Waste Recycling and Pollution Control Handbook

A. V. Bridgwater
and
C. J. Mumford

Preface

This book gives an overall coverage of practical management of all types of waste to meet the needs of process and plant engineers, managers, chemists, designers, contractors and those concerned with monitoring and enforcing relevant legislation. For the first time the interactions between all forms of pollution are identified and, particularly, the role that recycling has to play, not only in controlling pollution, but often as a significant contribution to controlling costs.

Two factors emerge as being of prime importance—environmental impact considerations reflected by legislation in defining what waste may not be discharged, and economics in defining the best way of handling the waste and assessing the options for recovery.

Since the incentive for effective waste treatment in most industrialised countries is legislative, current and proposed legislation is reviewed. Although this is exemplified by UK law, the principles, their scientific and technological bases and many of the specific constraints are valid internationally.

The incentive for recycling, however, is usually economics. An extensive chapter on technological economics is included which will enable the engineer or manager to evaluate completely not only a possible recycling process, but also the choice of the best waste handling system.

In order to avoid an encyclopaedic approach and to maintain a broad view and conciseness, it has occasionally been necessary to omit detailed descriptions or explanations. However, extensive referencing is included together with sources of more detailed information, with a classified bibliography. SI units have been used throughout, usually with the more commonly accepted industrial alternatives. However, many UK legislative measures are still based on Imperial units and conversion to SI can only, therefore, be regarded as approximate.

Finally, we would like to thank all our friends and colleagues, in the Department and in industry, for helpful discussions and comments during the preparation of the text.

University of Aston in Birmingham
June, 1979

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C. J. Mumford

Publisher's Note

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PART ONE

WASTE MANAGEMENT AND POLLUTION CONTROL

CHAPTER ONE

The Problem

Traditionally, the term 'pollution' has been connotative with waste and has referred mainly to reduction in purity of the atmosphere and, to a lesser extent, of water. Now, however, 'pollution' encompasses any change in our natural environment, including any contamination of air, water or land, and excessive noise, whereas 'waste' implies a lost resource potentially available for recovery.

Since disposal of waste can result in pollution, the two subjects cannot be considered separately. This text therefore covers a very wide range of wastes, emissions and effluents, their effects, and measures for their treatment, disposal or recovery.

Waste may be conveniently defined as a material that is considered by the producer to have no value. Familiar examples include household refuse, used lubricating oil and gaseous combustion products from coal. 'Scrap', 'residues', 'byproducts', 'effluents', are terms often used synonymously with waste, but which have different meanings according to the originating industry. Waste is associated with dirt, nuisance, lack of value and cost of disposal. It forms a label that is not easily lost even when the material is employed as feedstock for a recovery process.

Waste comprises a vast range of materials that is most conveniently classified by phase—gas, liquid or solid, and combinations of these (Table 1.1). This general format is adopted throughout the book.

Emissions and effluents are usually regarded as gaseous or liquid byproducts that are discharged from the boundary of the producer—to the atmosphere in the case of gaseous effluents, to a treatment or conveyance system in the case of liquid effluents. Although effluents are often considered as waste, examples of recovery or reuse are discussed later.

A pollutant may be simply and qualitatively defined as an unnatural and/or

TABLE 1.1 GENERAL CLASSIFICATION OF WASTE

Phase			Example
GAS	Gas		Sulphur dioxide
	Gas–liquid	Mist	Acid mist from scrubbers
	Gas–solid	Fume	Smoke
	Gas–liquid–solid		Paint spray
LIQUID	Liquid	Solution	Metal-plating solution
	Liquid–gas	Foam	Detergent foam
	Liquid–liquid	Emulsion	Soluble oil
	Liquid–solid	Slurry, suspension	China clay waste
SOLID	Solid		Colliery spoil
	Solid–liquid	Wet solid	Filter cake

obnoxious substance, that is released to the environment. Possible pollutants correspond almost to a complete list of chemicals and suitable ways of classifying these are also discussed later.

Pollution Control

Industrial growth and associated technical sophistication in the last three decades or so have resulted in increased potential for environmental pollution. Pollution control is needed both to avoid impairment of health amongst the community in the area in which an enterprise is located (and often elsewhere), and also to minimise loss of amenity.

