their idea, they should be flexible enough to develop alternatives or modifications. They should also be committed to the point of doing substantial background/support work and anticipating possible problems with the idea's implementation. Above all, they should keep in mind that an idea won't sell if the sponsors aren't sold on it themselves.

The first step in securing approval is to call attention to the idea. Identify the problem, noting how long it has persisted and is likely to persist without action. For example, a lack of efficient control at one stage of a process could be the source of a waste quantity associated with a constantly increasing disposal cost. An effective identification of the problem would include an outline of the process step, the method currently used to control it, and the past and present costs to the company (e.g. in terms of excess raw material usage plus waste management costs) attributable to the inefficiency. After summarizing the problem, describe the proposed solution, and spell out the material benefits to the company of underwriting the solution. Also, try to enlist the support of management at this point, especially those with primary profit responsibility in your area. Keep in mind that the greater the organizational authority on the part of an idea's main backer(s), the more likely the idea will be implemented.

Knowing the level within the corporation that has approval authority for capital projects will help in enlisting the appropriate support. For example, smaller projects may be approved at the plant manager level, medium-size projects at the divisional vice-president level, and larger projects at the executive committee level.

While soliciting additional sponsorship of an idea, it is important to assemble solid analytical and documentary support. Evaluate the performance of the project under different sets of assumptions, taking care not to "fix" the results positively but to stay close to realistic expectations of future costs and prices, production quantities, tax laws, etc. Use a number of different performance measures (e.g., internal rate of return, net present value, payback period, the timing and amount of net cash flow, and so on). In presenting the analysis, briefly outline how it was done (i.e., what assumptions have been made, whether they are conservative, and how the project generates net cash flow). For example, if the project meets performance requirements even though current disposal fees were used in calculations covering the entire life of the project, point out that these fees can realistically be expected to rise in the future, resulting in even greater avoided costs than estimated. In summarizing your analysis, present all measures of performance to aid in the making of an informed decision. Also include a qualitative assessment of intangible costs or benefits occurring to the company and their effect on project desirability.

The analysis should include not only how much the project will cost and its expected performance, but also how it will be done. It is important to discuss:

- whether the technology is established, with brief mention of successful applications;

- the required resources (e.g., technical expertise and labor time) procurable in-house versus those that must be brought in;
- estimated production downtime;
- estimated construction period, and
- how the performance of the project can be evaluated after it is implemented.

In addition, think through the project for possible alternatives or modifications. Be flexible, as long as the original goal is not obscured. Discuss your idea in advance with operation and maintenance supervision to verify safety and efficient use of manpower. If your idea is for a change in production methods, be prepared to answer questions about the project's effect on the quality of the final product.

The size of the capital outlay and the level of authority needed for approval determine the extent of the necessary analysis and exploration. Decisions on larger capital outlays generally require a more thorough examination of project economic performance in the face of changing business conditions, increased competition, etc.

The next step is to develop a suggested course of action. Develop a detailed schedule for implementing the project, noting when it is most feasible for production downtime to occur, or suggest that the project be referred to an evaluation team. A team can review the project in the context of:

- past experience in this area of operations;
- what the market and the competition are doing;
- how the implementation program fits into the company's overall business strategy; and
- advantages of the proposal in relation to competing requests for capital funding.

An evaluation team made up of financial and technical personnel can ensure that a sponsor's enthusiasm is balanced by objectivity. In like manner, it can also serve to quell opposing "can't be done" or "if it isn't broken, don't fix it" attitudes which the idea could encounter in the organizational structure.

<u>Waste reduction projects generally involve improvements in process efficiency and/or reductions in operating costs of waste management</u>. Cost reduction is certainly an objective of any well-run business. However, the firm's capital resources may be prioritized towards enhancing future revenues (e.g., moving into new lines of business, expanding plant capacity, or acquiring other companies, rather than towards cutting

current costs). If this is the case, then a sound waste reduction project could be postponed until the next capital budgeting period. It is then up to the project sponsor to ensure that the project is reconsidered at that time.

4.8 Measurement of Waste Reduction

Having implemented waste minimization alternatives, it is important to document how successful the alternatives are. You may be able to measure your success by real benefits such as savings in the costs of waste disposal or raw materials (see Section 4.7). However, a more analytical approach to monitor waste reduction is to calculate percentage reduction based on production as follows:

$$WR = \left(\left[\frac{W1}{P1} - \frac{W2}{P2} \right] / \frac{W1}{P1} \right) X\ 100\%$$

where,

WR= percentage of waste reduction
W1= waste generated in year "1"
P1= production output in year "1"
W2= waste generated in year "2"
P2= production output in year "2".

Example:

During 1985 a process generated 50,000 kilograms of waste and produced 500,000 kilograms of product. During 1986, some process modifications were made to reduce waste and improve efficiency, so that 60,000 kilograms of waste were generated, but the process produced 800,000 kilograms of product.

W1= 50,000 kg   P1= 500,000 kg
W2= 60,000 kg   P2= 800,000 kg

WR= (((50/60) - (500/800)) / (50/60) X 100%

WR= 25 percent waste reduction

4.9 References 4.1-4.8

Fromm, C. H., and M. Callahan. 1986. Waste reduction audit procedure: A Methodolgy for Assessment and Screening of Waste Minimization Options. Conference Precedings at the Hazardous Materials Control Research Institute, 4-6 March, Atlanta, Georgia.

Turman, C. E. Hazardous Waste Control Through Source Reduction.

4.10 Bibliography 4.1-4.8

Campbell, Monica E., and William M. Glen. 1982. Profit From Pollution Prevention - A Guide to Industrial Waste Reduction and Recycling. Toronto, Ontario, Canada: Pollution Probe Foundation.

Congress of the United States. 1986. Serious Reduction of Hazardous Waste. Washington, D.C.: Office of Technology Assessment.

Huisingh, Donald, et al. 1985. Profits of Pollution Prevention - A Compendium of North Carolina Case Studies in Resource Conversation and Waste Reduction. Pollution Prevention Pays Program. Raleigh, North Carolina: Department of Natural Resources and Community Development.

Huisingh, Donald, et al. 1985. Proven Profits from Pollution Prevention - Case Studies in Resource Conservation and Waste Reduction. Washington, D.C.: Institute for Self-Reliance.

Personal communication with Dr. Bill Bibb, Director of Research and Waste Management Division, Department of Energy, Oak Ridge Operations, Oak Ridge, Tennessee.

Sarokin, David J., et al. 1985. Cutting Chemical Wastes-What 29 Organic Chemical Plants are Doing to Reduce Hazardous Wastes. New York: INFORM.

Shanghai Resource Recovery and Utilization Company. 1984. Resource recovery and utilization in Shanghai, edited by C.G. Gunnerson. Paper presented at the International Resource Recovery and Utilization Seminar, November, Shanghai, Peoples Republic of China.

U.S. Department of Energy. 1986. Waste Minimization: Less is Better. Draft. Oak Ridge, Tennessee: Waste Management Technology Division.

U.S. Environmental Protection Agency. 1986. Meeting hazardous waste requirements for metal finishers. Seminar materials.

ANNEX 4A - Cost/Benefit Analyses of Waste Minimization

The following two examples illustrate how waste generators treat the cost/benefit analysis of waste minimizations strategies. In each case, the treatment of the prospect were developed first, and the analysis focused on the resulting economic feasibility.

Example 1. Secondary Solvent Recovery

A resin compounding operation uses 1,1,1-trichloroethane solvent for equipment cleaning. The present configuration uses a single stage atmosphere still for solvent recovery. The still recovers 92 percent of 3,455 lbs. of spent solvent per day. The still bottoms, which contain 20 percent solids by weight, are sent to a facility for solidification prior to landfilling.

The company is investigating the feasibility of adding a secondary recovery system to produce a nearly solvent-free, "dry" cake consisting of filler solids and polymerized resin.

The current and planned solvent recycling scheme is depicted in the lock flow diagram in Figure 4A-1. For secondary recovery, a scraped-drum evaporator is being investigated. The equipment list with pertinent technical and cost information is presented in Table 4A-1. Important operating cost parameters are presented in Table 4A-2.

A fixed-cost discounted cash-flow analysis, which assumes no inflation and no change in the real relationships among costs, results in an internal rate of return of 28 percent and a payback period of 3.3 years for this project. The present Accelerated Cost Recovery Schedule[1] (ACRS) is assumed to apply for equipment depreciation. The half of the installed cost is assumed to be met with retained earnings; the other half is financed over 5 years at a real cost of capital of 6.67 percent (12 percent nominal rate of interest with 5 percent inflation). The unit has an assumed operating life of 10 years and no salvage value. Project cash flows under these assumptions are displayed in Table 4A-3.

Table 4A-4 shows project cash flows under the same set of assumptions, but with no account taken of savings through avoided disposal costs. The internal rate of return has fallen to 8.7 percent, and the payback period has increased to nearly six years. On the basis of recovered solvent alone, there is apparently little justification for recovering the 8 percent of solvent remaining after distillation. However, the presence of significant avoided

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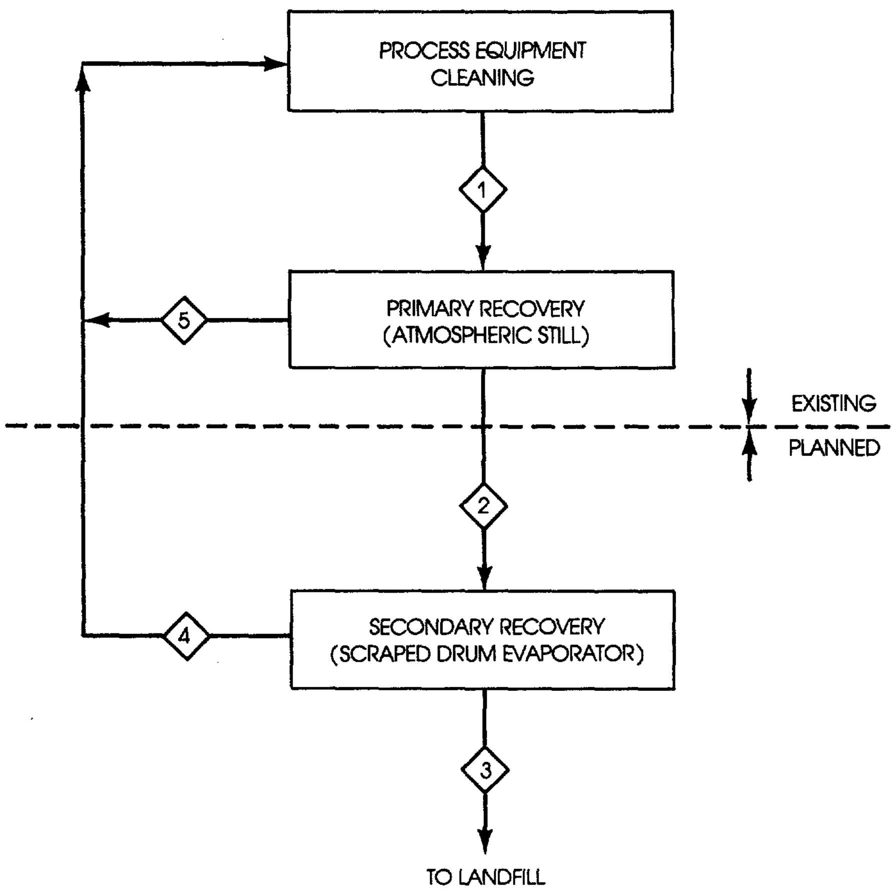
1/ Under ACRS, the equipment portion of a capital investment may be completely depreciated over 5 years beginning with the first (whole or partial) year of operation. The yearly allowable amounts are 15, 21, 21, 21, and 22 percent.

FIGURE 4A-1

Block Flow Diagram and Mass Balance for Solvent Recovery System



Stream	1	2	3	4	5
Solvent	3,455	270	27	243	3,185
Resin	30	30	30	0	0
Filler	76	76	76	0	0
Total, lb/day	3,551	376	133	243	3,185

Source: Butler, D., C.T. Timm, C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

TABLE 4A-1

Secondary Solvent Recovery System
Equipment Data and Cost Information

Service	Description	Delivered Cost
Feed Pump	10 gph, gear type 1/4 HP, Hastelloy C casing, Teflon gears	$ 620
Scraped Drum Evaporator	10,000 BTU/hr, steam heated 1 HP drive, double 6"Ø x 8" drums (titanium), Teflon coated housing	$34,000
Condenser	10,000 BTU/hr, 3.5 ft^2 graphite block	$ 3,000
Receiver Tank	100 gal capacity	$ 1,800
Mixer	1/4 HP	$ 600
Discharge Pump	10 gpm, 3/4 HP, Teflon-coated casing and impeller, magnetic-coupled	$ 950
		$40,970
Piping and Instrumentation		$ 2,000
Engineering, Design and Procurement (in-house)		8,600
Installation Labor and Materials		12,000
DEPRECIABLE FIXED CAPITAL INVESTMENT		$63,570
Allowance for Unforseen/Cash Requirements		6,000
TOTAL CAPITAL COST		$69,570

Source: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

TABLE 4A-2

Secondary Solvent Recovery System
Summary of Operating Parameters and Costs

Element	Rate	Unit Cost	Annual Cost
Solvent Recovered	60,750 lb/yr	$ 0.38/lb	$23,085
Inhibitor Makeup	1,814 lb/yr	$ 1.02/lb	1,850
Utilities (includes steam, cooling water and electricity)			240
Operating Labor and Supervision	1.5 hr/day	$16,00/hr (burdened)	6,000
Maintenance and Spare Parts	6.0% of capital cost		4,250
Waste Disposal			
without secondary recovery	94,000 lb/yr	$ 0.15/lb	$14,100
with secondary recovery	33,250 lb/yr	$ 0.04/lb	$ 1,330

Source: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

TABLE 4A-3

Scraped-drum Evaporator

	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)
Gross savings:										
Solvent recovered	$ 11538	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$23075
Avoided disposal	6388	12775	12775	12775	12775	12775	12775	12775	12775	12775
Total savings	$ 17925	$ 35850	$ 35850	$ 35850	$ 35850	$ 35850	$ 35850	$ 35850	$ 35850	$ 35850
Operating costs:										
Feedstock/power	$ 100	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200
Feedstock/steam	20	40	40	40	40	40	40	40	40	40
Inhibitor	925	1850	1850	1850	1850	1850	1850	1850	1850	1850
Labor	3000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Maintenance	2125	4250	4250	4250	4250	4250	4250	4250	4250	4250
Total cost	$ 6170	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340
Operating income	$ 11755	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510
Less:										
Cost of working capital	179	359	359	359	359	359	359	359	359	359
Depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Interest expense	2131	1710	1267	789	281	0	0	0	0	0
Taxable income	$ 86	$ 8340	$ 8783	$ 9261	$ 9145	$ 23152	$ 23152	$ 23152	$ 23152	$ 23152
Less:										
Tax liability	43	4170	4391	4630	4572	11576	11576	11576	11576	11576
Post tax income	$ 43	$ 4170	$ 4391	$ 4630	$ 4572	$ 11576	$ 11576	$ 11576	$ 11576	11576
Add back depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Add back tax credits	6567	0	0	0	0	0	0	0	0	0
Post tax cast flow	$ 15969	$ 17272	$ 17493	$ 17732	$ 18298	$ 11576	$ 11576	$ 11576	$ 11576	$ 11576
Cumulative cash flow	$ 15969	$ 33241	$ 50734	$ 68466	$ 86764	$ 98340	$109916	$121492	$133067	$144643

TABLE 4A-3 (continued)

	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)
Less:										
Equity payment	34785	0	0	0	0	0	0	0	0	0
Principal repayment	6070	6491	6934	7412	7920	0	0	0	0	0
Net cash flow	$-24885	$ 10781	$ 10560	$ 10321	$ 10379	$ 11576	$ 11576	$ 11576	$ 11576	$ 11576
Real cumulative cash flow	$-24885	$-14104	$ -3545	$ 6776	$ 17155	$ 28731	$ 40306	$ 51882	$ 63458	$ 75034
For the internal rate of return (IRR)										
Operating income	$ 11755	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510	$ 23510
Cost of working capital	179	359	359	359	359	359	359	359	359	359
Depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Taxable income	$ 2217	$ 10050	$ 10050	$ 10050	$ 9426	$ 23152	$ 23152	$ 23152	$ 23152	$ 23152
Less tax liability	1109	5025	5025	5025	4713	11576	11576	11576	11576	11576
After tax income	$ 1109	$ 5025	$ 5025	$ 5025	$ 4713	$ 11576	$ 11576	$ 11576	$ 11576	$ 11576
Add back depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Add back tax credits	6567	0	0	0	0	0	0	0	0	
Post tax net cash flow	$ 17035	$ 18127	$ 18127	$ 18127	$ 18439	$ 11576	$ 11576	$ 11576	$ 11576	$ 11576

Internal rate of return = 28.48%
Payback period = 3.3 years

Source: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

TABLE 4A-4

Evaporator w/o Disposal Savings

	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)
Gross savings:										
Solvent recovered	$ 11538	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075
Avoided disposal	0	0	0	0	0	0	0	0	0	0
Total savings	$ 11538	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075	$ 23075
Operating costs:										
Feedstock/power	$ 100	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200
Feedstock/steam	20	40	40	40	40	40	40	40	40	40
Inhibitor	925	1850	1850	1850	1850	1850	1850	1850	1850	1850
Labor	3000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Maintenance	2125	4250	4250	4250	4250	4250	4250	4250	4250	4250
Total cost	$ 6170	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$ 12340	$12340	$ 12340
Operating income	$ 5368	$ 10735	$ 10735	$ 10735	$ 10735	$ 10735	$ 10735	$ 10735	$10735	$10735
Less:										
Cost of working capital	115	231	231	231	231	231	231	231	231	231
Depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Interest expense	2131	1710	1267	789	281	0	0	0	0	0
Taxable income	$ -6237	$ -4308	$ -3865	$ -3387	$ -3503	$ 10504	$ 10504	$ 10504	$ 10504	$ 10504
Less:										
Tax liability	-3119	-2154	-1932	-1693	-1751	5252	5252	5252	5252	5252
Post tax income	$ -3119	$ -2154	$ -1932	$ -1693	$ -1751	$ 5252	$ 5252	$ 5252	$ 5252	$ 5252
Add back depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Add back tax credits	6567	0	0	0	0	0	0	0	0	0
Post tax cash flow	$ 12807	$ 10948	$ 11170	$ 11409	$ 11975	$ 5252	$ 5252	$ 5252	$ 5252	$ 5252
Cumulative cash flow	$ 12807	$ 23755	$ 34925	$ 46334	$ 58308	$ 63560	$ 68812	$ 74065	$ 79317	$ 84569

TABLE 4A-4 (continued)

	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)
Less:										
Equity payment	34785	0	0	0	0	0	0	0	0	0
Principal repayment	6070	6491	6934	7412	7920	0	0	0	0	0
New cash flow	$-28047	$ 4458	$ 4236	$ 3997	$ 4055	$ 5252	$ 5252	$ 5252	$ 5252	$ 5252
Real cumulative cash flow	$-28047	$-23590	$-19354	$-15357	$-11302	$ -6049	$ -797	$ 4455	$ 9707	$ 14959
For the internal rate of return (IRR)										
Operating income	$ 5368	$ 10735	$ 10735	$ 10735	$ 10735	$ 10735	$ 10735	$ 10735	$ 107535	$ 10735
Cost of working capital	115	231	231	231	231	231	231	231	231	231
Depreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Taxable income	$ -4106	$ -2598	$ -2598	$ -2598	$ -3222	$ 10504	$ 10504	$ 10504	$ 10504	$ 10504
Less tax liability	-2053	-1299	-1299	-1299	-1611	5252	5252	5252	5252	5252
After tax income	$ -2053	$ -1299	$ -1299	$ -1299	$ -1611	$ 5252	$ 5252	$ 5252	$ 5252	$ 5252
Add back drepreciation	9359	13102	13102	13102	13726	0	0	0	0	0
Add back tax credits	6567	0	0	0	0	0	0	0	0	0
Post tax net cash flow	$ 13873	$ 11803	$ 11803	$ 11803	$ 12115	$ 5252	$ 5252	$ 5252	$ 5252	$ 5252

Internal rate of return = 8.66%
Payback period = 5.9 years

Source: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

disposal costs makes the difference between a marginal (probably unacceptable) project and a project that can compete with other projects for capital funding.

