# OPERATOR HAZARDS IN TOXIC WASTE DISPOSAL

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## SUMMARY

The nature of dangers (excluding radio-activity and simple accidents) to workers engaged in the disposal of solid toxic waste were investigated. Two methods were used·

1) Site visits involving inspections and measurements;
2) Experimental and theoretical studies, involving laboratory and wind tunnel experiments and mathematical modelling.

Consideration was given to the characteristics of the waste disposal industry, the hazards inherent in the current low cost operations and the important influence of legislation.

A scoring system was used to grade selected sites according to their safety rating. Unsatisfactory conditions were noted on many sites, but there was some improvement over the period of the study. Analysis was made of the applicability of quantitative risk criteria to waste disposal operations, specific safety training systems and codes of practice.

Mathematical modelling of evaporation of solvents from pools provided generation rates which were extrapolated to provide likely down wind concentrations on sites. A critical distance formula and simple relationship were evaluated for the specification of safe distances from certain waste disposal operations. Laboratory experiments to ascertain toxic gas generation rates provided data which was used in wind tunnel experiments on models of typical road tankers to check the veracity of calculations on dispersion patterns.

It was concluded that the potential existed for serious hazards to operators; many of the difficulties encountered were due to the constraints imposed by the highly competitive nature of the waste disposal operations. A lack of positive identification of wastes and the generally uncontrolled nature of waste handling operations were major problems. There was also over-reliance on open air operation to disperse potentially harmful gases or dusts. Outline recommendations were made for legislation governing operator safety and a field kit was developed to facilitate checks on the nature of deposited waste.

Recommendations were made for further work to accumulate data on site hazards, to produce codes of practice, to improve training schemes and to extend the study to environmental impact considerations.

WASTE DISPOSAL TOXIC OPERATOR

HAZARDS

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# CHAPTER 1

# GENERAL INTRODUCTION

## 1.1 Background to the study

Over 160 million tonnes of solid waste are generated annually in the U.K. The main sources are summarized in Table 1.1.

TABLE 1.1

Masses of solid waste arising in 1973, million of tonnes(1)

| | |
|---|---|
| Coal mining .. .. .. .. .. .. .. .. | 58 |
| Mining other than coal .. .. .. .. .. .. | 3 |
| China clay quarrying .. .. .. .. .. .. | 22 |
| Other quarrying .. .. .. .. .. .. .. | 27 |
| Domestic and trade refuse .. .. .. .. .. | 18 |
| Industrial waste .. .. .. .. .. .. .. | 23 |
| Ash and clinker from power stations .. .. .. | 12 |
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As much as five million tonnes may possess properties which permit it to be classified as toxic or dangerous (2).

The concern which has been expressed in recent years, over potential threats to the health of workers engaged in waste disposal is exemplified by the following quotations: The first was found in the California Solid Waste Planning Study (3).

"Handling procedures and techniques now in use tend to expose workers and others to toxic and inflammable materials by direct contact, inhalation of dust, contact with contaminated water and contact with or breathing the fumes from open burning or inadequate incineration. Equipment operators have been hospitalized and equipment has been damaged as a result of contact with toxic chemicals, or as a result of explosions caused by the crushing of containers filled with chemicals. Disposal site personnel were often unaware of the content of containers or toxic nature of materials."

The second, again American, was published by the Institute of Chemical Engineers (4).

"Accidents involving chemical and petro-chemical wastes have been reported by landfill operators. Explosions have occurred during compaction of certain industrial wastes, toxic chemicals such as herbicides, pesticides and tetra-ethyl lead have caused illness in sanitation workers and acetylene wastes have been known to cause noxious landfill fires. It is important to protect landfill operating personnel by appropriate hazardous waste management including the provision of appropriate safety equipment such as air filters, garments and fire extinguishers".

Tipping (or Landfill) is the major disposal method for all solid waste. Despite the range of options shown in Figure 1.1 for all forms of waste disposal it is also predominant for toxic waste disposal. The Key Committee on the Disposal of Solid Toxic Waste (5) said that the operation was a low cost exercise and estimated that in 1970 the proportions disposed of by various methods were as set out in Table 1.2.

TABLE 1.2

Disposal methods for toxic waste in the U.K.(5)

| Method | Percentage |
|---|---|
| Landfill | 95.0 |
| Incineration | 4.0 |
| Sea Dumping | 1.0 |
| Mineshafts | 0.5 |

Several chemical waste treatment plants have come into operation since 1970 but many are still operating well below their possible throughput and the total capacity of the plants probably amounts to only 10% of the U.K. output of toxic waste (6).