With regard to health hazards, it is becoming increasingly clear that the effects of some materials are only manifested after many years of cumulative exposure or, with carcinogens, for example crocidolite asbestos, possibly many years after first exposure. With materials of these types, where the effect of potential exposure is not immediately apparent, it is difficult to assess safe exposure levels. Of course, workers in particular factories tend to be nearer the source of pollution so that, for example, airborne concentrations of dust and fumes or noise levels to which they may be exposed are likely to be higher than for the population in general. However, it is known that there is wide variation between individuals in susceptibility to toxic agents. Thus embryos and children, in whom tissues are growing rapidly, are affected to a greater extent by various toxic agents: poisoning by heavy metals is one example. Similar considerations apply to people who have pre-existing conditions which may be exacerbated by exposure to, for example, air pollution by sulphur dioxide (as with chronic bronchitics).

Increase in public awareness is reflected in increased provision for statutory control. Hence, in the UK, the indiscriminate dumping of relatively small quantities of poisonous wastes, in particular cyanide residues, on tips and in quarries received considerable publicity in early 1972 and was partly responsible for the introduction of the Deposit of Poisonous Waste Act.

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Some damage to visual amenity is often associated with industry, due, for example, to the impact of structures or operations such as:

Storage facilities, tank farms
Electric power transmission lines
Spoil heaps
Cooling towers, chimneys
Pipelines,
Extraction of fuel or minerals
Transportation of raw materials and products (road, rail, sea).

Aesthetic considerations are in general outside the scope of this text, but may be taken into account in cost–benefit analyses.

A certain amount of pollution arises naturally. Indeed, a high proportion of the total atmospheric pollution worldwide arises from natural emissions, i.e. sand and dust storms, forest fires, volcanic eruptions, the decay of animal and vegetable matter, and pollen dispersion. However, manmade contributions to atmospheric pollution are generally concentrated in industrial and heavily populated areas, and therefore give rise to more concern. It is widely accepted that, since the capacity of the biosphere to absorb pollutants may be limited, it is necessary to control the quantum and character of pollution (there is, however, a tendency here for the less informed to over-react). Furthermore, air, water and land pollution cannot be considered separately when determining limits or engineering control methods, since they often interact, while in many areas there is a lack of quantitative biological data on the degree of treatment necessary for waste discharges.

Ideally, waste discharges should have no perceptible effect on the environment, but with the development of sophisticated methods of detection and quantitative measurement, it follows that what is measurable does not necessarily constitute 'pollution'. It would be rather impracticable to introduce one of the chemical or allied industries into a fresh environment without any impairment of air, water or land. Nevertheless, given consideration at the design stage, pollution from such plants can be kept within reasonable limits. The needs and costs of environmental conservation should therefore be among the factors considered when selecting a process and an operating site. It is also advisable to carry out a pre-operational survey to obtain base levels of noise and of air and water qualities. Table 1.2 gives an example of measures taken in the pollution-conscious design, engineering and construction of an oil-refining plant.

The aim, therefore, must be to develop and apply the best practicable means to minimise the effects of industrial activities upon their surroundings. For process plants this may involve an expenditure of between 4% and 8% of the total capital investment.

Practical measures are not restricted to better ways of treating discharges but include the replacement of traditional manufacturing methods or products by others which create less, or more easily treated, wastes. Even then, opera-

TABLE 1.2 SOME DESIGN, ENGINEERING AND CONSTRUCTION PROVISIONS TO REDUCE POLLUTION FROM OIL-REFINING PLANT

Adequate bunding
Tall stacks
Selective burning of low sulphur fuel
Floating roof tanks for low volatile products
Liquid sewer seals and covered separators
Segregation of process and storm sewer systems
Waste product incinerators: gas, liquid and solid
Sour water strippers
Absorption and adsorption processes
Air cooling
Recirculation of cooling water
Electrostatic precipitation and cyclone separators
Silencing compressors and prime movers
Oil recovery from waste-water

tion needs conservation-conscious staff and good housekeeping practice, backed up by a regular scheduled maintenance system.

In recent years there have been numerous examples of the disastrous effects of inadequate pollution control measures. For example, in Japan 31 people were awarded damages for injuries resulting from the ingestion of cadmium by drinking water or eating rice contaminated by cadmium-containing wastes which had been dumped into a river 20 miles away. Similarly, pollution of the Rhine by an insecticide in June 1969 killed millions of fish and caused cities in Holland to curtail drinking-water supplies.

Wide publicity has been given in Britain to pollution problems such as the fouling of the beaches by oil (e.g. 117 000 tonnes of heavy Kuwait crude oil from the wreck of the Torrey Canyon, to which was added over 10 000 tonnes of detergent which compounded the damage) and warnings of abnormal lead levels in the blood of children living near a smelting works on the Isle of Dogs. As a result, and because the minimum quality of environment which the public is prepared to accept has increased considerably, 'environmental conservation' has become a complex and often controversial subject.