Example 2. Retubing of Heat Exchanger

A paper mill facility is using a 8200-ft2 tubular-exchanger as an evaporator for the forced circulation black liquor evaporator service. Severe fouling conditions dictate daily water washings and an average of four shutdowns a year for a hydroblasting (high pressure water jet cleaning) of tubes.

The company has tested electropolished tubes in this service. The test data indicate that while daily washings may still be necessary, the cleaning frequency can be reduced to once a year. The company is now set to evaluate the economic feasibility of retubing. Initial analyses are based on cleaning cost savings alone (i.e., they ignore savings in steam and pumping costs). Since there is a spare unit, there is no loss of production. Basic parameters are summarized in Table 4A-5.

As in Example 1, a fixed-cost discounted cash-flow analysis is conducted to determine the internal rate of return and payback period for this project. Assumptions about project financing are the same: half of the money is borrowed over 5 years at a real rate of interest of 6.67% and the other half is covered by the company's retained earnings. Again, the Accelerated Cost Recovery Schedule (ACRS) is assumed in effect for equipment depreciation, and the investment tax credit is taken. The new tubes are assumed to last 15 years before requiring replacements. Salvage value is assumed to be zero.

The cash flows generated by the proposed retubing project are found in Figure 3. Under the stated assumptions, the project has an internal rate of return of 9.94% and a payback period of 6.3 years. The real cumulative cash flow does not become positive until the ninth year. These are indications of a marginal project. Based on this analysis the acceptability of retubing the heat exchanger would to some degree depend on the ability of the facility to absorb the deficit cash generation until the project's later years. However, inclusion of avoided steam and pumping costs should enhance the project economics considerably. In addition, intangibles such as reduced worker exposure have not been evaluated. On the basis of avoided cleaning costs alone, this project comes close to being feasible. (See Table 4A-4, Table 4A-5 and Table 4A-6).

Source for Annex 4A: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

TABLE 4A-5

Retubing of Heat Exchanger
Summary of Technical and Economic Parameters

Parameter	Description
Heat Exchanger	Long tube vertical evaporator, 8200 ft^2, fixed tubesheet, 800 tubes, 1.5" OD X 0.059" wall, 26 ft-long bundle, 316 SS.
Cost to Retube	$80,000 Includes cost of material (316 stainless electropolished tubes: Tubec tubes - Avesta Stainless Co.), shop and field labor, freight.
Cost of Cleaning (single occurrence)	$4,200 Includes shutdown, disassembly and setup, hydroblasting, re-assembly and cleanup, waste handling and general/administrative indirect costs. The wastes are incinerated on-site using a conventional kraft mill recovery furnace.
Savings in Steam	See Note
Savings in Pumping Costs	See Note

Note: These costs were not included in the analysis in order to isolate the effect of cleanup costs. Energy cost savings can be substantial and must be included in a comprehensive project analysis.

Source: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

TABLE 4A-6

Retubing with Electropolished Tubes

	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)
Gross savings:										
Disassembly	$ 638	$ 2550	$ 2550	$ 2550	$ 2550	$ 2550	$ 2550	$ 2550	$ 2550	$ 2550
Hydroblasting	1200	4800	4800	4800	4800	4800	4800	4800	4800	4800
Assembly	563	2250	2250	2250	2250	2250	2250	2250	2250	2250
Filtration	188	750	750	750	750	750	750	750	750	750
Disposal	0	0	0	0	0	0	0	0	0	0
Indirects	563	2250	2250	2250	2250	2250	2250	2250	2250	2250
Total Savings	$ 3150	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600
Operating income	$ 3150	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$12600	$ 12600	$ 12600
Less:										
Cost of working capital	32	126	126	126	126	126	126	126	126	126
Depreciation	11748	16448	16448	16448	17231	0	0	0	0	0
Interest expense	1464	2526	1963	1356	709	99	0	0	0	0
Taxable income	$-10094	$ -6500	$ -5937	$ -5330	$ -5466	$ 12375	$ 12474	$ 12474	$ 12474	$ 12474
Less:										
Tax liability	-5047	-3250	-2968	-2665	-2733	6188	6237	6237	6237	6237
Post tax income	$ -5047	$ -3250	$ -2968	$ -2665	$ -2733	$ 6188	$ 6237	$ 6237	$ 6237	$ 6237
Add back depreciation	11748	16448	16448	16448	17231	0	0	0	0	0
Add back tax credits	8244	0	0	0	0	0	0	0	0	0
Post tax cash flow	$ 14946	$ 13198	$ 13479	$ 13783	$ 14498	$ 6188	$ 6237	$ 6237	$ 6237	$6237
Cumulative cash flow	$ 14946	$ 28144	$ 41623	$ 55406	$ 69903	$ 76091	$ 82328	$ 88565	$ 94802	$101039
Less:										
Equity payment	45600	0	0	0	0	0	0	0	0	0
Principal repayment	3911	8224	8787	9394	10041	5276	0	0	0	0
Net cash flow	$-34565	$ 4974	$ 4692	$ 4389	$ 4457	$ 911	$ 6237	$ 6237	$ 6237	$ 6237

TABLE 4A-6 (continued)

	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)
Real cumulative cash flow	$-34565	$-29591	$-24899	$-20510	$-16053	$-15142	$ -8905	$ -2668	$ 3569	$ 9806
For the internal rate of return (IRR)										
Operating income	$ 3150	$ 12600	$ 126000	$ 126000	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600	$ 12600
Cost of working capital	32	126	126	126	126	126	126	126	126	126
Depreciation	11748	16448	16448	16448	17231	0	0	0	0	0
Taxable income	$ -8630	$ -3974	$ -3974	$ -3974	$ -4757	$ 12474	$ 12474	$ 12474	$ 12474	$ 12474
Less tax liability	-4315	-1987	-1987	-1987	-2378	6237	6237	6237	6237	6237
After tax income	$ -4315	$ -1987	$ -1987	$ -1987	$ -2378	$ 6237	$ 6237	$ 6237	$ 6237	$ 6237
Add back depreciation	11748	16448	16448	16448	17231	0	0	0	0	0
Add back tax credits	8244	0	0	0	0	0	0	0	0	0
Post tax net cash flow	$ 15678	$ 14461	$ 14461	$ 14461	$ 14852	$ 6237	$ 6237	$ 6237	$ 6237	$ 6237

Internal rate of return = 9.94%
Payback period = 6.3 years

Source: Butler, D., C. Timm, and C. Fromm. 1986. Justification of Waste Reduction Projects by Comprehensive Cost-Benefit Analysis. Washington, D.C.: Jacobs Engineering Group, Inc.

ANNEX 4B - Examples of Successful Waste Minimization Programs

Examples of Successful Waste Minimization Programs

- Allied Chemical Corporation of Metropolis, Illinois, recycled its waste calcium fluoride into the production of anhydrous hydrofluoric acid at another facility. The project required a capital outlay of $4.3 million and resulted in the recycling of 1,000 cubic yards per month. Annual cost savings came to $1.0 million, giving a project payback of about 4.5 years (Huisingh et al. 1985).

- Borden Chemical Co. of Fremont, California, was able to reduce its phenolic resin waste by 95 percent through filter rinse and reuse of phenolic resin from the rinsate. The company also implemented tank rinsing in 2 stages and set up a program to instruct operating personnel about the importance of waste reduction. Capital outlay was minimal (Huisingh et al. 1985).

- Texagulf of Saltville, Virginia, makers of defluorinated phosphate, installed a closed-loop recycling system to remove inorganic fluorides from its process water discharge stream. The system reduced wastewater volume by 280,000 gallons per day, resulting in an annual cost savings of $2 million and a payback in one year (Huisingh et al. 1985).

- Intel Corporation of Albuquerque, New Mexico, installed an in-line acid neutralization unit for their hydrofluoric acid waste. The company realized a payback in 8 months by avoiding the generation of 601 tons of hydrofluoric acid waste which they had previously shipped to California for treatment and disposal (Jacobs Engineering 1986).

- Monsanto Corp. in Baxley, Georgia, was able to find a market for their sodium hydroxide waste as a chemical neutralizer. No longer burdened with the cost disposal, the company is saving $400,000 annually (Sobrino 1985).

- United Globe Corporation, a furniture manufacturer in Lexington, North Carolina, turned in 1982 to incineration of process wastewater solids and solvent wastes to produce process steam. The project involved an outlay of $1.5 million and paid back in less than 3 years on an annual savings of $905,000 (Huisingh et al. 1985).

- Lumberton Dyeing and Finishing Co., a textile firm in Lumberton, North Carolina, modified their process by installing a counterflow heat recovery system to heat process water with exhaust and to precipitate out hydrocarbon pollutants. The system had a payback of five months (Campbell and Glenn 1982).

- Numerous solvent-using companies have installed distillation units and carbon adsorption systems to reduce solvent waste and vapor emissions. Some also burn spent solvents for heat recovery. In all, 22 of the 116 companies examined practiced a form of solvent recovery/reuse. Riker Laboratories of Northridge, California, a pharmaceuticals division of 3M Corporation, was able to eliminate 24 tons of their organic-based solvent waste per year by modifying their process to accept water-based solvent for tablet coating (Garrison 1985). Companies such as Fisher Body of Lansing, Michigan, and Caterpillar Tractor Co. in Mossville, Illinois, have significantly reduced solvent waste by switching to electrocoating and water-borne paints (Campbell and Glenn 1982).

- At DuPont's petrochemicals facility in Victoria, Texas, the use of a new process to produce adiponitrile (ADN) eliminated one intermediate. Wastewater was reduced by 50 percent (400 gallons per minute).

- DuPont's petrochemicals facility in Sabine, Texas, practices distillation of waste for recovery of chemical inputs to other processes and subsequently incinerates the distillation residues to achieve an 80 percent reduction in hazardous waste. The facility also recovers and sells alumina instead of disposing of it off site.

- At DuPont's Cape Fear plant, cobalt is recovered from one process for reformulation as a catalyst in the dimethyl terephthalate (DMT) manufacturing process. In addition, raw materials are recovered out of by-product streams from DMT production, and off-gases are burned to generate heat. The facility has also switched to the use of safer solvents.

    - Other measures taken by DuPont include (League of Women Voters of Massachusetts 1985):

    - Sale of waste ferric chloride instead of ocean dumping

    - Pre-treatment of waste aluminum oxide for sale to recycler

    - Conversion of waste HCl into chlorine

- Type of industry - Automobile Mirror Manufacturer
  Name - Dominion Automotive Industries, Inc.
  Location - Sevierville, Tennessee

  Description - Dominion Automotive Industries manufactures mirrors for automobiles and small trucks. Prior to an analysis of their production process and subsequent modifications, they were prohibited from disposing of their waste water in the local publicly owned waste water treatment plant because of the hazardous constituents (organics and heavy metals). The company was spending approximately $60,000 US per year to transport and dispose of waste water.

  Waste Reduction Methods - House-keeping methods were improved to keep the organic contaminants out of the waste water stream. Organic solvents, primarily methylene chloride are shipped offsite for solvent reprocessing. An ultrafiltration unit and ion exchange unit were installed to remove metals and other contaminants.

  Waste Reduction Costs - $30,000 US

  Payback period - 2 years

Annual Savings - $50,000

Other benefits - Dominion has segregated its hazardous waste from other non-hazardous waste streams. The threat of environmental contamination is significantly lowered and the long term liability to the company is all but eliminated.

Source - Personal Communication Mr. Fred Valentich, Environmental Manager, Dominion Automotive (Garrison 1985).

o Type of Industry - Dye and Epoxy Resin
Name - CIBA-GEIGY
Location - Toms River, New Jersey

Description - The Toms River CIBA-GEIGY Plant has the capacity to produce about 500 different products including dyes and epoxy resins. The plant has the capacity to produce 220,000 and 105,000 pounds per day of dyes and resin respectively. The plant used a significant number of organic solvents in its manufacturing process as evidenced by over 100 air permits filed with the New Jersey Department of Environmental Protection. In its anthraquinone dyes manufacturing process the company used a standard process which relied on mercury as a catalyst. About 2,280 pounds of mercury catalyst ended up in waste streams, the most significant of which was 39,500 lbs of contaminated material.

Waste Reduction Methods - The Toms River Plant has instituted many waste reduction projects but one stands out as superior. In 1983 a new process was instituted at the plant which eliminated the need for mercury as a catalyst in the manufacturing process. This process was developed by the corporation's research staff in Switzerland.

Waste Reduction Costs - Not Reported

Payback Period - Not Reported

Annual Savings - Not Reported

Other Benefits - Mercury is a particularly toxic and persistent chemical in the environment. Elimination of the use of the chemical is a major benefit to the environment and public health.

Source - INFORM (Campbell and Glenn 1982).

o Type of Industry - Power Tool Manufacturer
Name - Emerson Electric Company
Location - Murphy, North Carolina

Description - The Emerson Electric Company produces stationary power tools. Key steps in the finishing of the products are painting and metal finishing. Manufacturing lines of interest include: an electrostatic paint line, zinc electroplating, a paint stripping line and parts washing.

Waste Reduction Methods - Emerson Electric installed a modern automated electroplating process and replaced their organic solvent-based paint system with an aqueous-based anodic electrostatic immersion system. Because they installed the water-based system, Emerson has been able to recover and reuse paint. Cost for raw materials has decreased $600,000 US per year. The company has also improved its house-keeping and general waste management practices.

Waste Reduction Costs - $1,254,000

Payback Period - 1.2 years

Annual Savings - $998,000

Other Benefits - Emerson has implemented a wide variety of waste reduction methods. Invested costs are recovered in little over a year and the financial benefits will continue to accrue thereafter.

Source - North Carolina Pollution Prevention Pays Program (Kohl, Moses, and Triplett 1984).

o Type of Industry - U.S. Government-Owned Research and Production Facility Name - Department of Energy/Oak Ridge Operations (DOE/ORO) Location - Oak Ridge, Tennessee.

Description - The Department of Energy Facilities at Oak Ridge historically have produced large volumes of both radioactive and mixed radioactive and hazardous wastes. Rather than continuing to ignore waste production as had always been the case in the past, the DOE site managers recently instituted a waste reduction program which penalized generating organizations for producing waste.

Waste Reduction Methods - In 1985 a cost recovery system was instituted by charging the manufacturing and research organization $1.50 per gallon of waste. This fee increased to $3.00 in October 1986. The facility has implemented numerous waste reduction techniques but the results of only two are reported here. In 1982 a process was developed to recover silver from used photographic chemicals. The process has been refined and scaled up to production level. Second, at one of the machining facilities a non-hazardous water-based coolant (propylene glycol and borax) was substituted for an organic solvent-based coolant (tetrachloroethylene and mineral oil).

Waste Reduction Costs - unavailable

Payback Period - unavailable

Annual Savings - $60,000 (for silver recovery only)

Other Benefits - The recent emphasis by this US Government Department on waste reduction is an indication that the government is willing to set an example particularly for small and medium-sized industries which are still unaware of the economic and environmental benefits.

Source - Waste Management Technology Document (Draft) (Huisingh, et al. 1985) and personal communication with Dr. Bill Bibb, Director of Research and Waste Management Division DOE/ORO (Kohl, Moses, and Triplett 1984).

o Type of Industry - Leather Tanning
Name - Not Reported
Location - Italy

Description - Leather tanning is an age-old process which has continued to improve. The application of new treatment technologies has improved the efficiency of tanning even more. In summary, the tanning process involves:

1. soaking with salt to prevent bacterial degradation;
2. fleshing to remove unwanted remaining flesh and fat;
3. unhairing using a line and sodium sulphide solution; and
4. tanning using either the vegetable, chrome, or alum process.

Waste Reduction Method - This relates only to the unhairing operation and recovery of salt and sulphide. Ultrafiltration is the technology selected to recover the make-up materials in this bath. The salts and sulphides pass through a membrane while the contaminants such as solids, proteins and oils do not. The membrane has a projected useful life of about three years.

Waste Reduction Costs - $80,000 (1979)

Payback Period - 2.93 years (including accelerated equipment depreciation)

Annual Savings - New uses are being developed for the waste proteins and solids generated in the tanning process. Use for these materials range from foodstuffs to cosmetics.

Source - Pollution Probe Foundation (League of Women Voters of Massachusetts 1985)

o Type of Industry - Auto Engine Remanufacture
Name - Vulcan Automotive Equipment Ltd
Location - Vancouver, B.C., Canada

Description - Vulcan Automotive remanufactures used auto engines. As part of the remanufacturing process, they clean the old block and parts prior to reconstruction. The old cleaning process which they used involved the wet application of caustic soda followed by scrubbing and rinsing. The caustic sludge was stored on-site in tanks prior to off-site disposal. Costs for disposal ranged from $15,000 to $18,000 per year.

Waste Reduction Methods - The company installed a new parts-cleaning system. The two step process involves heating the metal parts to remove the volatile organic oil and greases. Second, the parts are sprayed with a high velocity stream of aluminum shot. The new process is more efficient and less costly than the alkaline-based process.

Waste Reduction Costs - $75,000 US

Payback Period - 2 years

Annual Savings - $41,000 US

Other Benefits - The installation of the new dry washing process has eliminated the need for approximately 48,000 gal/yr of water as well as reduced the manpower requirements for the washing process.