There is extensive literature on the practical aspects of landfill (7) but only in very recent years have research studies been carried out and these have almost exclusively been directed towards the environmental impact of landfill. The centrally funded research programme which has recently been completed in the UK was to enquire into the environmental impact of landfill notably with respect to hydrogeological implications(8). Recently emphasis has also been laid on this issue by the European Economic Community which has pointed out that more research could usefully be done with respect to asbestos emissions during landfill operations(9).

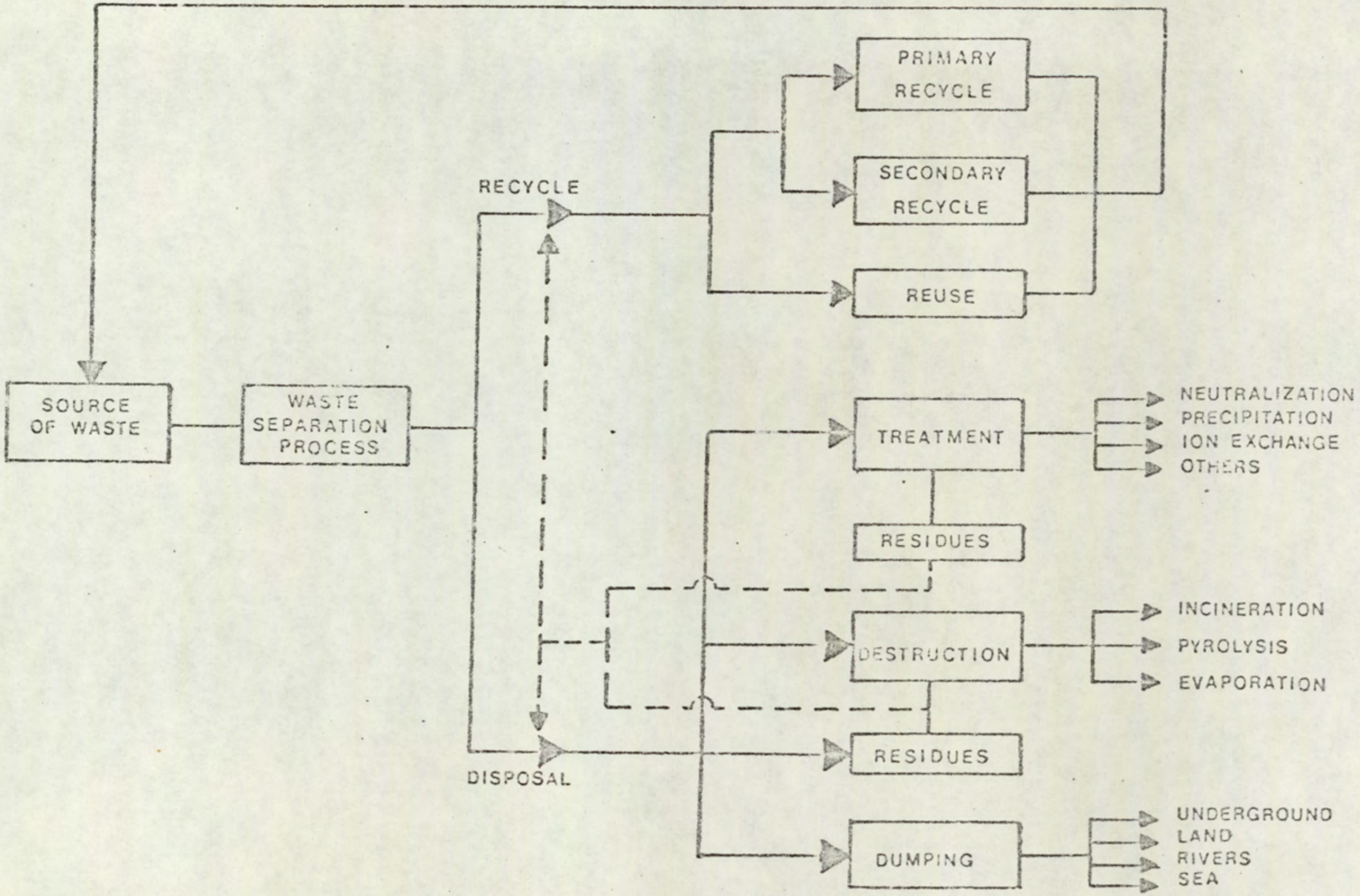


Fig. 1.1 Schematic representation of the waste treatment options

Increasing concern about the environmental impact of uncontrolled toxic waste disposal resulted in the Deposit of Poisonous Waste Act, 1972(10).This Act, and the regulations made under it, produced a radical change in certain aspects of the disposal of toxic solid waste. The effect on industry is reviewed in Appendices I&II (11)

Following the introduction of this Act, the disposal methods remained almost unchanged i.e. still predominantly landfill, but disposal was, in effect,concentrated on a relatively small number of sites. For example, the rate of intake of toxic waste to one large landfill site in Essex increased by over 300% in the period immediately following the implementation of the Act (12).