There can be no doubt that any industrial pollution considered unacceptable can be avoided; this is not basically a technological problem but one of economics and the price must be borne by the consumer. Perhaps the sole exception is the problem of long-lived radioactive wastes: there is no safe and proven method of disposing of these wastes, which have to be kept away from the living environment for hundreds or, in some cases, many thousands of years.

Generally, it is for governments and for individual managements to balance what is socially desirable against what is economically possible. This may be achieved by the adoption of 'standards', that is, limits to pollutant concentrations, defined by official regulations. These may be air or water quality standards which specify a limit for total concentration of a specific pollutant without reference to source. Alternatively, or in addition, there may be 'emission standards' which place a limit upon the amount of pollution permitted from each individual source. In some areas of pollution control in the UK, for example under the Alkali Act, rigid standards are avoided and reliance is placed upon the concept of the 'best practicable means' being installed and operated to minimise pollution (see Chapter 4).

This leads naturally to a consideration of recovery or reutilisation of waste products. Although it is possible to recycle most wastes in some form, the decision is based upon several factors which are affected by technological changes, market cycles and public opinion.

Recovery versus Disposal

The choice between recovery of valuable materials from waste and disposal of waste depends mainly on three factors: technology, economics and attitude. Generalisations are difficult because so much depends on the detailed circumstances of individual cases. However, technology is not usually a problem as there are adequate chemical and physical methods available to treat, dispose of or recover values from most wastes.

Economics is perhaps the most important factor and also the most difficult to analyse. For disposal, the cheapest alternative is not always chosen; convenience and attitude often influence the producer in choosing the disposal method. But he tends to disregard all problems arising from disposal once the waste has left the factory gate, and hence economic considerations such as loss of resources, environmental damage and inherent value are neglected.

It is perhaps true that where any material can be readily and economically recovered or recycled, this is already being done. Well established examples include metals: the secondary metal industries are a major and essential part of commerce. For instance, more than half the lead produced in the UK is recovered scrap.

When considering the viability of a recovery process, the high cost of recovering low-value materials and consequent relative unprofitability frequently deter the potential reprocessor or recycling agent. He is usually sufficiently 'commercially minded' to ignore national requirements for resource conservation, risk of environmental damage and comparative costs of other methods of disposal in the interest of a quick, sound profit. Little change in this attitude is likely until some effective form of economic incentive or legislative control is introduced.

What is often missed, however, is the opportunity to use recycling itself as a means of disposal: an unprofitable recovery proposal may appear attractive when viewed as a disposal method. Resource recovery by means of incineration or pyrolysis of household refuse may thus be regarded as an increasingly attractive method of disposal in view of the rapidly increasing cost of landfill, transport and fuel.

Finally, attitude is impossible to quantify. Even where recovery is technically, economically and commercially viable, it is sometimes ignored for one of a range of reasons, including prejudice, stigma, politics, apathy, self-interest and conscience. This is perhaps the most difficult area for positive comment. Although considerable research effort and political encouragement have been directed to resource conservation in recent years, few significant new recycling technologies have been implemented. The process of education is inevitably slow, but the benefits and, in fact, the inescapable necessity for conservation must eventually come to be appreciated.

CHAPTER 2

Recovery versus Disposal

Characterisation of gas, liquid and solid wastes (see Chapter 3) begins with the origin of the waste. This is immediately identified with the *waste producer*, who is the central figure in any discussion of choice of handling method: he has two basic alternatives, recycling and disposal. A waste may be subdivided, part being recycled and part disposed of. Subsidiary operations may be required to enable recycling or disposal to be carried out safely, effectively and legally. These additional steps are generally classified as treatment, storage and conveyance.

It is convenient to distinguish between on-site and off-site operations, since in the former the waste producer assumes responsibility for recycling, treatment and storage or disposal of the waste; beyond the site boundary, conveyance is necessary before these operations are carried out, in this case usually by a *disposal contractor* and/or a *recycling agent.*

The disposal contractor's main function seems to be the provision of transport, and this is certainly where most of the cost lies. He may need to treat the waste before providing safe disposal and in all this he has certain legal and contractual obligations which are discussed in Chapter 4.