Source - Institute for Local Self-Reliance (Huisingh, et al. 1985).

o Type of Industry - Electroplating
Name of Process - Providence Method
Location - Many

Problem - The majority of contaminated waste from electro-plating facilities is caused by drag out. This leads to the generation of large quantities of hazardous waste, but also to high treatment costs and high raw materials cost. Typically in a batch system, drag-out can account for between 50 per cent and 90 per cent of the chemical raw material use.

Solution - Process modification designed to remove the majority of the drag-out in one or two counter-flow tanks not connected to the final flowing rinse tank resulted in final effluent which required at most pH adjustment and which could then be discharged to sewer. Volume of waste requiring batch treatment was reduced by up to 99 per cent.

Reduction in waste treatment costs - US $60,000 assuming conventional treatment method water flow of 36,000 gpd reduced to 10,000 gpd.

Other benefits - up to 50 per cent saving in process chemicals.

Source - USEPA - Meeting Hazardous Waste Requirement for Metal Finishers (1986).

The cases cited here may now be taken for granted by experienced chemical engineers as common yield-improvement measures, but each one has contributed to significant waste reduction while improving profitability.

Of the more than 115 cases of waste reduction which were examined, 29 included data on payback period. This information is summarized in Table 4B-1. As seen in the table, more than 80 percent of the 29 cases had payback periods of less than 3 years, which indicates fairly rapid capital recovery and suggests solid profitability. Of course, waste reduction could be an unprofitable undertaking. One case was found where a process modification resulted in a net annual cost to the company. However, because the modification helped the company achieve regulatory compliance and improve its community relations, management indicated that the cost was warranted.

TABLE 4B-1

Waste Reduction Project Payback Periods

Payback Period (Years)	Cases	Percent
Under 1	16	55
1-2	6	21
2-3	2	7
3-4	3	10
Over 4	2	7
Total	29	100

Source: Jacobs Engineering. 1986. Washington, D.C.

References for Annex 4B

Huisingh, D. et al.. 1985. Proven Profit from Pollution Prevention. Washington, D.C.: Institute for Local Self-Reliance.

Jacobs Engineering. 1986. Private survey. Washington, D.C.

Sobrino, F. 1985. Resource recovery attracts attention of waste generators. Chemical Market Reporter (November 18).

Campbell, M., and W. Glenn. 1982. Profit from Pollution Prevention, p.298. Toranto: Pollution Probe Foundation.

Garrison, L. S.. 1985. Dupont News 14(9): 1.

Kohl, J., P. Moses, and B. Triplet. 1984. Managing and Recycling Solvents: North Carolina Practices, Facilities and Regulations, Releigh, North Carolina: North Carolina State University, Industrial Extension Service.

League of Women Voters of Massachusetts. 1985. Waste Reduction: The Untold Story. Proceedings of conference at the National Academy of Sciences Conference Center, June 19-21, Woods Hole, Massachusetts.

Fromm, C. H., and M. Callahan. 1986. Waste reduction audit procedure: A methodology for identification, assessment and screening of waste minimization options. Hazardous Materials Control Research Institute, Paper from the 3rd National Conference Proceedings, March 4-6, Atlanta, Georgia.

ANNEX 4C - Bringing About Change in Hazardous Waste Management

Written by Jerome Kohl, North Carolina State University, Raleigh, North Carolina

Introduction

This chapter provides information on North Carolina generators and some United States experience in working with hazardous waste. Most of the experience is North Carolina experience; however, some information is presented on California, Massachusetts, and New York practices.

The basic thesis is: (1) We have developed a hierarchy covering waste management options, in this hierarchy eliminating generation of the wastes is our first choice and land disposal (burial) is last. Other disposal options fall in between; (2) As a result of problems with land disposal we recognize that we need to bring about a change in the waste handling practices of our waste generators; and (3) To bring about this change requires that we educate the generators on alternatives available to them and the pros and cons of each alternative and that we motivate them to make a change. This chapter describes the options, North Carolina educational mechanisms, and efforts at motivation and our recommendations.

First, a little background on North Carolina, our hazardous wastes and their regulation; and our hazardous waste treatment, storage, and disposal facilities.

North Carolina, which is shown in perspective to Spain in Table 4C-1, manages generation, treatment, storage, and disposal of its wastes under permits from the United States Environmental Protection Agency (USEPA). North Carolina Regulations cannot be less strict than those of EPA by EPA rule and cannot be more strict by State Law. So the State Regulations parallel those of the EPA. Enforcement is by a Solid and Hazardous Waste Management Branch of the Department of Human Resources. We also have a Pollution Prevention Pays (PPP) group in the Environmental Management Division of the Department of Natural Resources and Community Development (NRCD). NRCD enforces air and water pollution regulations.

North Carolina has a "Governor's Waste Management Board" which fosters public education and has certain authority in case a company seeking to set up a new treating or disposal facility is in disagreement with a local authority on local charges (this situation has not yet arisen). A two-year-old "Waste Management Commission" overseas is the establishment of the needed facilities. This multiplicity of interested agencies in different departments leads to confusion and competition.

North Carolina generators comprise private industries often owned out of state (and out of country); Federal installations including many military bases; state and local institutions, including schools, prisons, and hospitals.

TABLE 4C-1

A Perspective

	Area in Sq. Miles	Population
Spain	195,000	34,000,000
USA	3,000,000	226,545,000
Vizcaya	853	1,200,000
North Carolina	49,000	6,000,000
Bilbao		433,000
Raleigh		300,000

Bringing About Change

Psychological Factors Involved in Change

The purpose of this Annex is to provide information on how we in North Carolina have helped people and organizations to improve their operations in regard to production and disposal of their hazardous wastes through better management and recycling. Improving here meant getting individuals and organizations to do things differently. It is well known that such changes do not occur easily or naturally. People and organizations have a strong tendency to continue doing things the way they are used to doing them. If changes are to be made, it is necessary that persons and groups be well-informed, be well-motivated, be cooperative and have a positive attitude toward the new ideas. These are all psychological factors. Changes are not likely to be brought about by giving orders or by an appeal to the good intentions of people. Changing the behavior of people in work organizations is a difficult task that requires considerable thought and planning even though it seems perfectly clear that such changes will benefit everyone. Creating change in an organization requires a change agent, that is, a person who will see to it that the conditions necessary for change are established. That person cannot bring about change directly. He or she must do it through people.

Change Agent -----> Supervisors -----> Workers -----> Change

Here are some suggestions that should help in bringing about desired changes.

(1) In influencing people to change their attitudes and behavior, we should keep in mind the following:

(a) The way people perform or behave results from two major factors -- motivation and ability. They not only must want to do something, they must know how, if things are to happen. Neither motivation nor ability by itself is enough. If we wrote this idea in mathematical form, it might look like this:

$\underline{P = M \times A}$.

P is performance, M is motivation and A is ability. Note that the relationship between M and A is multiplicative. If either M or A is zero, nothing will happen. Neither high ability with low motivation nor low ability with high motivation is likely to be very productive.

(b) People are goal oriented in their behavior. They do things because it will make them better off in some sense. The fact that you may not understand or approve of that reason does not matter except that if you do not understand their goals, you will probably not be effective in influencing them. It is also worth remembering that personal goals are often different from organizational goals.

(c) While we tend to think of people as individuals, the social forces in their behavior are extremely important. People do things because of what other people think or do. Hence, we have to plan our operations so as to affect people as groups and not just individuals. A working organization is not merely a collection of individuals; it is a social system. That means that any change in operation that one person makes will affect many other persons and they will react to that change.

(2) The following are some ways of influencing or changing behavior with brief comments on their effectiveness:

(a) Giving orders for desired behavior often causes resentment. This procedure overlooks levels of motivation and ability and usually deals with people as individuals and ignores social factors.

(b) The use of incentives or rewards is a necessary condition. Usually we think of financial incentives only, but other important incentives are promotion, praise, and social approval. An incentive will be of no value if it is not desired by the person. Giving awards to a few only may result in animosity toward management and other workers.

(c) Procedural changes based on social and group factors are usually more effective than those directed at individuals only.

(d) Involving the employee in the decision to make changes and in the process of making changes increases the chance that he will be cooperative and will contribute effectively to improving the process. People like to have control over their own behavior even at work.

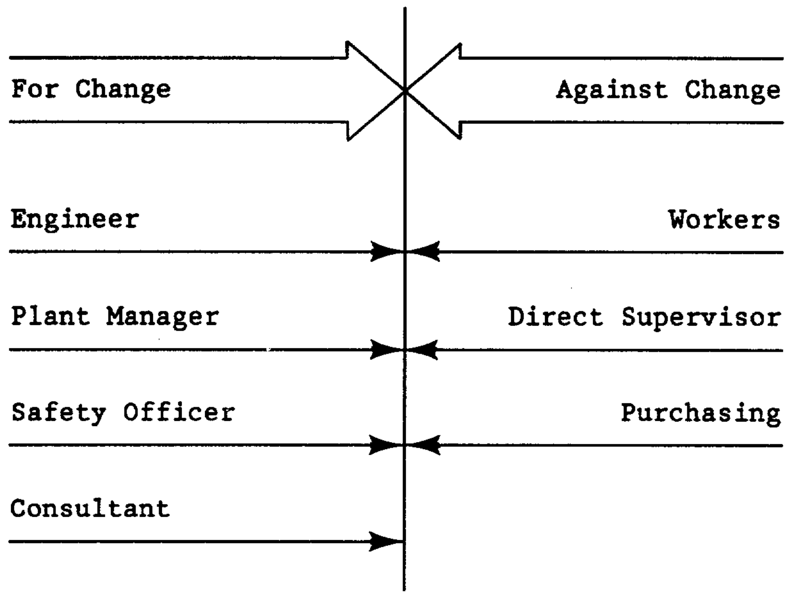
(e) Make full use of the employee's knowledge and his ability to think; treating employees like mental incompetents leads to resentment. Employees usually are the source of the best ideas.

(f) The cooperation and support of all levels of management is important and necessary, if changes are to be made. Make sure management is informed and supportive.

(3) In planning change it is a good idea to make some assessment of the forces in your organization that are for the change and those likely to be opposed to it. We call this "Force Field Analysis." Examine all the forces in your organization; try to determine whether they are for or against the new procedure and the amount of their support or opposition. As an example, these forces might include -- Plant Manager, Safety Officer, Direct Supervisor, Workers, Engineering, Purchasing. You might diagram these forces as follows in Figure 4C-1:

FIGURE 4C-1

Force Field Analisis Diagram



You can see from this balance of forces, pro and con, that you will have some problems in bringing about your change. While you seem to have power and reason on your side, the forces against you might defeat you in the long run. A careful analysis of all forces will give you guidance on how to proceed and what tactics to use in achieving your change.

Economics

One important factor motivating change in the manner of handling wastes is the economic factor. In the case studies included in this paper, the motivation is often economic. For each proposed change, an estimate of costs and savings will need to be made so a payout can be determined.

Some of the lesser-known incentives involve actions by the State of North Carolina and by the Federal Government to encourage companies to do something to reduce hazards and to reduce the danger of groundwater pollution.

Incentives are offered by the Federal and State governments for the following reasons:

(i) To encourage compliance with state and federal pollution abatement requirements

(ii) To avoid or mitigate economic harm to industries forced to comply with pollution clean-up requirements

(iii) To help ensure that complying companies are not at a competitive disadvantage to non-complying companies

The incentives offered by our governments include:

(i) Rapid amortization of investments

(ii) Investment tax credit

(iii) Deduction against franchise tax liability

(iv) Tax-exempt Industrial Development and Pollution Control Bonds

(v) Penalties as incentives:

   (a) RCRA legislation and EPA policies prohibit the EPA from approving or recommending to private parties any facilities that have Category 1 violations.

   (b) RCRA legislation and EPA policies require that penalties be large enough to offset any economic gain from non-compliance.

   (c) Normal business expenses through compliance are tax deductible but penalty expenses are not tax deductible. For example, the cost of buying new drums for a leaky drums penalty is not tax deductible.

(d) The cost of lost goodwill is immeasurable in terms of lost customers, etc.

The North Carolina state incentives currently in existence are:

(i) Tax Exempt Industrial Development and Pollution Control Bonds (N.C. General Statute 159c-2) must meet certain criteria and be approved by appropriate local and state authorities.

(ii) Exclusion from local property tax (N.C. General Statute 105-275) of property used to abate water pollution or to recycle or provide resource recovery of solid waste.

(iii) Reduction of franchise tax (N.C. General Statute 102-122) for costs of property used as in (ii) above.

(iv) Sixty-month amortization (N.C. General Statute 105-122b) on costs of property used as in (ii) above.

Federal incentives are:

(i) Tax-exempt bonds for water pollution control facilities and solid waste disposal facilities.

Other economic incentives to change include:

(i) The need to maintain and enhance the status of the company in the eyes of the community and its customers.

(ii) Early payback of investment or a satisfactory return on the investment.

Hierarchy

There are a variety of options for managing any hazardous waste. As an example this chapter uses electroplating sludge. To reduce sludge production three are options such as recycling, solidifying or otherwise disposing of the sludge. The factors determining the hierarchy include:

(i) Liability

Liability may be the most important consideration in a decision on how to handle sludges. The RCRA "cradle to grave" philosophy and the lawsuits being carried out under Superfund against electroplaters, who in the past legally disposed of waste that must now be pulled out of a landfill and reburied, are strong factors motivating minimizing the use of landfills -- even hazardous waste landfills. While it is difficult to assess a per day cost of this future liability, it must be considered in making decisions regarding disposition of sludges.

(ii) Regulations

Any actions are desirable that can be taken to minimize applicable regulations, reduce the paperwork and record keeping.

(iii) Costs

In trying to assess the costs, for example, of paying someone to reuse a spent solution or a sludge, one must balance this cost against the total disposal cost and liability. A factor often not included in cost consideration is that of liability insurance. This insurance cost should be factored in when the waste is stored or disposed of in such a way that future liability could be incurred.

(iv) Conservation of Resources

Chromium, nickel, and copper are all elements of limited supply. It is foolish to take solids with high concentrations of these metals and to mix these solids with many other types of waste materials and then bury the mixture in a manner that makes it difficult to ultimately retrieve the metals. From the long-term point of view, it is in the best interest of electroplaters to minimize their purchase of newly mined metals.

In light of the factors described above, we suggest that a hierarchy for handling electroplating sludge can be developed which will resemble Figure 4C-2. Note that we indicate that the most desirable option with the least liability is changing the process and/or housekeeping to reduce or eliminate sludge generation. We suggest that the poorest option with the greatest long-term liability is the placement of solidified waste in a landfill. Table 4C-2 summarizes the liability and economics of the various sludge handling methods.

Education - Spreading the Word

Due to its lack of treatment facilities and inability to overcome local opposition to siting new facilities, North Carolina is trying to move its hazardous waste generators up the hierarchy shown in Figure 4C-2. Table 4C-3 lists the techniques used in North Carolina for informing generators of the options available to them and the pros and cons of each option. An Advisory Committee of Generators is used to help develop workshops and manuals and a Consulting Behavioral Psychologist provides counsel on motivation. Table 4C-4 lists New York techniques. California uses the above ideas and has set up a program to review manifests. If the manifest indicates that sludge was buried that could have been recycled, the generator is told of his error and instructed to change his ways to a new technique for which he is given information. Massachusetts offers a phone-in-for-help system.

For example, working with S.E. chapters of the Electroplating and Surface Finishing Society, two one-day meetings were organized on "Reducing Metal Losses and Sludge Production in the Electroplating Industry." For and from these meetings a manual, "Managing and Minimizing Hazardous Waste Metal Sludges," (December 1984, J. Kohl. and B. Triplett) was developed. Funding for the workshops and manual came from the N.C. Legislature (via the Governor's Waste Management Board). The Table of Contents of this manual is shown in Tables 4C-5, and 4C-6, and 4C-7 are case studies taken from the manual. Exhibitors (vendors of equipment to electroplaters) were encouraged to participate in the workshops. The manual includes a list of equipment suppliers and a list of companies accepting electroplating sludges and spent or

FIGURE 4C-2

Options for Managing Electroplating Sludges

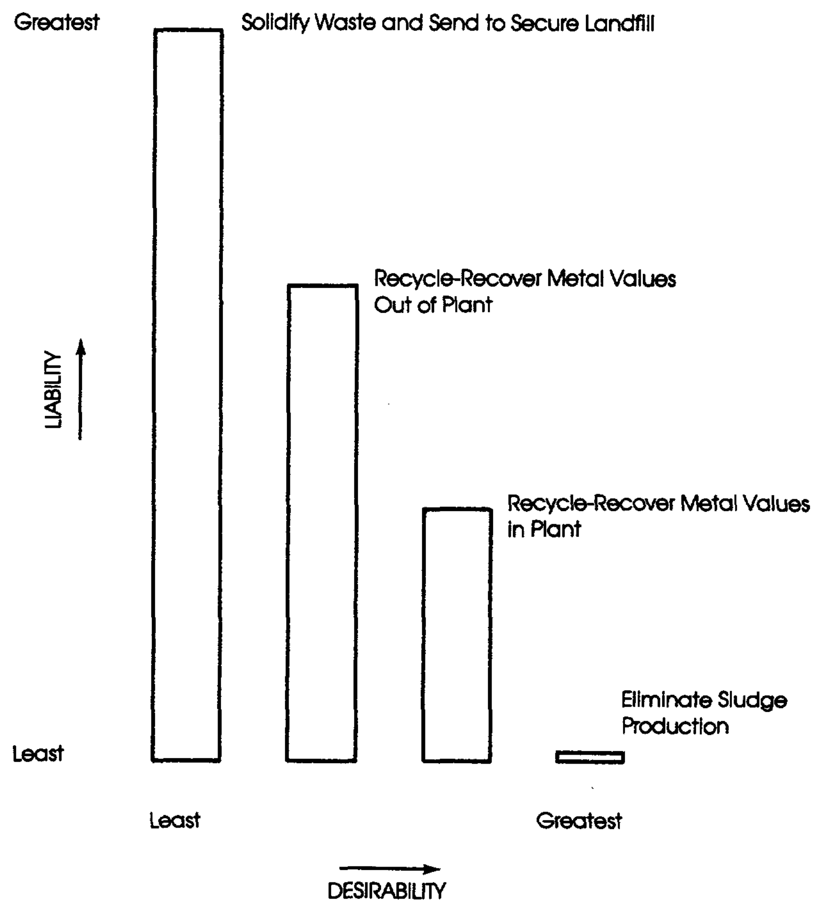


TABLE 4C-2

Overview of Various Handling Alternatives for Metal-Containing Wastes

Option	Limitations	Liability	Economics
Improve housekeeping practices to minimize waste generation	Management must be amenable to procedural changes	Reduced	Little or not capital investment
Change process to minimize or eliminate waste genera-	Process and management must be amenable to change	Greatly reduced or eliminated	Depends on particular situation
Recycle in-plant	Capital for equipment, operating and maintenance problems and expenses	Greatly reduced or eliminated	Depends on particular situation
Recycle out-of-plant	Concentration levels of contaminants in solutions and sludges, modification of process may be necessary	Greatly reduced, but: transportation, failure of recycler, disposal of residue	Process modification expense, transportation, usually cheaper than landfilling
Solidify - place in secure landfill	Expense for solidification process as well as for secure landfill	Reduced, but: transportation, future site problems	\$25-\$250 per ton for solidification, \$85-\$100 per barrel for secure landfilling
Secure landfill	No free liquids	Transportation; future site problems	\$85-\$100 per barrel
Solidify - place in non-secure landfill		Delisting may be withdrawn; site problems	\$25-\$250 per ton

TABLE 4C-3

Generator Motivation

Motivating Action in North Carolina

Governor's Award for Excellence in Waste Management

Pollution Prevention Pays Matching Grants ($5,000)

Regulations Limiting Placement of Electroplating Sludge in Landfills

Enforcement of Regulations - Fines

Other Motivating Factors

Rising Costs of Metals and Land Filling

Lack of Nearby Disposal Facilities

Concern over Liability from Land Filled Wastes

Fear by Employees of Hazards, Waste Responsibilities

Note: New York taxes generators on a per ton basis according to the mode of waste disposal employed.

TABLE 4C-4

Generator Education

New York

Environmental Facilities Corp. - Not a regulatory agency

Information Services

Waste Exchange (particularly underwrites costs)

Assistance with understanding regulations

Waste Stream Evaluation and Analysis - identification of most economical options, evaluation of alternatives

Referral to outside consultants

Assistance with tax free financing options for industrial pollution control project

TABLE 4C-5

Managing and Minimizing Hazardous Waste Metal Sludge Manual, December 1984

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TABLE 4C-5 (continued)

TABLE 4C-6

Evaporator Case Study

Company:	Eastern Plating
Location:	Newport, Tennessee
Contact:	Roger Woods
Phone:	(615) 623-0062
Purpose:	Recover Ni, Cr^{+3}, Cr^{+6}
Motivation:	(1) Economic - less expensive to operator than any other system (2) The evaporator can put every thing back in tank (3) Eliminates necessity for landfilling or sewering waste
Equipment Supplier:	Techmatic, Inc.
Payback:	6 weeks - 6 months
Comments:	Almost maintenance free; inexpensive to operator
Reported:	Personal communications, August 1984

Source: Kohl, J., and B. Triplett. 1984. Managing and Minimizing Hazardous Waste Metal Sludges Manual. Prepared for workshop on "Reducing Metal Losses and Sludge Production in the Electroplating Industry," December, Raleigh, North Carolina.

TABLE 4C-7

Reverse Osmosis Case Study

Company:	Stanley Tools
Location:	100 Stanley Road Cheraw, South Carolina 29520
Contact:	Mike Vannest
Phone:	(803) 537-9311
Purpose:	Nickel salts recovery
Motivation:	Cost reduction
Equipment Supplier:	Osmonics
Payback:	1.3 years
Comments:	Low maintenance, very positive experience
Reported:	Personal communication, August 1984 to B. Triplett

Source: Kohl, J., and B. Triplett. 1984. Managing and Minimizing Hazardous Waste Metal Sludges Manual. Prepared for workshop on "Reducing Metal Losses and Sludge Production in the Electroplating Industry," December, Raleigh, North Carolina.

surplus solutions. Tables 4C-8 and 4C-9 show a section of such a list and a complementary table.

Similar meetings have been developed and presented on Managing and Recycling Solvents, Managing Used Oils, Managing and Recycling Solvents in the Furniture Industry. Over 100 workshops have been developed and presented to hazardous waste generators and small generators throughout North Carolina. For these workshops, manuals and video tapes were developed. Industry specific programs and video tapes have been developed for dry cleaners, pesticide applicators, and vehicle repair facilities.

We lack an objective, quantitative evaluation of the results of applying the techniques described in this Annex. Based on experience, small workshops (30-40 participants) are recommended with generators presenting case studies as speakers, and with plenty of time for discussion. Exhibition of equipment is encouraged and exhibitors are offered 5 minutes on the program to explain their product and its uses. Manuals should include case studies. The more "local" the case study, the better. "In-plant" visits are arranged to enable generators to see first hand good housekeeping and advanced recovery techniques.

For an in-plant workshop we use a company practicing a good waste management technique and willing to "show-off" their practice to other companies. This provides an opportunity for a prospect for change to see for himself what works, to ask questions, to get pay back information. U.S. experience with bringing about change in agricultural processes has demonstrated that trial plots by farmers open for inspection by their neighbors is the number one means of bringing about change. Our feedback says that bibliographies are not much used and if prepared, should only list readily available publications. Recommendations for a successful workshop and manual are shown in Figures 11 and Tables 4C-10 and 4C-11.

Conclusion

We strongly believe that education of generators on available options is not enough. Indeed some of our experiences, indicate that knowledge of an option such as sludge drying with a pay off under two years still will not lead to the purchase of a sludge dryer. An additional boost is often needed beyond economic advantage or good pay off.

From our discussions with generators and with suppliers we have found that a waste generator is most likely to change his ways when he knows of a better option, know that it will pay out in one or two years and when he is convinced that his present practice could lead to a clash with the regulators or to a possible liability. Figure 4C-3 illustrates this point. When enforcement of regulations is consistent, when there are indeed fines and prison sentences, pollution abatement equipment sales rise. With faltering uncertain enforcement, we experience a reluctance to change.

TABLE 4C-8

Equipment Suppliers

The following list was compiled through personal interviews, telephone conversations and sales literature. The preparers of this list take no responsibility for the list's completeness nor for the quality of services offered by these firms.

Baker Brother/Systems
Post Office Box 707
Raeford, North Carolina 28376
Phone: (919) 875-4169
Contact: David Gibson, Manager
Equipment: Electrodialysis

Barnett-Hormberg, Inc.
1709 East Boulevard
Charlotte, North Carolina 28203
Phone: (704) 332-1597
Contact: H. C. Martin
Equipment: Corrosion control linings, air pollution control systems, fiber glass tanks, portable and fixed agitators, FRP grating, structural members, heat exchangers (steam and electric)

Corning Glass Works
Corning Process Systems
BF Plant
Big Flats, New York 14814
Phone: (607) 974-0280
Contact: Raymond Baker
Equipment: Corning Evaporator

ECO-TEC
925 Brock Road South
Toronto, Ontario, Canada L1W 2X9
Phone: (416) 831-3400
Contact: Mike Dejak
Equipment: Ion exchanger

Filtration Technology, Inc.
Post Office Box 31442
Raleigh, North Carolina 27622
Phone: (919) 787-3988
Contact: Jim Grantham
Equipment: Fluid filtration

Frederick Gumm Chemical Company
1280 Wall Street, West Lyndhurst
New Jersey 07071
Phone: (201) 460-7900
Contact: Joe Cahill, Product Mgr.
Equipment and Supplies: Full line of equipment and chemicals for electro and electroless plating

Harshaw/Filtrol
3915 D Valley Court
Winston-Salem, North Carolina 27106
Phone: (1-800) 321-4802
Contact: Louis Gianelos
Equipment: Evaporators

Innova Technology, Inc.
5170 126th Avenue,
Noth Clearwater, Florida 33520
Phone: (813) 577-3888
Contact: Ted Nohren
Equipment: Chrome Napper

JWI, Inc.
2155 112th Avenue
Holland, MI 49423
Phone: (616) 772-9011
Equipment: Sludge Dryers

Lancy International, Inc.
Post Office Box 490
Zelienople, Pennsylvania 16063
Phone: (412) 452-9360
Contact: James Knight
Equipment: Electrolytic metal, electrodialysis, ultrafilters, evaporators, etc.

TABLE 4C-9

Desirable Characteristics of Electroplating Metal Wastes from the Recyler's Point-of-View

	Amlon Metals	Atomergic Chemicals	Capital Assay Labs Ltd.	Gowen Chemical	Macdermid Inc.	Madison Industries	Northland Chemical Company	World Resources Company
Wastes Accepted	Sludges	Sludges and solns, copper stripping solns and and cyanides	Sludges, solutions, cyanides	Reclaim A1 etchants, acids, ferric chlorides aluminum materials	Reclaim spent solutions: Cu etchants., Cr solns., Sn and Pb strippers, solder conditioner	Sludges, etchants	Copper etchants from circuit board industry	Sludges
Metals Recovered	Cu, Cr, Sn, Ni, precious metals	Cu, most base metals, precious metals	Cu, precious metals, cyanide	Same as Wastes Accepted above	Same as Wastes Accepted above	Cu, Zn	Cu	Cu, Sn, Ni, precious metals
Required Metal Content	Generally 20% or higher of Cu; 2-20% other metals	Item basis, higher % better isolated waste streams a plus	No % requirement for Cu bearing materials; mixtures OK	High A1 content, individually based material content	Metal content not applicable	Metal content not applicable; accept various amounts of waste	14 oz Cu/gal., low level parts of other metals (100 ppm)	No % requirement; mixture OK
Other Special Requirements	Sample size; 2 oz	Low amounts of As, Be, Pb	Sample size 2 oz sludge, 100 ml liquid	Sample size; 1 pint	Prefer to deal with own customers but will consider outside sources	Wastes only from circuit board industry; sample size: 1 qt.	Prefer low Fe, As, Pb	Sample: 2 lbs dry cake or 1 gal. liquid sludge
$	Payment for metals, precious metals, penalty for undesirable compounds	$ decisions based on profit, cost factors	Payment for Rh, Pt, Au, Ag, Pd precious metals	Payment based on A1 content	Payment 28 cents/gal. for Cu, etchants, etc.	Payment for Cu, Zn	Payment only for Cu etchants with low concentration of Fe, As, and Pb	Payment for metals and precious metals

TABLE 4C-9 (continued)

	Amlon Metals	Atomergic Chemicals	Capital Assay Labs Ltd.	Gowen Chemical	Macdermid Inc.	Madison Industries	Northland Chemical Company	World Resources Company
Transport		Seller pays	Seller or recycler pays	Depends on location and quantity of material	Seller pays	Seller pays	Charges for own trucking allowing credit for Cu	"Variable" as to who transport and $ factors
Product	Ship to overseas refineries	Resalable technical grade metal	Solid metal	Basic chemicals	Rejuvenated spent solutions, reclaimed metals used in new plating solutions	Copper and zinc chemicals	Copper chemicals	
Permits	None (Broker)	Part B	Hazard Permit, seeking a delisted status	None	Part B	No RCRA permits	Interim status	Part B

TABLE 4C-10

Formula for a Successful Workshop on Minimizing Electroplating Sludge

Work with a 10-20 member advisory committee, comprised of suppliers and prospective attendees or speakers

Include exhibitors: give each 5 minutes on program

Help speakers develop good visuals and handouts

Limit presentations to 10-20 minutes

Encourage and don't limit discussion and questions

Provide hourly breaks with fruit, juices, etc.

Emphasize case studies - preferably local

Include information on motivating factors and pay back

TABLE 4C-11

Formula for a Successful Manual on Minimizing Electroplating Sludge

Work with an Advisory Committee of generators, treaters, etc.

Emphasize Case Studies, preferably local

Include accurate, up-to-date information on:

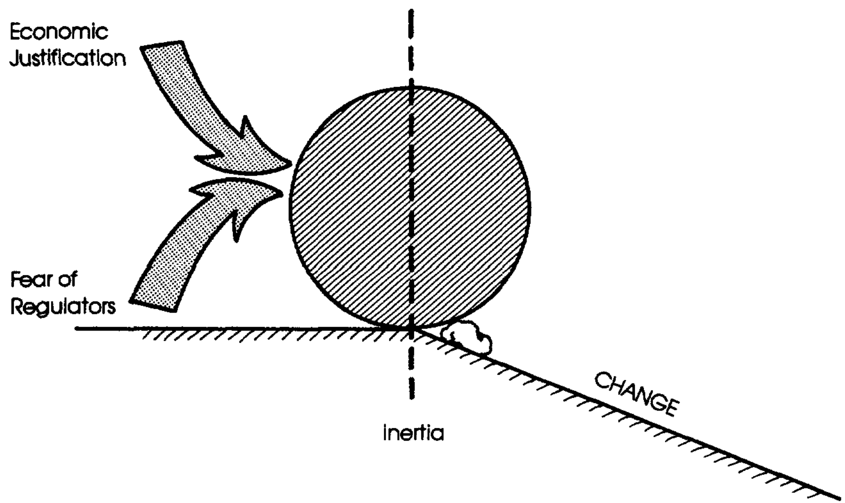
suppliers, transporters, recylers, incinerators, buyers, landfills, services

Provide contacts for information on regulations

Provide a complete, clear Table of Contents

FIGURE 4C-3

Implementing Change



References Annex 4C

N.C. General Statute 159C-2.

N.C. General Statute 105-275.

N.C. General Statute 102-122.

N.C. General Statute 105-122(b).

For reference material on tax and other incentives for pollution abatement equipment, contact Dr. Linda W. Little, Executive Director, Governor's Waste Management Board, 513 Albermarle Building, 325 N. Salisbury St., Raleigh, N.E., 27611, USA, (919) 733-9020.

Note: The N.C. Pollution Prevention Pays (PPP) Program offers assistance to small businesses and communities to find ways to reduce, recycle, and prevent wastes before they become pollutants. The program offers the following publications: 1) Pollution Prevention Bibliography by Industrial Classification; 2) Directory of N.C. Resource Recovery Firms; 3) Environmental Auditing Information Package; 4) Accomplishments of N.C. Industries; and 5) United nations Compendium of Low and Non-Waste Technologies. For access to the PPP program contact:

Mr. Roger Schector, Director - PPP Program
Division of Environmental Management
Department of natural Resources and Community Development
Post Office Box 27687
Raleigh, North Carolina 27611
(919) 733-5083

CHAPTER 5 - Infrastructure of Hazardous Waste Management Systems

5.1 Introduction

The need for a hazardous waste management system begins directly upon generation of waste and continues through all subsequent stages to final treatment and disposal. This system is really a series of management actions to control and contain the waste coordination among various persons and groups of persons. In this simplest form, a hazardous waste management system consists of three units:

- o storage upon generation;
- o collection/transportation; and
- o final treatment/disposal.

This chapter reviews the elements of an overall management system that are applicable to onsite and offsite management of hazardous waste.

5.2 Storage upon Generation

The first stage in this infrastructure is storing waste after it is generated. The waste generator needs to have a system to safely store waste until it can be transferred for further storage, treatment, or disposal. Typically, this storage is done in containers or bulk tanks. Methods like surface impoundments are discussed in Chapter 7.3.1 on disposal technologies. Which is used depends largely on how and where the waste is generated and the physical state of the waste.

5.2.1 Containers

Containers offer the advantages of being very portable, suitable for any physical state of waste, and flexible as to means of filing. They can be kept next to the waste generating process until full, then easily moved to a waste storage area awaiting further transfer.

Most containers are suitable for many types of waste, form liquids, sludges to bulky solids. Containers may be filled by any available method, for example, pumping, shovelling, or tipping. Empty containers which had contained raw material may be suitable for storing waste, depending on the compatibility of waste with the container and with any residues which may be left in the container. Compatibility with the container is important so that the container's integrity is not impaired. For example, a plastic container should not be used to store solvent waste. Care must be taken that residues from the container's previous contents will not react with the waste; example, a container which had contained cyanide salts should not be used for waste acid.

Disadvantages of containers are:

(1) they are easily damaged and toppled;

(2) because they are easily moved and stacked, they accumulate easily and may lead to over-storage at the waste producer's site; and

(3) large groups of stacked containers are difficult to inspect for leaks and spills.

5.2.2 Tanks

Tanks are useful for accumulating wastes that are easily handled by bulk materials handling systems such as pipelines, shutes, or belt conveyors. Tanks offer more rigid and integral containment than containers and are easier to inspect for leaks and spills.

5.3 Collection/Transportation

5.3.1 Packaging/Labelling

All containers or tanks containing waste destined for transportation should be clearly labelled with the type of waste and its hazards. The packaging should be secure enough to prevent leaks, spills, and vaporization during transport. Suggested packaging includes:

- wastes oils and solvents: 200 litre steel bung drums or steel tankers;

- solid or semi-solid organic wastes: 200 litres steel clamp-lid drums;

- inorganic liquid wastes: 30,45 or 200 litre plastic cans or polyethylene tanks; and

- inorganic solids and sludges: 200 litre steel or plastic clamp-lid drums.

5.3.2 Paperwork Tracking System

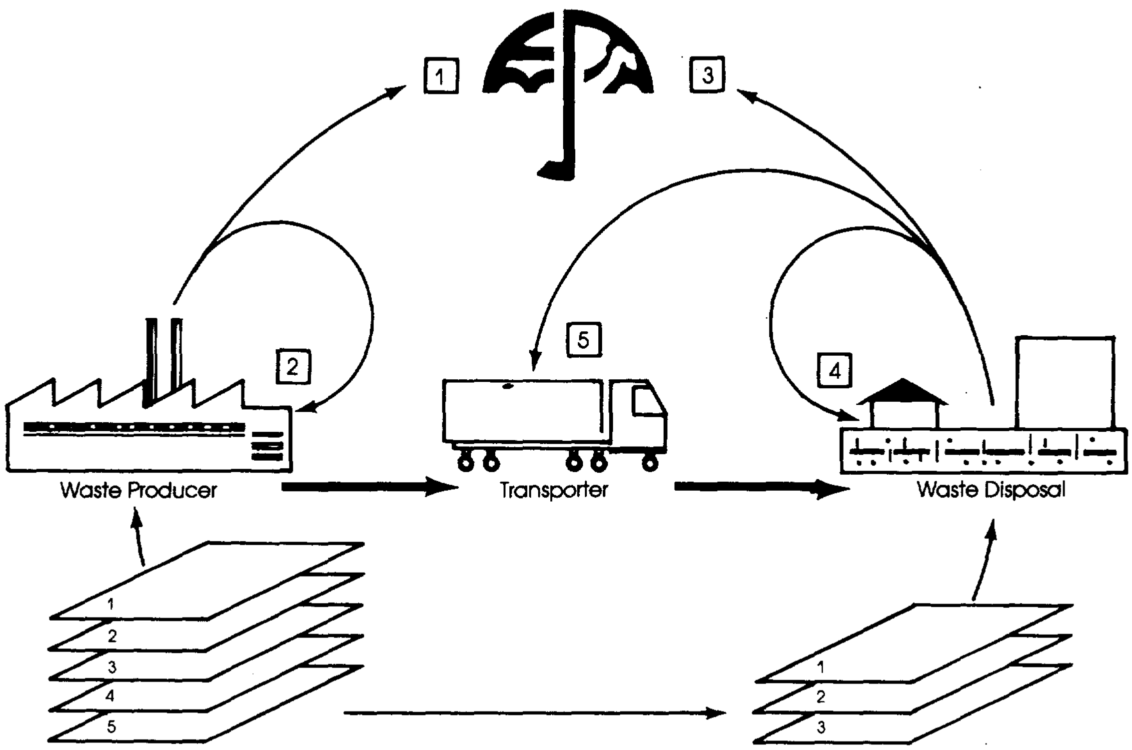
Many countries have adopted a paperwork tracking or manifest system to document the generation of a hazardous waste, all the later processes that it may go through, and offsite waste transportation. The paperwork accompanies the waste shipment and provides a record of waste movement from the waste producer through each intermediate management stage to final treatment and disposal. The paperwork serves as a "chain of custody" document. Every time the waste shipment changes hands, the responsible persons sign the paperwork. Often the government regulatory agency must receive a copy of the paperwork at crucial stages in the transfer to monitor the transfer. The system in the State of Victoria, Australia, is shown in Figure 5-1 (EPA 1985). (See Figures 5-1 and 5-2.)