Where the waste is sold to a recycling agent or waste processor, this is done in some industries on a free-market basis, while in others long-term contracts are more usual. The product, i.e. the reprocessed material, may be sold either on the open market or under contract, possibly to the original waste producer who may not be able to afford reprocessing facilities, or to an intermediate supplier for redistribution. Cable burning, for example, has traditionally been performed on a contract basis under which the recovered copper never passes out of the ownership of the supplier; oils may be treated on a similar basis. The buying and selling of waste and reprocessed materials can often be a volatile

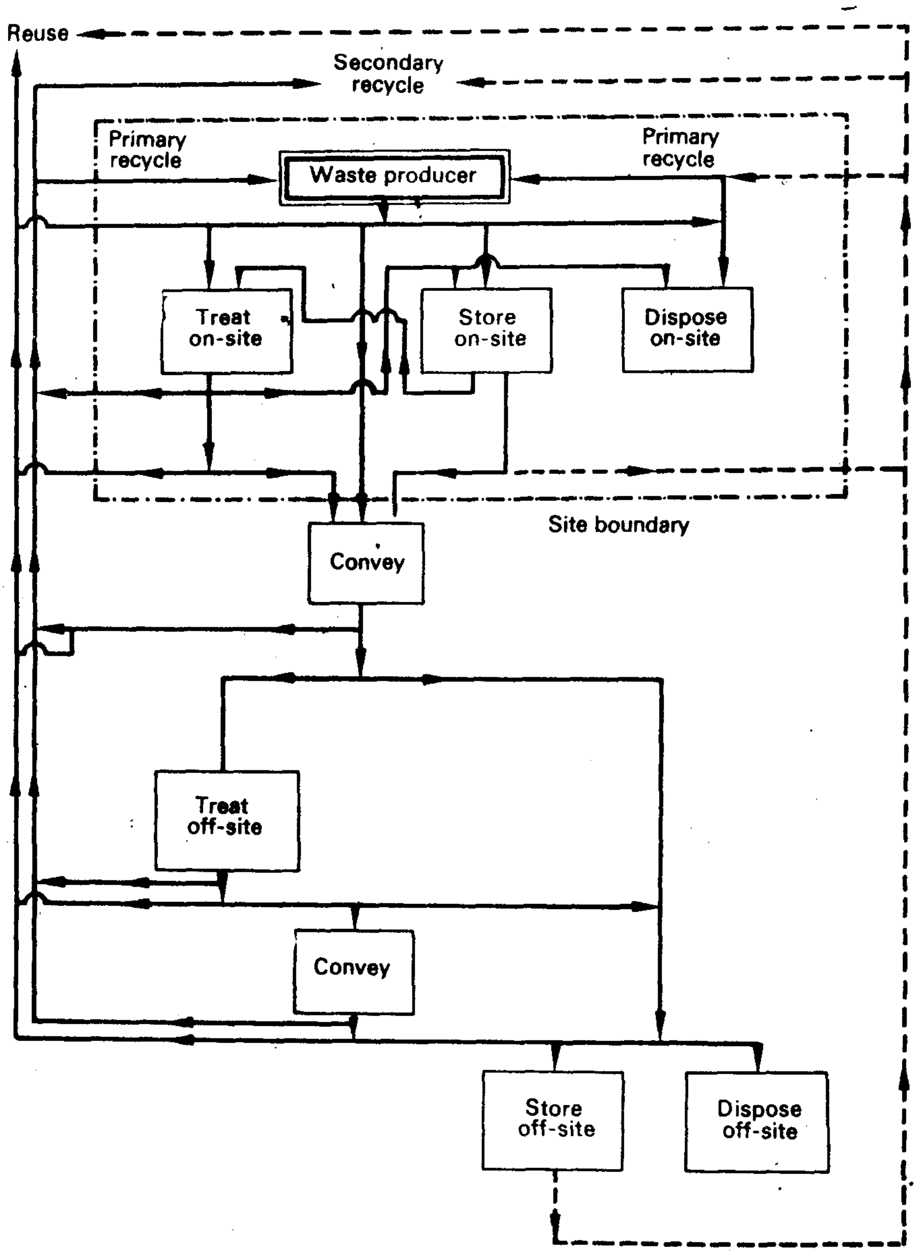

Fig. 2.1 Overall handling system showing interrelationships of the three basic techniques—treatment, storage, conveyance—to effect recycle or disposal, either on- or off-site

commercial venture requiring considerable experience and judgment to be successful.

The recycler may, of course, produce some wastes, so that he in turn becomes a waste producer. These three activities are therefore closely linked in

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