5.3.3 Direct Transfer/Collection Station

Waste may be transferred offsite either directly or via a collection or transfer station. Direct transfer is economical if a large enough shipment can be sent from a single waste producer, or if a truck picks up waste from more than one waste producer.

FIGURE 5-1

Australian EPA Transportation Scheme



Waste Disposal

CERTIFICATE 1 Forwarded to the EPA by the Waste Producer.
CERTIFICATE 2 Retained by the Waste Producer.
CERTIFICATE 3 Forwarded to the EPA by the Disposal Site Attendant.
CERTIFICATE 4 Retained by the Disposal Site Attendant.
CERTIFICATE 5 Retained by the Waste Transporter.

Source: Australian Environmental Protection Agency. 1985. Draft Industrial Waste Strategy. Victoria, Melbourne.

FIGURE 5-2

Transport Certificate - Australian Environmental Protection Agency

—PLEASE COMPLETE IN BLOCK LETTERS—

PART A. To be completed by Waste Producer

Name of Producer

Postcode

Telephone No.

Waste Code No.

Quantity

Units-cross appropriate square: m^3 kg

Waste Type (place x in appropriate squares)

☐ Inert ☐ Incinerable ☐ Odorous ☐ Highly reactive ☐ Infectious

☐ Poisonous (toxic) ☐ Corrosive ☐ Solid ☐ Liquid sludge

INTENDED DISPOSAL ROUTE

☐ Recycling ☐ Incineration

☐ Land ☐ Immobilisation

☐ Others ☐ Phys./Chem. Treatment

(Refer to E.P.A. ph. 6514224 for further advice)

Description of Waste including indentification of any Hazardous Components

Nominated Disposal Site
(please name selected site)

Further Comments

refer to E.P.A. for list of current facilities

Signature of Waste Producer

Signature of Driver

PART 3 - To be completed by Transporter

Name of Transporter

Transport Permit No.

Loading Date 1 9

Vehicle Reg. No.

PART 4 - To be completed by Disposal/Treatment Site Attendant

NAME OF DISPOSAL/TREATMENT SITE

Site Licence No.

Deposit Date 1 9

Signature of Site Attendant

ORIGINAL TO BE FORWARDED BY THE WASTE PRODUCER TO THE E.P.A. WITHIN 7 DAYS

Source: Australian Environmental Protection Agency. 1985. Draft Industrial Waste Strategy. Victoria, Melbourne.

The Danish Kommunekemi system is a model for collection and transfer station operation, moving chemical wastes from households, industry and farms to a central treatment plant (Palmark 1984).

Each municipality has at least one **collection station**, designed to receive chemical wastes from households. These typically consist of a 4m x 5m x 2m shed with fireproof walls, concrete floor and in circulation, preventing the accumulation of toxic and explosive gases. Inside the shed are two 200 litre drums for liquid wastes, two 200 litre clamp-lid drums for packaged wastes and a box for storing toxic wastes. Private households are not obliged to deliver their wastes, but have the right to do so without charge.

The municipality transports from the collection stations to a smaller number of **transfer stations**, owned and operated by a group of municipalities. Industrial waste producers and farms inform the local authorities of waste accumulation, and notify them when waste is to be moved, using forms similar to those shown in Figure 5-2. Transportation, directly to the transfer stations, is provided by the generators themselves or by private contractors. The scheme is illustrated in Figure 5-3.

In Denmark, sites for transfer stations were selected so that the system could use the existing railway network. A transfer station consists of tanks for bulk liquid storage, and oil separation system and covered bays for the storage of drummed waste and solids. Staffing consists of 1-2 men working 8 hours per day. Besides handling waste deliveries and loading wastes on railcars, etc., some control and administrative work is carried out. A waste transport certificate similar to that in Figure 5-2 and completed by the generator accompanies the waste. After ensuring that the information contained in it is correct, the transfer station attendant hands one copy to the transporter and retains one for his records. The waste is sent by rail from the transfer stations to the central treatment plant. Firms may also transport the waste themselves direct to the site - the procedure and documentation is similar to that discussed in Chapter 5.3.2. The organization of a transfer station is shown in Figure 5-4.

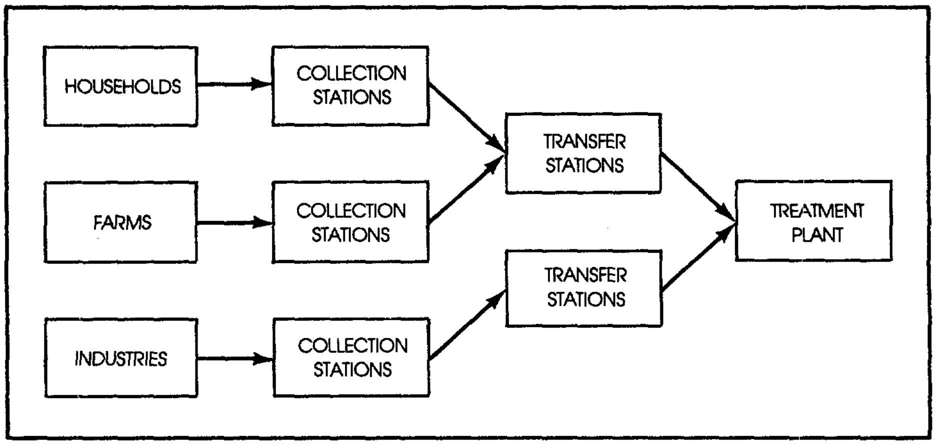
The Kommunekemi system also accommodates waste in small quantities. For example, redundant medicines from private households, doctors and hospitals are received by the pharmacists, who bring them to the collection stations for subsequent transportation and disposal. A further collaboration with producers and importers of mercury batteries ensures that stocklists are supplied with boxes for the collection of used batteries. These boxes are also dispatched to the collecting stations. (See Figures 5-3 and 5-4.)

5.3.4 Transportation

The most common means of transportation of hazardous chemical waste is by road. Hazards associated with on and off-loading activities pose a greater risk than the transport itself. Provided trained drivers in reliable vehicles are employed, and waste is properly packaged, the risks to the community are small. But transport risks should be assessed as

FIGURE 5-3

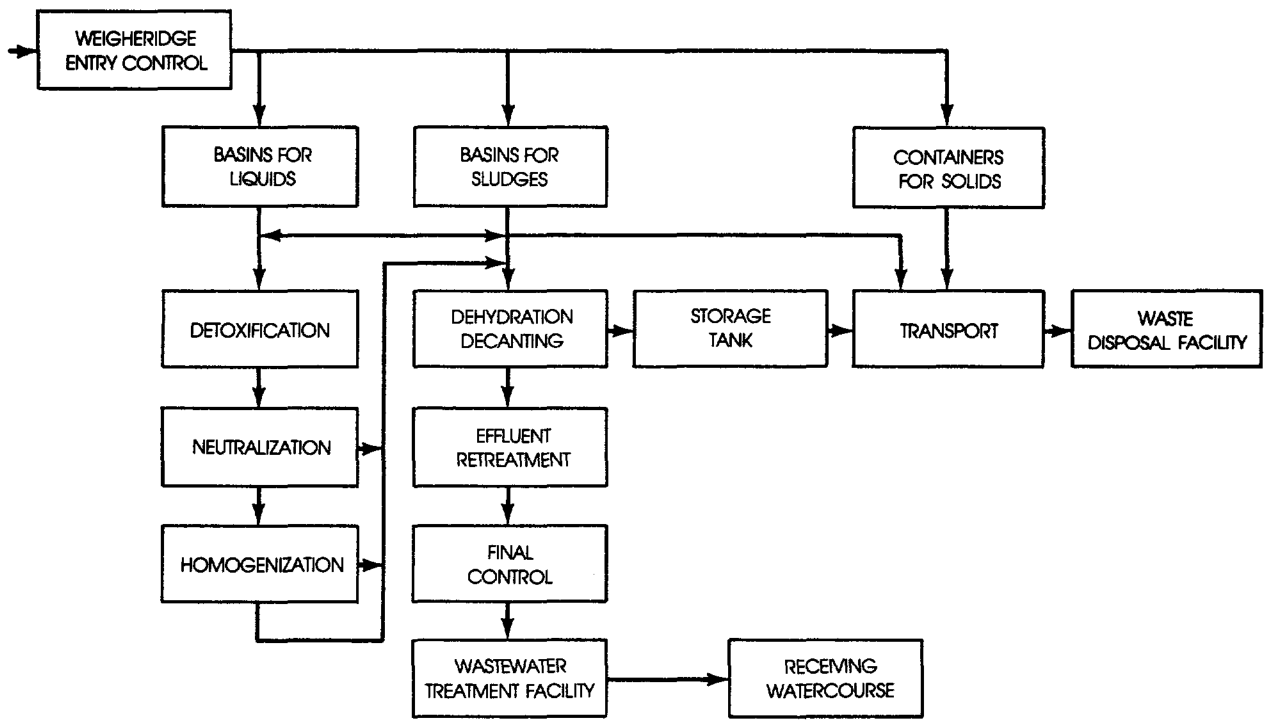
Waste Collection Scheme - Kommunekemi



Source: Rasmussen, I. 1984. Paper presented at the "2nd International Symposium on Operating European Centralized Hazardous Waste Management Facilities" in Odense, Denmark.

FIGURE 5-4

Organization of a Transfer Station



Source: World Health Organization. 1983. Management of Hazardous Waste. Copenhagen.

discussed in Chapter 2. The following controls are desirable:

- o transportation of hazardous waste should be subject to a permit issued by the regulatory authority to contractors with approved vehicles and trained drivers;
- o each vehicle carrying prescribed hazardous waste should be identified using the appropriate hazard symbols;
- o each movement of waste on public roads should require a transport certificate showing its origin and destination;
- o the carrier must ensure that he has the necessary information on the material to be transported, and has formulated an emergency plan in the event of spillage.

5.4 Management Plans and Programs

Any hazardous waste management facility, whether a complex central treatment plant or a simple onsite storage facility, needs plans and programs to guide day-to-day operations and prevent incidents which may cause a health or environment problem. The level of complexity of these plans will vary according to the type of activity, but the essential elements are the same.

5.4.1 Waste Characterization

Waste characterization plays a crucial role in the day-to-day operations of any waste management facility. Before a facility agrees to accept a waste for management, the facility must characterize the waste. Proper characterization begins with obtaining a sample which is representative of the waste. Representative sampling can be difficult since a waste may not be homogeneous. It may consist of anomalies such as various phases, particle sizes, concentration gradients, and "pockets of contamination". Any sampling plan should be designed to discover such anomalies and collect a sample that reflects them. An analysis plan should prescribe analytical procedures, equipment, calibration methods, and quality assurance/quality control procedures.

Sampling and analysis procedures should satisfy three goals:

- o identify the inherent hazards of the waste;
- o characterize the waste enough to effectively manage it; and
- o find a characteristic to easily identify shipments of waste as delivered.

Inherent hazards of the waste need to be known so one may take precautions to prevent accidents caused by the waste. For example: wastes which are flammable, reactive, corrosive, or incompatible with certain materials require special care and handling; wastes which contain highly soluble contaminants should be protected from rain; wastes which create explosive dust clouds should be managed so dusting is minimized.

Specifications of the waste are particularly important to design a program of effective treatment and disposal of the waste. A waste which contains heavy metals and cyanide requires a much different treatment scheme than waste caustic soda.

Waste shipments arriving at a facility must be identified to ensure that it is the same waste that the facility has agreed to accept. The facility should decide upon a test that will easily and readily identify each waste the facility agrees to accept. The test might be for example, pH, flashpoint, chloride, sulphate, TOC, calorific value, cyanide, heavy metals, etc.

5.4.2 Site Security

The facility should maintain adequate security to prevent unauthorized access to the site. There are three reasons for maintaining security. First, to prevent people and livestock from wandering onto the site and becoming harmed from contact with wastes or equipment. Second, it protects equipment from damage. Third, it prevents scavengers from being exposed to and from carrying off contaminated materials. Security can be maintained with fences, natural barriers, or guards.

5.4.3 Equipment Inspection/Maintenance

The facility should establish an inspection program that will check the condition of process equipment, storage vessels and containers, process control devices, emergency equipment, and other equipment necessary for operation of the facility. The inspection checklist and frequency depends on factors such as expected rate of deterioration, sensitivity, and how accident-prone the equipment is. For example, process monitoring equipment crucial to controlling waste treatment requires more frequent and detailed inspection than a drum storage area. The inspection program should include a program for repairing items which are found to be deficient during inspections.

5.4.4 Employee Training

Properly trained employees are necessary for effective operation of any facility. The facility should have training procedures which show, for every job at the facility, the level and type of training necessary for that job and how that training is accomplished. The training may take many forms: from supervised on-the-job training to formal classroom training. The objective of training is to ensure that the employees know how to perform their functions in an effective and safe manner and to respond to an emergency. The level of training increases with complexity of equipment and process. Training, at minimum, should include: safe job practices and procedures, the hazards of wastes employees handle, and emergency procedures, both onsite and offsite.

5.4.5 Operating Record

The facility's operating record should document what the facility has done and reflect the present status of the facility. Examples of what should appear in an operating record are: process control data, waste types and quantities, locations of wastes, and environmental monitoring data. Maintaining an accurate operating record is necessary for scheduling waste deliveries, treatment operations, and facility planning.

5.4.6 Incident Prevention and Preparedness

Hazardous materials, including wastes, present hazards which can cause incidents such as spills, fires, and explosions. By identifying these hazards and preparing for the incidents that could happen, you can prevent many incidents from occurring and minimize the effects of incidents that do occur. The risk analysis approach outlined in Section 5.6 is useful for identifying hazards and potential incidents. Preparing for incidents depends on the hazards and potential incidents identified. If fire from flammable wastes is identified as a potential incident, a preparedness measure could be installation of appropriate fire fighting equipment near the location where fires could occur. The necessary fire protection measures should be designed for each site by appropriate experts and tested frequently. If liquid spillage is a potential problem, curbing in the area may prevent a contamination incident.

5.4.7 Emergency Planning

Facilities should have a set of procedures for employees to follow if an emergency occurs. These procedures should identify the type of emergency, the type of waste, and what to do to minimize the effect of the incident. Safety analysis is a useful tool in designing these procedures. The following should be emphasized:

(1) how to protect employees during the incident;

(2) how to minimize effect of the incident on the environment;

(3) protection of facility equipment;

(4) interaction with community services (police, fire department, etc.) to develop full scale emergency planning. Also drills and tests need to be conducted at regularly scheduled intervals to test the plan and ensure employee preparedness.

5.4.8 Closure Planning

Experience has shown that the best time to plan for final closing of waste management facility is during the design of the facility, which should be updated as experience is gained during operation. The objective is to have a clear, orderly method of closure so that after closure the facility poses minimum risk and requires minimum post-closure maintenance.

The closure of a waste facility involves one of two approaches, depending on the nature of the facility:

- o final treatment and disposal of all wastes and residues and decontamination of equipment; or

- o onsite containment of waste.

The first approach applies to treatment and storage facilities, the second applies to waste that will be left onsite in disposal facilities.

The plan should outline what will be done, what steps will be followed, how the facility will be decontaminated, and how wastes and residues will ultimately be disposed of.

5.5 Example: Central Waste Treatment Plant

5.5.1 Basic Concepts

The central treatment plant discussed here is the Kommunekemi plant in Denmark, which chemically treats inorganic wastes and incinerates a wide range of organic wastes. This plant is illustrated in Figure 5-5.

Since the aim of central treatment plants is to protect the environment by providing safe disposal facilities, the design and operation of such a plant must incorporate safeguards against all forms of environmental pollution which could result from such an operation. In particular (Coleman 1975):

- o aqueous effluent derived from process operations must conform to the relevant discharge specifications;

- o gaseous effluents from incineration operations must also conform to emission standards. Gas cleaning equipment is an essential component of incinerator design;

- o solid residues resulting from the treatment processes must be sufficiently inert, to be safely landfilled;

- o within the treatment plant, the possibility of ground contamination due to waste transfer operations, pipe and tank fracture, site flooding, etc. must be minimized by the adoption of safe working practices and systems of treatment;

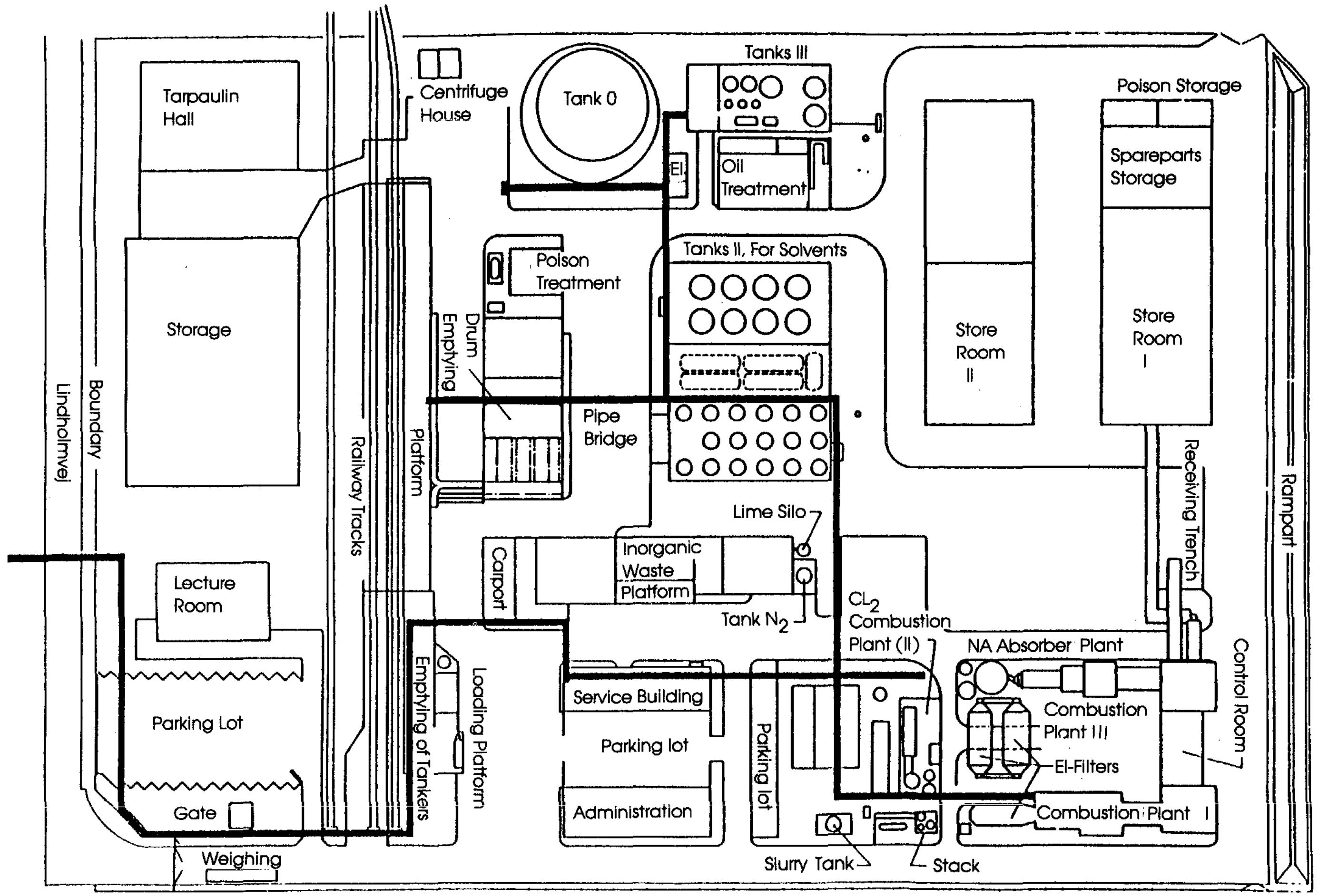
- o measures should be adopted for the adequate treatment of spillages, and emergency plans formulated in anticipation of an incident such as fire, explosion, etc.

5.5.2 Siting

The hazards associated with waste treatment are similar to those of chemical manufacture and processing, and therefore similar siting criteria

FIGURE 5-5

Central Treatment Plant Layout - Kommunekemi



Source: Palmark, Mogens. 1984. Paper presented at the 2nd International Symposium on Operating European Centralized Hazardous (Chemical) Waste Management Facilities in September, Odense, Denmark.

are appropriate. Because such facilities deal with hazardous substances, they must be located so that possible malfunction and emissions do not adversely affect the environment.

Siting of waste treatment facilities is discussed in Chapter 3.9.

5.5.3 Design Philosophy

The design philosophy of central treatment plants catering for chemical treatment of inorganic wastes and incineration of organic wastes is illustrated in Figure 5-6.

The sequence of waste through the facility will typically be:

- o Receiving
- o Inspection
- o Assay
- o Treatability Test, etc.
- o Storage/Blending
- o Solid/Liquid Separation

- o Incineration
- o Chemical Treatment
- o Residue Disposal.

The need for strict laboratory control at all stages of the operation is emphasized by the prominent position of laboratory controls in the characterization of wastes, process scheduling and environmental controls. It may be noted that while both forms of treatment are located on one site, they are essentially independent entities, the only common points being the laboratory, maintenance and administration facilities. The design philosophy therefore also applies to plants catering for just one form of treatment.

5.5.4 Process Descriptions

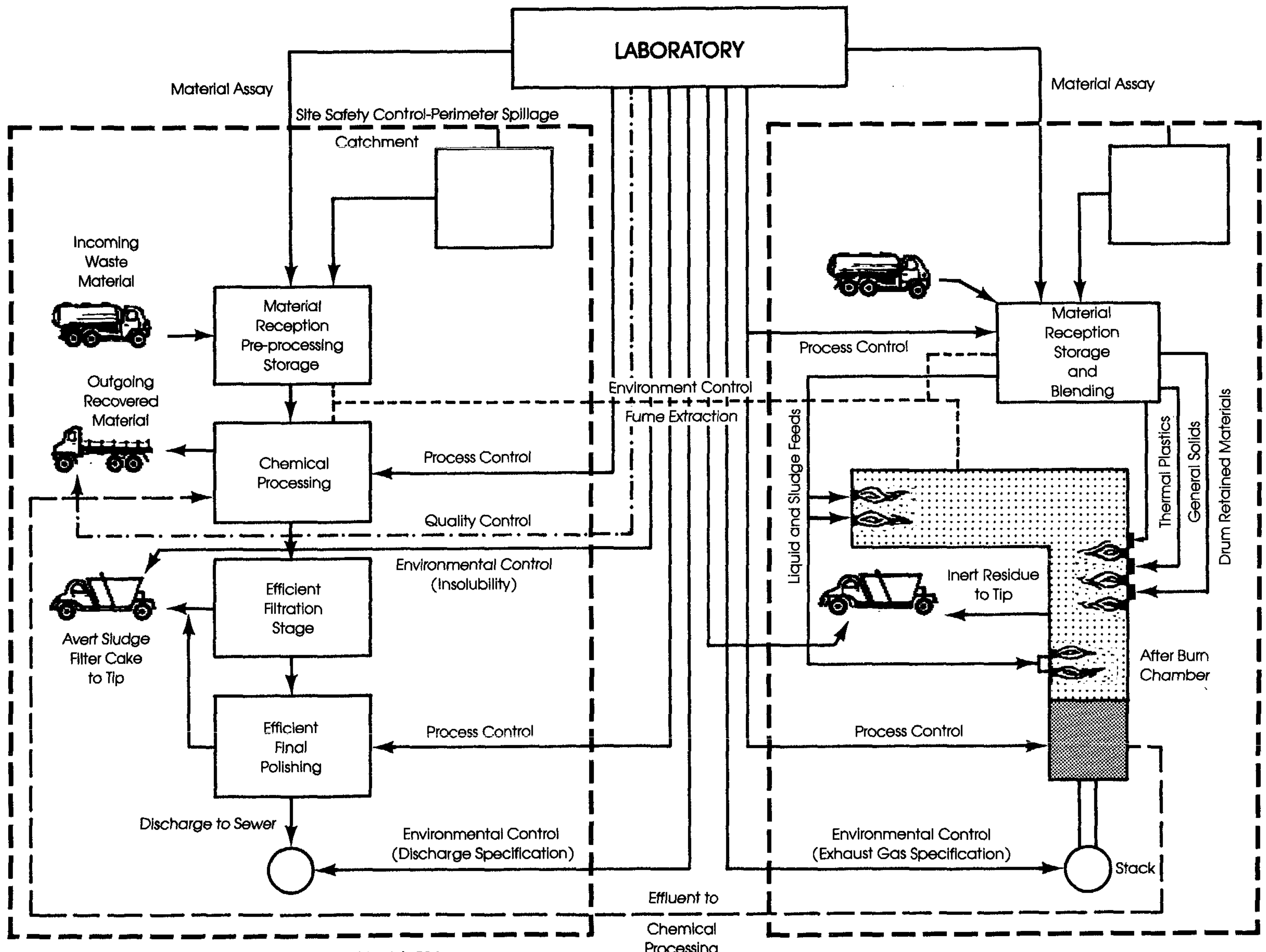
The descriptions below are taken from Coleman (1975).

(i) Chemical Processing of Inorganic Wastes

The first commitment on the plant is the reception of waste materials into pre-processing storage. Receipt may be in bulk via road tanker or in packaged lots comprising any combination of conventional 30, 45 or 200 litre containers. Solid waste may be received by vehicle in various types of removable container; for smaller consignments, kegs and clamp-lid drums may be used. Here the laboratory is involved in chemical assaying to ensure that the material conforms to the in-coming schedule and to provide records of waste characteristics. Waste characteristics such as contaminant concentration determine the type and amount of processing chemicals to treat the waste.

After assaying, the waste is scheduled into the chemical processing

FIGURE 5-6 **Design Philosophy of a Central Treatment Plant**



Source: Coleman, A.K. 1975. Chemistry & Industry (5 July), 534.

programme and the necessary chemical treatment is carried out on a batch basis. At this stage, the laboratory exercises the appropriate process control by monitoring the reaction stages. This monitoring is either by direct instrumentation or by selective chemical analysis. To eliminate smells from this area, the fumes are extracted from the processing vats and passed either to the incinerator for combustion, or into a separate scrubber system.

If the chemical processing has produced a product for recovery, the product receives a quality control check from the laboratory and is then schedule for dispatch to the purchaser.

The non-recovered material passes through a solid/liquid separation (effluent filtration) stage, where the water insoluble solids in suspension are removed from the water. This usually comprises a sludge-thickening stage where solids are settled out under gravity, followed by a pressure filtration stage in which the thickened sludge is physically de-watered. The resultant inert sludge filter cake is removed from the filter press into disposal bins. After the laboratory tests certifies that the material is water insoluble, the material is dispatched to landfill site.

The water phase from the filter system is sampled for analysis by the laboratory. If unacceptably high levels of toxic components are found to be present, the batch is subjected to a 'polishing' chemical process to remove the contamination. Any resultant solid phases are passed back to the filter cake disposal bins.

The quality of the final effluent is subject to a discharge consent specification imposed by the receiving local authority. It is therefore essential that the laboratory certifies each batch of effluent before it is discharged.

(ii) Incineration

As Figure 5-6 shows, the first stage of the incineration plant is reception of waste material into storage. As in the case of inorganic waste, organic is accepted in bulk via road tanker or in a variety of packaged lots including container vehicles for solids such as baled plastics. Again the laboratory is involved in material assay for essentially the same reasons. The materials are programmed from storage to provide the requisite blending in terms of viscosity, calorific values, water content and material types. The liquid and sludge wastes, after blending, are passed to the incinerator feed systems and ignited in the appropriate chamber, according to previously prepared loading schedules. Drums of organic waste are punctured just before loading into the rotary drum incinerator.

The combustion gases pass into an after-burner chamber to ensure complete combustion and thence into a gas washing chamber designed to remove acidic gases, such as hydrochloric acid produced in the combustion of chlorinated hydrocarbons and chlorinated plastics, and particulate matter from the exhaust gas stream. The acidity of the washwater is monitored by the laboratory. From the gas-washing chamber the cleaned gases pass through into the discharge stack. At this stage the laboratory monitors the quality of the discharge gases.

Inert residues are removed from the incinerator, transferred into waste storage bins and, after being certified as inert by the laboratory, are dispatched to a landfilled site. The gas washing liquor is neutralized, passed though a settlement chamber/sand filter to remove particulates, and discharged along with the liquid effluent from chemical treatment.

(iii) Odour Control

The drum opening area associated with material handling operations is equipped with air extraction systems to collect and control fumes. Fumes are collected and fed into the incinerator thus preventing odour problems within the confines of the site. Similarly, air extraction systems are installed on certain storage tanks to control odours from the unloading and storage of certain obnoxious materials in those tanks.

(iv) Site Drainage and Spillage Control

Finally, from the diagram it will be observed that both facilities are surrounded by a spillage catchment drain, which is linked to a catchment sump for each function. In the event of any spillage, the area can be cleaned, washed down and the combined spillage and wash liquors pumped from the respective sump into the material-storage area for processing in the correct manner.

(v) Support Facilities

The site also houses the offices of support functions such as: sales, accounting, administration and maintenance.

5.5.5 Plant Layout

Two examples of the layout of a central treatment plant are provided. The Kommunekemi facility in Denmark is shown in Figure 5-5. The plant covers approximately 6.5 ha. The main sections are:

- o wastes receiving and emptying section;
- o tank farm;
- o waste oil recovery plant;
- o chemical treatment plant for inorganic wastes;
- o incineration plants for organic wastes.

Warehouses for solid packaged wastes, administration/laboratory building, maintenance building, gatehouse and weighbridge, etc. are also located on the site. Plant capacity is 33,000 t/yr for incineration and 2,500 t/yr for chemical treatment.

The layout of a smaller facility, more appropriate to developing countries, is that of ReChem International in UK shown in Figure 5-7. The site occupies 1.5 ha. All the relevant information is provided in the key accompanying the layout, and the design philosophy described in this section is applicable.

Chemical treatment and incineration operations are independent, each having separate tank farms, drum storage and bunded areas for acids, alkalis, support fuel, and general organic wastes. Chemical treatment is performed on a batch basis, in five stirred, stainless steel lined reaction vessels, each of 10m3 capacity. The maximum annual throughput of inorganic waste is 10,000 tonnes. The incinerator has a throughput of 2t/h. (See Figure 5-7).

5.5.6 Administrative Procedures

(i) Introduction

The procedures involved in the operation of a central treatment plant are broadly similar to those employed in a manufacturing facility, and include:

- input-receipt of (waste) material;
- material storage/stock control;
- scheduling of processes;
- process control;
- output-release (discharge) of (waste) products after checking that they conform to regulatory criteria.

Records are kept at each stage of the waste consignment's progress through the plant. Some aspects of these procedures are discussed below, and a booking/recording procedure is described.

(ii) Waste Review/Costing

Figure 5-8 is a form that the treatment plant uses to review wastes and offer the waste producer a quotation of the cost of treatment. The waste producer describes waste characteristics and known analyses in Part A of the form and submits a sample of the waste. The form and sample are given to the central treatment plant's laboratory which reviews the Part A information and performs any additional analyses necessary to design a treatment scheme of the waste and records its work in Part B. The form is then sent to the processing manager who describes in Part C how the waste will be treated. The form then is sent to administration personnel who calculate a treatment cost based on the information on the form. Among

FIGURE 5-8

Example of a Laboratory Analysis Report Form

Application for Analysis and Quotation for Disposal of Waste by -

(NAME AND ADDRRESS OF CENTRAL TREATMENT PLANT)

Waste Producer Informationn

Form Ref. No. _______ Serial No. _______

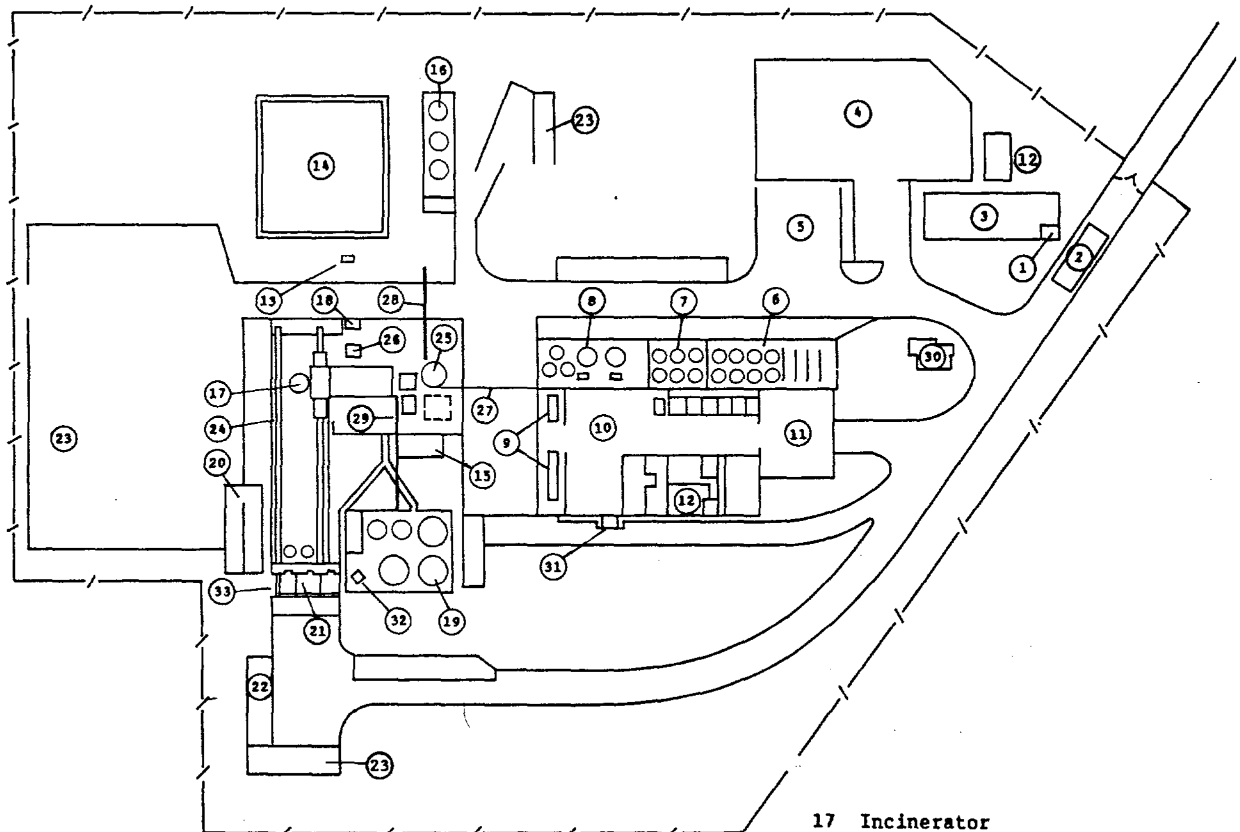
Information provided by Waste Producer (A)	Laboratory Analysis (B)	Plant
General Type of Industry	Sample No.	Transport Requirement
Process producing waste	Date into lab.	Type of vehicle
Main chemical and biological components		Size
Physical nature		Lining
Viscosity/mobility		Receipt into plant
Suspended solids, common		Precautions
Odour/reason		
S. G.		Proposed Final
pH		Storage area
Inorganic Acids/Alkalis Content		Fuel tank Residues Tank C.T. tank / which
Anions present/content (e.g. Cyanide, sulphide, sulphate)		Drum area Other
Metals/content		Plant processing
Organic Halogens (Fluorine, Chlorine, Bromine, Iodine) content		Chemical treatment
Sulpher, Nitrogen, Phosphorus content		Fuel Bulk residues
Water content		Willet system
Calorific value		Special residues
Ash content		Hearth solid
Metal content of ash		Pallet
Flashpoint/flammability		Other
Compatibility with other liquids		Rate of processing
Other Information		

COLLECTION ADDRESS/WASTE PRODUCER	
Name	
Address	
Contact	
Position	
Telephone	Ext.
Telex	

CONTRACTOR (if applicable)
Name
Address

FIGURE 5-7

Central Treatment Plant Layout - ReChem International Limited



1 Gate House
2 Weigh Bridge
3 Offices, Canteen, etc.
4 Car Park
5 Lorry Park
6 Alkali Bund
7 Acid Bund
8 Polishing Plant
9 Filter Presses
10 Reaction Vessels
11 Bunded Store
12 Laboratory, Stores, etc.
13 Emergency Fire Pump
14 Reservoir
15 Control Room - Sub Station
16 Support Fuel Tank Farm
17 Incinerator
18 Ash Skip
19 Sludge Tank Farm
20 Separator
21 Solids & Sludge Hoppers
22 Skip Storage
23 Drum Storage
24 Incinerator Solid Feed System
25 Sedimentation Tank
26 Soot Ash Handling System
27 Fume Duct
28 Pipe Bridge
29 Pipe Bridge
30 Sewage Treatment Plant
31 Oil Storage Tank
32 Reception Screen
33 Centrifuge

Source: ReChem International Limited. 1986. Personal Communication. Southampton.

FIGURE 5-8 (continued)

Example of a Laboratory Analysis Report Form

Application for Analysis and
Quotation for Disposal of Waste by -

Waste Producer Informationn

Form Ref. No. _______ Serial No. _______

Contact Position Telephone Ext. Telex	

Present quantity of waste/where
and how stored

Bulk Stored in

Type of tank

Drums/Pack Numbers by size, type

Rate of arising

Information provided by Waste Producer (A)	Laboratory Analysis (B)	Plant
Precautionary measures	Toxicity Comments Signed Date	Rate of intake Signed Date

Data sheets (if available)
attached
Is waste classified as Special
Waste Yes/No

Signed for waste producer
Position
Date

Charge: Disposa £				Transprt £
QUOTATION				
Letter/Telex/Verbal Date given To whom (if verbal) By whom	Follow up Date By whom	Planned	Actual	Outcome Order Date To competitor Who Price Why

the factors affecting the treatment cost are: the quantity and cost of chemicals to be used for treatment, the degree and complexity of the treatment scheme, and the handling difficulty of the waste. (See Figure 5-8).

(iii) Receipt of Waste

When the quotation is accepted, the procedures of recording the waste begin. A Job Ticket is raised for each consignment of waste. This can comprise of four colours on the form which identify the waste. The information required on the form is filled in with copies to the gatehouse, the laboratory, and the Plant Manager. The gatehouse, having prior knowledge of an incoming consignment, directs the load to the weighbridge and then to the appropriate tank farm/drum storage area. It is a safe and wise practice to verify the contents of the load (waste characteristics) before emptying the contents into storage tanks. A wrong pH or other error could cause an unexpected reaction. The empty vehicle is weighed again as it leaves the plant. A weight ticket is attached to Copy 1 of the Job Ticket, which is returned to administration. Copy 2, with the weight recorded, is sent to the laboratory. Here, an additional analysis is performed on a sample of the consignment, to confirm that it matches the previous description, and recorded on Copy 2. Copies 2 and 3 are then returned to the Plant Manager. A register is maintained at the gatehouse, detailing job numbers and the names of the waste producers, as a permanent record of incoming wastes. Wastes are labelled with the Job Ticket code when they are stored.

(iv) Treatment Schedule

A daily meeting is held with Incineration, Chemical Treatment, Laboratory and Plant Manager, to determine the treatment schedule. A list is drawn up, detailing job numbers (i.e., the code on the Job Ticket), the storage area of the consignments, and the mode and rate of treatment. Incineration schedules will include details of blending operations, and any special requirements, for example, maintaining high temperatures for PCB incineration.

(v) Process Control and Record Keeping

Chemical treatment and incineration process control is exercised by the laboratory (if chemical analysis is required) and by the operators. Incinerator operating conditions such as temperature, induced-draught fan pressure drop, and scrubber water pH are measured with on-line analyzers and recorded on chart recorders. These measurements are also manually logged at half-hour intervals on a daily form. This form also lists feed rates of wastes and identifies their storage origin (tank number, drum number etc.) and job number, following the schedule laid down for that day.

Chemical reactions in the chemical treatment plant are monitored by the operators, and logged to provide a permanent record of the fate of a particular consignment of waste, again identified by its job number. Alarm systems are important. All chemical reactions should have automated monitors for pH, temperature, pressure, etc. All necessary safety equipment should be provided and regularly maintained in case of runaway reactions and other emergencies.

Permanent records are also kept of the emissions from the central treatment plant. Chemical treatment effluents are only released to the receiving system after an analysis has established that they conform to regulatory criteria. A weekly composite form is prepared from the daily records, for both chemical treatment and incineration effluents. These are shown in Figures 5-9 and 5-10.

Finally, a record is made on copies 1,2 and 3 of the Job Ticket, of the date of treatment for the consignment. The copies are then filed.

5.6 Site Safety Analysis

5.6.1 Introduction

A hazardous waste management facility generally caters for a wide range of chemicals and processes. The inherent uncertainties in feed material composition, the potential for human errors, and the failures of equipment, all pose an element of danger to employees and the surrounding community. As an illustration, some possible malfunctions of a incinerator plant are listed in Table 5-1.

Safety analysis is a technique used for identifying possible malfunctions and their consequences. The analysis helps a plant look at potential dangers and take appropriate action to minimize risks. Risk-minimizing actions might include improving operating procedures, redesigning the layout to reduce incident potential and incorporating adequate safety systems.

Safety Analysis involves the following steps (World Bank 1988):

- problem characterization;
- identification of potential hazards and failure modes (**faults**);
- quantification of probability of occurrences (**events**);
- quantification of consequences;
- assessment of the range of risks;
- recommendations for hazard mitigation, improved safety and emergency response.

Plant data relating to equipment, organization and procedures, and statistical failure data for standard components, are used to assess the risks associated with failures. The analytical tools range from simple check-list to computer simulations of failure sequences and consequences such as fire and atmospheric dispersion of toxic substances. The calculated consequences are interpreted in relation to health effects, material damage, or environmental effects.

FIGURE 5-9

Example of a Chemical Treatment Weekly Report Form

Week __________

	Liquid Effluent													Filter Cake									
Day	Sample	pH	CN^- ppm	Cr ppm	$SO_4^=$ gl	Ni ppm	Cu ppm	Zn ppm	Pb ppm	Cd ppm	COD ppmO_2	S/Solids ppm	Remarks	pH	CN^- ppm	Cr ppm	$S^=$ ppm	Ni ppm	Cu ppm	Zn ppm	Pb ppm	Cd ppm	Remarks Skip No
Monday																							
Tuesday																							
Wednesday																							
Thursday																							
Friday																							

FIGURE 5-10

Example of an Incineration Weekly Data Form

Incineration Weekly Data **Week** ____________

		Monday	Tuesday	Wednesday	Thursday	Friday
Stock Gas Acidity	HCl gms/m^3					
Scrubber System	Weir Water: pH					
	T.D.S. % ^{w}/w					
	Feed Water: pH					
	T.D.S. % ^{w}/w					
	S/Solids ppm					
Incinerator Ash	Ash % ^{w}/w					
	Slurried pH					
	Organics					
	S					
	ppm Levels N1 2n Pb Cd Cu Cr					
Residues Feed	Tank No.					
	pH					
	CV KJ/Kg					
	Ash % ^{w}/w					
	Cl % ^{w}/w					
	Heavy Metals % ^{w}/w					
Loads to Residue Tanks	Tank no. To residues feed					

TABLE 5-1
Potential Operational Malfunctions at an Incineration Facility

Operation	Possible Malfunction	Consequence
Tank filling	1. Overall on level interlock	Waste spill
	2. Leakage due to pump seal, valve packing material corrosion, etc.	Small waste spill
	3. Inclusion of unauthorized waste by subversion of quality control procedures	Possible incineration difficulties.
Waste transfer through pump and filter	1. Leakage due to pump seal, material corrosion, etc.	Small waste spill
	2. Filter plugging	None if filters switched on high pump discharge pressure measurement
Waste injection to incinerator	1. Nozzle plugging (low flow detection)	Temporary shut down
	2. Atomization air loss on air blower failure	Failure to combust, toxic vapour discharge, liquid accumulation
Incineration	1. Burner flame loss (flame-out) due to loss of fuel pressure, loss of primary combustion air, coking, or water slug in feed	Transcient toxic vapour discharge prior to automatic shutdown on flame loss detection (or low combustion temperature. A water layer in the tank can be isolated by conductivity measurement interlock to the waste feed pump
	2. Improper fuel rate	Excess waste production discharge
	3. Improper air/fuel ratio	Inefficient combustion
	4. Injection into a cool combustion zone on start up	Inefficient combustion
Stack Gas scrubbing	1. Scrubbing solution circulating pump fails	High HCl concentration in stack gases
	2. Weak scrubbing solution	Not much change, even water scrubbing is very effective for HCl removal
	3. Pump, valve, or tank leaks	Scrubbing solution spill (no consequence if water is used for scrubbing)
Waste water treatment	1. Chemical addition pump fails	Low pH discharge
	2. Pump, valve, or tank leaks	Small waste water spill

Source: Shih, C. C. et al. 1978. Paper number 600/2-78-190 August. Environmental Protection Agency.

5.6.2 Safety Goals

The following safety goals were proposed in a safety analysis of the Kommunekemi central treatment plant (Rasmussen 1984). The underlying principle was that the safety level should be as high as that of a current, high standard chemical plant processing hazardous chemicals. The goals were translated into quantitative fatality risk levels:

- o individual risk for nearest neighbor: probability less than 10^{-7} per year, or in a year there will likely be less than one fatality among ten million people;
- o collective risk for community: probability inversely proportional to the number of fatalities;
- o occupational risk (employees): probability less than 4 per 10^8 working hours with no single hazard contributing more than 10% of the total, and with an allowance of 50% for general industrial accidents.

As a supplement to the quantitative goals, **good standard practice** goals were established to cover such factors which have a general background effect on failure probabilities. These included safe systems of work, operating procedure, maintenance schedules, etc.

5.6.3 Basic Approach

A brief description of the procedures involved in conducting a risk analysis is given below. Detailed information with worked examples may be obtained from references (COVO Steering Committee, Rijnmond Council).

5.6.4 Identification of Failure Cases

The first requirement is to generate a list of possible failure cases which fully represent the spectrum of all possible accidents. Two methods may be used.

(i) The Check-list Method

In this method, failure cases are derived from a list based on knowledge of actual previous accidents. An inventory of the hazardous materials is made, and their intrinsic hazards reviewed. The various possible means of escape are then identified using the check-list (flange leaks, rupture or tanks, pipe breakages, etc.), and each termed a failure case. (World Bank 1988).

(ii) Hazard and Operability Study

The study involves the detailed examination of each component, considering in turn all the possible variations from the design condition which that component could undergo. Some deviations will be found to be physically possible and potentially hazardous under conceivable fault conditions. The deviation will therefore suggest possible failure cases.

5.6.5 Fault-tree Analysis

Starting from each failure case, a tree is constructed downwards in a step by step fashion, by determining at each stage the causative events associated with the previous stage. The tree is complete when the basic causative events remaining are all simple and quantifiable events. All the basic events are then assigned probability values for events higher up the tree calculated by appropriate combination of the basic events. Ultimately, the total probability of the failure case is calculated.

5.6.6 Event-tree Analysis

An event-tree is a logic diagram in which all of the possible outcomes of a single initiating event are listed. The probabilities of a set of outcomes are calculated for each failure case.

5.6.7 Calculation of Consequences and Assessment of Risk

Using models to describe the release, dispersion and ultimate health effect of a chemical on employees and the community, a **consequence** in terms of fatalities is calculated for each outcome. The summation of (probability x consequence) for all outcomes gives a measure of the severity of the failure case, in terms of average rates of death among employees and the general population.

These risks are viewed in relation to the safety goals listed in Chapter 5.6.2. Failure cases associated with unacceptable risks are then reviewed, and improved equipment/work procedures/safety equipment is put into operation to lower the risk to acceptable levels.

5.6.8 Recommendations

As an example of how risk analysis is used to locate and correct for possible malfunction, four potential hazards identified in the Kommunekemi study are listed below (Rasmussen 1984):

- o evaporation of light compounds from waste oil contaminated with solvents, leading to relief valve opening, followed by ignition. Recommendations were made concerning improved reliability of pumping pressure control;

- o chlorine generation as a result of pumping errors to a hypochlorite plant. Recommendations were for separate piping with coding of connections to improve the reliability of the transfer operation;

- o chlorine generation caused by the passage of hypochlorite to a basin of acid waste, via a drain. Recommendation was for relocation of the drain.

- o Sudan analysis is also useful for making siting decisions and for specifying the extent of safety exclusion zones around the facility.

5.6.9 Site Safety

The health and safety of the plant employees and the public is of prime importance in hazardous waste management. The following items are considered to be essential for the safe operation of the facility.

(i) Plant Safety and Training Officer

The role of a safety and training officer is to perform regular safety audits, bring to the attention of plant management deficiencies in operating procedures that might result in a dangerous occurrence injury, and ensure that operators are properly trained and have adequate protection (impervious clothing, breathing apparatus, etc.) against chemicals.

(ii) Operating Procedures and Systems of Work

These are manuals containing detailed information of specific plant activities, such as maintenance procedures, transfer and pumping of wastes and processing of waste. The manual contains, for each item, a summary of the potential hazards associated with the activity, safety precautions such as clothing, decontamination and emergency procedures, and a detailed system of work. It is the responsibility of the Managers to ensure that operators adhere to these procedures, and to regularly update them in the light of the best available information.

(iii) Trained Operators

Operators should be trained to perform plant functions in a sage and responsible manner, adhering at all times to a specified system of work, and safe work practices.

(iv) Housekeeping and Maintenance

Good housekeeping is essential to prevent the dispersion of hazardous chemicals. Immediate clean-up of spills using established procedures, the prevention of fire, the diversion of stormwater from storage and processing areas, are all operations that require constant vigilance.

Lack of maintenance can result in a fractured pipe, leaking pump seals etc., possibly leading to a dangerous occurrence. A regular maintenance programme should be initiated.

(v) Emergency Procedures

Procedures for the evacuation of the site in the event of an incident, should be drawn up and rehearsed. The site should maintain adequate fire-fighting equipment, hydrants, emergency showers, protective clothing and breathing apparatus.

(vi) Operator Hygiene

Operators should be trained to observe basic rules of hygiene, such as changing out of dirty overalls and use of washing facilities before entering the canteen or leaving the site. Smoking and eating should be prohibited in all areas, except the canteen and administration buildings.

5.7 Measurements to be Taken in Case of Unintentional Exposure to Hazardous Waste

It is important that in any case where potential exposure is discovered from hazardous waste the public authorities and public are informed swiftly and adequately about the source of exposure and the potential risks involved. An information communication system should be set up to ensure that the progress of ongoing investigations is being reported adequately and all necessary precautions to protect the public are implemented. Such information is necessary in order to prevent public over-reaction and political exploitation of fears and concern.

Measures should be taken to limit or eliminate exposure and to confine the waste to a controlled area or site.

5.7.1 Health and Safety of Personnel Handling Hazardous Waste

Individuals at most risk from exposure to hazardous waste are those who are involved in handling the waste either during collection, transportation, storage, treatment or disposal. To prevent exposure of these workers to hazardous agents through inhalation, ingestion or absorption through skin contact (through injuries or through splashes into the eyes) safety procedures should be instigated as part of a general safety programme. To be adequate, such a programme should incorporate the following aspects: Information, training, work organization, personal protection, personal hygiene, medical surveillance, and environmental monitoring.

(i) Information

All personnel should be given detailed information regarding risks involved with different types of waste, together with possible routes or exposure, methods of avoidance and measures to be taken should exposure occur. Personnel should be made fully aware of the consequence if they do not follow the prescribed safety precautions. Any change in the composition of waste or working procedures should be adequately and effectively brought to the attention of all worker before changes are implemented.

(ii) Training

All persons handling hazardous waste should be given training in the handling procedures by experienced personnel. They should also be given written instructions about normal procedures, safety precautions and about actions to be taken if complications arise. When procedures are changed, special training courses should be organized for personnel involved.

(iii) Work Organization

(a) Standardized Operating Procedures

An important way to reduce the possibility of harm to personnel is to work out standardized operating procedures. Such procedures should be based on the best available knowledge, operational principles and technical guidance. The initial procedures should be properly tested, reviewed and revised from time to time by competent safety professionals. The procedures should be practical and applicable without sacrificing the level of safety. They should be described in understandable instructions and made available to all relevant personnel.

(b) Plant Layout

The workplace should be properly organized. Appropriate work areas should be established identifying areas where access is forbidden, where entry is restricted, where support services and equipment should be located and where decontamination can be carried out. Where appropriate, a decontamination procedure should be established for workers prior to leaving the plant site. When appropriate, wind indicators should be set out to provide indications for upwind escape in case of an emergency.

Mixing different wastes of unknown compositions should as a rule not be permitted unless tests and chemical expertise have shown or adjudged that this can be performed without any hazard.

When wearing self-contained breathing apparatus or fully encapsulated suites, or when operating in confined spaces, personnel in the hazardous waste area should work in pairs at all times. Pairs should pre-arrange hand signals for communication of if available establish radio contact. Use of self-contained breathing apparatus or fully encapsulated suits requires one or two additional persons suitably equipped as a safety back-up. Communication between all members must be maintained at all times. It is important to emphasize that the number of personnel and the amount of equipment in the hazardous area should be minimized.

Safety plans for all potentially dangerous incidents should be developed, regularly updated and made available to all personnel.

(iv) Personal Protection Equipment

Personnel may be protected from inhalation of hazardous dust and gases, by the use of breathing apparatus. Protection of eyes and skin can be achieved with protective glasses and clothing. If splashing is a possibility, eye rinsing and sometimes whole body shower equipment should be made available at suitable locations. Depending on the type of hazardous waste and on the level of protection required, various combinations of such equipment may be required.

(v) Respiratory Equipment

The choice of respirator is determined by the type and extent of the hazard. Respiratory hazards fall into the following groups:

(a) Oxygen deficiency, and

(b) Air contamination by: particulates, vapours and gases or a combination of these.

The purpose of any respirator is to protect the respiratory system from harmful physical or chemical airborne agents either by removing the contaminant from the air before it is inhaled or by supplying an independent source of respirable air. If a device removes contaminants, it is an air purifying respirator. It does not supply oxygen and therefore must never be used in an oxygen deficient atmosphere. In most cases, unless the specific hazard is known and an air purifying respirator has been determined to be appropriate, this type of respirator would not be used in an emergency response situation.

Breathing supply respirators are the basic response apparatus and are normally referred to as a self-contained breathing apparatus (SCBA). SCBA's are classified as "closed" or "open" circuit systems. A closed system is a rebreathing device in which the exhaled air has been scrubbed and oxygen content restored. An open circuit SCBA emits the exhaled air to the atmosphere. Air is inhaled from a compressed air tank which passes through a two stage regulator which reduces the pressure for delivery to the face piece. Two types of open circuit SCBA's are available, "demand" and "pressure-demand". With the demand system, air flows into the face piece only upon the inhalation or "demand" or the water. The danger of a demand system is that the negative pressure in the face piece caused by inhalation (felt by the wearer as suction), not only triggers air flow from the regulator but could draw contaminated air in through leaks around the face piece.

The pressure-demand system causes a small continuous flow of air to be passed into the face piece through the regulator. Even with or without inhalation there will be air and positive pressure in the face piece, and contaminated air will not be drawn in through leaks around the face piece. A face piece whose exhalation valve is designed for demand operation should never be used with a pressure-demand system, as air will flow continually out of the exhalation valve, quickly exhausting the air supply.

A demand type SCBA should never be used in an atmosphere considered to be immediately dangerous to life or health. In this case a pressure-demand SCBA must be used.

All SCBA's must be worn with full face pieces. Many are designed to fit inside a particular type of fully encapsulated suit. In such arrangements there may be vision problems due to condensation on visors.

(vi) Protective Clothing

The hazardous properties of chemical substances necessitate the use of protective clothing. The degree of protection required is dictated by the inherent physical, chemical, or toxic property of the material. For example, protection required for a corrosive compound is different from that of a compound which releases a highly toxic vapour. The type of activity, must also be considered when assigning protective clothing. As with the selection of proper protective respiratory apparatus, a thorough assessment of the encountered hazards must be completed before making a decision.

Several factors must be considered in the selection of clothing. The most important is the safety of the individual. The level of protection assigned must be in accordance with the severity of the hazard. It is also very important that the individual is well trained in the use of protective apparel and is familiar with the necessary standard operating procedures for site activities. Other factors include cost, availability, compatibility with other equipment, suitability, and most important, performance.

Protective clothing ranges from safety glasses, helmet, and safety shoes to a fully encapsulating suit with a breathing supply. A variety of clothing includes disposable overalls, fire-retardant clothing, splashsuits and many other types of clothing utilizing a range of materials providing specialized protection against a variety of hazards.

The primary safeguard of any protective clothing is the material from which it is manufactured. There are six main characteristics of a material to be considered for acceptable performance:

strength:	resists damage
chemical resistance:	resists degradation and permeation;
thermal resistance:	protects under adverse heat conditions;
dexterity/flexibility:	facilitates activity, ease of movement;
cleanability:	facilitates cleaning and decontamination; and
ageing resistance:	durable over time.

The three general classes of materials used to manufacture protective clothing are cellulose-based, natural and synthetic fabrics, and elastomers. Each is useful for specific purposes.

(vii) The Heat Factor

With any clothing which provides protection against hazardous substances it is important to recognize the hazards created by wearing such clothing.

Because the body is shielded from normal circulation of air it is prevented from carrying out its normal cooling functions. Perspiration generated within an elastomer suit does not evaporate, thus inhibiting the body's major mechanism of losing heat. Without this mechanism, the body is prone to heat stress which can exhibited as heat stroke of heat exhaustion. This is most likely to occur when the ambient temperature is above 18-21^{o}C. Work schedules in fully encapsulated clothing must be regulated very carefully as heat stress may become more of a threat than the chemical hazard itself. Response personnel should be trained to recognize the symptoms and provide first aid for these conditions.

(viii) Personal Hygiene

Although personal protective equipment helps to minimize the hazard, the main determining factor when handling hazardous waste is personal hygiene and behaviour habits. Eating, drinking, chewing tobacco or smoking are activities which should not be carried out in the vicinity of waste material where there is a possibility for contamination by micro-organisms and toxic chemicals. Personnel should frequently change clothing and shower whenever they leave the work place. Facilities should be provided at a suitable distance from the work place where personnel can eat and rest and where washing facilities are provided. In these areas no work clothes should be allowed. Smoking is an effective method of transferring hazardous material from the hands to the lungs and gastrointestinal tract and must therefore be avoided during working hours. During work, personnel should avoid contact with potentially contaminating substances and not walk through puddles, pools, muds etc., and avoid whenever possible, kneeling on the ground, leaning or sitting on waste drums and machinery. If respiratory equipment is required, facial hair (e.g., beards), interfering with the correct fitting of masks, should be removed.

(ix) Medical Surveillance and Safety Programme

Personnel working with hazardous waste should be kept under constant medical surveillance. A proper immunization programme should be administered where appropriate and a programme of regular medical monitoring relevant to the type of exposures should also be carried out. Necessary first aid equipment and relevant antidotes to toxic substances should always be close at hand. Special personnel, including staff safety representative and safety officers should be assigned to ensure compliance with proposed safety measures.

(x) Environmental Monitoring

When certain hazardous wastes are handled, it will be desirable to monitor the environment of the workplace to ensure that dangerously high levels of contamination are not reached. Monitoring may be carried out by either personnel or static sampling; and by the use of techniques ranging from relatively simple ones using detector tubes and hand-held pumps to highly sophisticated operators which requires professionally qualified personnel to both operate and interpret.

5.8 Economic, Institutional, and Financial Considerations

5.8.1 Cost

Costs associated with hazardous waste management can be classified as avoidance costs, abatement costs, damage costs, compensation costs, and transaction costs. A national program in hazardous waste management should determine what institutional arrangements and what economic policies are necessary to assure that all of these costs receive attention and can be adequately financed. One goal could be to minimize the sum of avoidance, abatement, compensation, and transaction costs falling on potential cost bearers.

Avoidance costs are costs of hazardous waste management which could include efforts toward waste minimization, treatment to reduce risk, or disposal. Abatement costs are the remedial costs of removal and clean-up following improper hazardous waste management. Damage costs are the cost of damage to human health and the environment. Damage costs can be viewed alternatively as the benefits of proper hazardous waste management. Compensation costs are the funds transfered to injured individuals or society to compensate for hazardous waste damages. Transaction costs include governmental administrative and enforcement costs and the cost of acquiring information for the parties to a hazardous waste management transaction, including meeting a burden of proof in a court case.

There may be considerable merit in incurring avoidance costs sufficient to minimize future risk. This tends to eliminate future abatement and damage or compensation costs from hazardous waste management. As an example, the cost of proper disposal at the Love Canal site in New York is estimated at $4 million. This compares with abatement costs of $125 million and compensation costs resulting from $2.5 billion in claims for personal injury (Harvard Law Review 1981).

As a practical matter, one can readily see that managing liquid hazardous waste, which is in a 55-gallon drum, is easier than dealing with the same waste which leaks through and contaminates soil and subsequently contaminates ground water and the water bearing rock (aquifer) through which it travels. The cost of decontaminating the soil, ground water and aquifer would be abatement costs. A monetary value for the damage to human health and the environment caused by the contaminated soil or ground water would be damage costs. Finally, the monetary transfers to injured parties, including compensation to society for ecological damage, would be compensation costs.

5.8.2 Complexity and Uncertainty

Avoidance costs include:

- capital costs for procurement of land, facilities, and equipment; and
- operating and maintenance costs associated with hazardous waste management systems.

These costs are clearer, more certain, and more immediately apparent than abatement, compensation and transaction costs. Yet, even estimation of avoidance costs, which would provide an acceptable level of risk to human health and the environment, involves consideration complexity and uncertainty for a given waste generator:

- What wastes are hazardous? In what way?
- What sampling and analysis techniques are appropriate to verify that determination?
- What avoidance measures are most appropriate: changing raw material; changing production process; reuse, recovery, or recycling; treatment to reduce risk; disposal?
- What degree of human exposure or environmental vulnerability applies in this situation?

Abatement costs pose greater complications. For example, when are soils, ground water or aquifers (rock formations containing ground water) adequately cleaned-up? Damage costs involve putting monetary values on sometimes irreversible impairments to human health and the environment. Compensation costs involve difficult questions of causality and equity. Transaction costs involve policy decisions on the degree of government involvement as well as individual decisions by potential cost bearers regarding how much they are willing to spend for more information about hazardous waste management and its impacts.

Because of the complexity and uncertainty associated with hazardous waste management, government intervention is necessary to lower overall costs. In the absence of effective government action, emphasis is likely to fall on minimizing avoidance costs -- the cost of doing the job right in the first place -- thereby maximizing abatement and damage or compensation costs which can be many times greater than avoidance costs. The expert judgments needed from a wide variety of disciplines, including law, economics, toxicology, chemistry, engineering, and management, to achieve a proper governmental rule in hazardous waste management, must be properly coordinated in order to keep transaction costs manageable.

5.8.3 Liability

Liability laws can be a major factor in refocusing the attention of those responsible for managing hazardous waste from a narrow concentration on out-of-pocket avoidance costs to include potential abatement and compensation costs. To minimize the aggregate costs of avoidance, abatement, compensation, and the transaction costs of effecting hazardous waste management cost allocation, it is desirable to consider liability laws that are joint and several, strict, and continuing (Harvard Law Review 1981).

Hazardous waste generators, treaters, receivers, recyclers, reclaimers, and disposers will respond to economic incentives to reduce abatement, compensation, and avoidance costs. Joint and several liability gives firms this incentive by allowing them to bargain among themselves in order to reduce the total costs of hazardous waste management (Calabresi 1970).

Strict liability is appropriate for several reasons. First, costs stemming from hazardous wastes belong to the waste generating and waste management activities and should not, for example, be considered costs of living near a disposal site. Second, because in almost all cases it costs society less to prevent releases than to allow them, liability would usually be found even under a negligence standard when a release does occur. Strict liability avoids the high transaction costs required to prove this point on a case-by-case basis (Harvard Law Review 1981). Thirdly, it reinforces the generally accepted "Pollution Pays Principle", which is frequently incorporated into national environmental laws.

Continuing liability allows a waste generator's liability for costs stemming from its activities to be coextensive with the hazardous life of the waste plus the time reasonably necessary to discover any injuries caused by the waste. Any other approach is inconsistent with the principle that the polluter pays for damages caused and undermines deterrence to improper hazardous waste management (Harvard Law Review 1981).

The issue of liability has been considered by the United Nations General Assembly and by the United Nations Commission on International Trade Law (Schapp 1980). Although passage of national legislation on liability may appear to put that country at a relative disadvantage for industrial investment, recent events suggest that multi-national corporations would benefit from full consideration of all potential costs associated with hazardous materials, including hazardous wastes (Morehouse and Subramaniam 1986).

5.8.4 Relation to Emergency Response, Occupational Health and Safety, Consumers, and Toxic Substances Control

Much of the professional judgment, knowledge and expertise needed for a national program in hazardous waste management is also needed in national programs for emergency response to accidental spills of hazardous materials, protection of employees who handle hazardous material in the workplace, protection of consumers of hazardous products, and control of the manufacture of toxic substances. A scarcity of such resources in developing countries reflects the need for careful coordination in the development and operation of these programs, as well as a program of liquid and gaseous effluent solution control.

5.9 Economic Considerations

From the standpoint of economic theory, society has allocated the optimal degree of resources to hazardous waste management when the marginal cost of management of hazardous waste is equal to the marginal benefits of damages prevented by that expenditure (Haas 1984-85). Included in the assumptions underlying this view are that there are many sellers (purchasers of hazardous waste management) and many buyers (bearers of the damages), all of whom are well informed about the implications of the transaction. Perhaps because of the complexity and uncertainty associated with hazardous waste management, the unaided free market has sometimes led to undesirable consequences and government intervention has been undertaken.

An interesting question is who pays for hazardous waste management. Two possibilities are that the polluter pays and society pays. The polluter-pays principal suggests that the full cost of an economic activity should be reflected in the decisions of the producer of that economic good. Thus, all the costs from any hazardous waste management associated with an economic activity should be represented, including compensation for damages to human health and the environment and outlays for appropriate levels of clean-up. If these costs are included, then optimal levels of output are achieved. The society-pays concept recognizes the difficulty of anticipating damages and establishing causality between injured parties and hazardous waste managers. This is especially true if the injured parties are future generations. As a practical matter, society may wish to eliminate damages and the transaction costs of appropriating compensation by simply paying for proper hazardous waste management (Harvard Law Review 1981). It may also be appropriate to develop a combined approach which incorporates both concepts in an equitable balance.

5.10 Direct Regulation

One approach to achieving a better national balance among the costs of hazardous waste management is direct regulation. A body or bodies of the government prescribe measures (regulations) which must be followed by generators and other managers of hazardous waste. Penalties are prescribed for failure to comply, reporting requirements and right of entry are established, and an inspection and enforcement function is undertaken. Government bodies establishing regulations balance increased protection for human health and the environment against factors such as potential plant closures, loss of employment, and import/export impacts. Because developed countries have already invested considerable money and effort in establishing hazardous waste management regulations, it may be desirable to consider using them. However, to the extent possible, it would be desirable to review the basis for these regulations and make suitable adjustments for local factors in human health, environmental sensitivity, and economic considerations.

5.11 Economic Incentives

Another approach to achieving a better national balance among the costs of hazardous waste management is economic incentives. Economists have argued that market-based approaches can produce the socially desirable amount of pollution control and do so more cheaply than direct regulation. Such approaches include effluent charges, taxes on outputs, marketable discharge permits, subsidization proportional to waste reduction from a base level, and deposit-refund programs (See Note).

An effluent charge (Kneese and Bower 1968, and MacKintosh 1973) would be a tax per unit amount of hazardous waste discharged. The charge should be set so that the marginal cost of avoidance equals the marginal benefit of that avoidance (cost of abatement plus damage plus any compensation in excess of actual damages, ignoring transaction costs). This approach allows the generator to decide how much waste to control, with what technology, and how much to simply discharge and pay the fee. For toxic pollutants, direct regulation may be more appropriate than effluent charges or other economic incentives (Anderson et al. 1977). For less toxic hazardous waste where avoidance technology is not well characterized, economic incentives may be appropriate (Haas 1984-85).

Implementing an effluent charge scheme involves quantifying the benefit of controlling hazardous waste. This may involve estimating intangibles such as the value of human life, better health, more desirable recreation sites, and breathing comfort. Experts do not agree on the methodology to make such estimates (Revesz 1984, and Bailey 1980).

Many environmentalist believe that in balancing tangible costs against intangible benefits, the valve of the latter are down-played. In addition, it is psychologically costly for our society to assign a price to goods like a human life (Calabresi and Bobbitt 1978).

Marketable discharge permits (Kneese and Bower 1986, and MacKintosh 1973) are an economic incentive that avoids or minimizes these problems. Once an acceptable level of hazardous waste discharge is determined, perhaps by a legislative body, the available discharge amount is allocated by open competition among hazardous waste producers for discharge permits. Subsidization proportional to waste reduction from a base level (Kneese and Bower 1968, and MacKintosh 1973) encourages proper practice by paying hazardous waste generators and managers for improved practices. Setting subsidy amounts involves the same problems of setting effluent charges. Base levels might be set by a legislative body. This program suffers the drawback that hazardous waste generators and managers with the worst practices get the greatest rewards. Funding of such a system also poses difficult problems in developing countries.

Deposit-refund programs require deposits from hazardous waste generators which are returned when proof is given that a desirable technology has been used to manage the waste (Coase 1960, and Revesz 1984). Deposit-refund programs might be easier to implement for hazardous waste management than waste taxes (Solow 1971, and Bohm 1981).

5.12 References 5.0 - 5.11

Anderson, F. R. et al. 1977. Environmental Improvement Through Economic Incentives. Baltimore, Maryland: Johns Hopkins University Press.

Bailey, M. 1980. Reducing Risks to Life: Measurement of the Benefits. Washington, D.C.: American Enterprise Institute for Public Policy Research.

Bohm, P. 1981. Deposit - Refund Systems: Theory and Applications to Environmental, Conservation, and Consumer Policy. Baltimore, Maryland: Johns Hopkins University Press.

Calabresi, G. and P. Bobbitt. 1978. Tragic Choices, 32. New York: Norton.

Calabresi, G. 1970. The Costs of Accidents: A Legal and Economic Analysis, 135-140. New Haven: Yale University Press.

Coase, R. 1960. The problem of social costs. Journal of Law and Economics, Vol. 3.

Coleman, A. K. 1975. New concepts in the handling of industrial wastes. Chemistry & Industry (5 July): 534.

COVO Steering Committee, Rijnmond Council. 1982. Risk Analysis of Six Potentially Hazardous Industrial Objects in the Rijnmond Area, a Pilot Study. Dordrecht: D. Reidel Publishing Co.

Haas, Charles N. 1984-85. Incentive options for hazardous waste management. Journal of Environmental Systems 14(4).

Harvard Law Review. 1981. Allocating the costs of hazardous waste disposal. 94(3) (January): 584-604.

Kneese, A. V., and B. T. Bower. 1968. Managing Water Quality: Economics, Technology, Institutions. Baltimore, Maryland: Johns Hopkins University Press.

MacKintosh, D. R. 1973. The Economics of Airborne Emissions: The Case for an Air Rights Market. New York: Praeger.

Morehouse, W., and M. Arun Subramaniam. 1986. The Bhopal Tragedy: What Really Happened and What it Means for American Workers and Communities at Risk.

Palmark, M. 1984. The Danish System. In the 2nd international symposium on operating centralized hazardous waste management facilities, Odense, Denmark.

Paula Schapp. 1980. The case for strict liability in the infant formula industry. Brooklyn Journal of International Law (Spring): 88-110.

Rasmussen, I. 1984. Paper presented at the "2nd International Symposium on Operating European Centralized Hazardous Waste Management Facilities" in Odense, Denmark.

Solow, R. M. 1971. The economists' approach to pollution control. Science, Vol. 172.

World Bank. 1988. Techniques for Assessing Industrial Hazards. No. 55. Washington, D. C.

Note: See, for example:

Ackerman, B., et al. 1974. The Uncertain Search for Environmental Quality. New York: The Free Press.

Anderson, F. R., et al. 1977. Environmental Improvement Through Economic Incentives. Baltimore, Maryland: Johns Hopkins University Press.

Baumol, W., et al. 1979. Economics, Environmental Policy and the Quality of Life. Englewood Cliffs, New Jersey: Prentice-Hall.

Haas, C. N. 1985. Incentive options for hazardous waste management, Journal of Environmental Systems 14(4).

Kneese, A., and C. Schultze. 1975. Pollution, Prices and Public Policy. Washington, D. C.: Brookings Institution.

Lahey, W. L. 1984. Economic charges for environmental protection: Ocean dumping fees. Ecology Law Quarterly 11(3).

Revesz, R. L. 1984. Book Review: Incentives for environmental protection. Ecology Law Quarterly 11(3).

Schelling, T. C. ed. 1983. Incentives for Environmental Protection. Cambridge, Massachusetts: MIT Press.

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