This change in the disposal pattern, coupled with the increasing complexity of waste, was investigated by the author in a preliminary study concerning operator hazards on landfill sites handling toxic wastes (13). Malpractices, which before the passing of the Act might have arisen occasionally on almost any waste disposal site, had been concentrated upon a much smaller number of sites and thus became much easier to study.

The potential hazards consisted of:-

1. Entanglement risks
2. Inhalation of gases, fumes, dusts or fibres generated during loading and the disposal process itself. These hazards were found to be particularly acute in the case of workers entering confined spaces.
3. Skin contact and injection wounds contaminated with biologically active substances.
4. Ingestion risks resulting from inadequate ablution facilities.

These hazards stemmed from the nature of the operation and the dangerous materials handled but were compounded by the limited supervision and by lack of knowledge on the part of the operators. Furthermore, toxic waste disposal by landfill appeared to be a low priority - low cost exercise. Hence specialized facilities for coping with emergencies on site were almost without exception non existent, or non-operational. The basis and results of this study have been published (14, 15, 16,17); one of these papers is reproduced as Appendix III.

## 1.2 Scope of the present study

The above initial study was restricted to selected landfill sites. The object of the present work was:

(a) to widen the scope of the investigation;

(b) to examine a wider selection of disposal methods, such as chemical treatment and incineration;

(c) to quantify the potential hazards associated with gas generation on the basis of laboratory and wind tunnel experiments.

The overall aim was to assess whether it was possible to dispose of toxic wastes by existing procedures without subjecting operators to unacceptable hazards and, where appropriate, to propose measures, such as Codes of Practice, to improve the situation. The literature had been shown (13) to contain a dearth of information on safety in waste disposal. However, the need for such information was increased in 1974 by two legislative innovations, viz the Health and Safety at Work Act and the Control of Pollution Act. The former changed the status of the majority of workers engaged in solid toxic waste disposal by providing a framework for their statutory protection. Previously those workers not actually employed in 'premises', or merely undertaking crude disposal routines such as driving bulldozers on tips, did not come within the ambit of the Factories Act, 1961, and were without any legislative reinforcement of their common law rights (13). The absence of any previous requirement to notify accidents under section 80 of the Factories Act, 1961 therefore made it impracticable to assess the severity and frequency of accidents to disposal operators. The Control of Pollution Act provided for the licensing of all waste disposal sites by the County Waste Disposal Authorities and a requirement was introduced that operator hazards must be taken into account when drawing up the site licence conditions. Concurrent with the increased legislative control, attention, which had been attracted by the environmental impact of toxic wastes at certain disposal sites, was drawn to the issue of operator hazards by a fatal accident on one such site (18).

Occupational health implications of toxic waste are inevitably linked with environmental health considerations. However a parallel research project on the Environmental Health Implications of the Disposal of Toxic Waste on Landfill sites is not reported here (19) with the exception of part of the evidence presented by the author to the E.E.C. authorities on a directive covering toxic waste disposal. This incorporated outline proposals for the protection of the solid waste worker which are reproduced as Appendix IV (20).

## 1.3 Direction of study

### INTRODUCTION

The aim of this study was to evaluate hazards to operators engaged in disposal of solid toxic waste. However, some risks are more easily identifiable than others - the entanglement hazard for example is associated with the presence of heavy plant, a failure to enforce suitable work routines and the absence of proper maintenance designed to ensure that the equipment is at all times in an appropriately safe condition. If performance in respect of all these items is ascertained and set out in respect of a particular routine, some assessment is possible as to the safety, or otherwise, of that aspect of the operation.

Unfortunately, many aspects of toxic waste disposal are unpredictable. For example the substances are variable in composition and as operations often take place in the open air, even minor fluctuations in the weather can be highly significant. In the presence of so many variables and in the absence of a coherent body of informed opinion, evaluation of complex hazards is not straightforward. For example, a worker could theoretically be in contact with cyanide, lead, arsenic and vanadium compounds in turn during one day's operation of a loading shovel in the open air. Whilst contact with significant quantities of any one of these substances will produce symptoms of ill health and it is possible, in theory, to project the likely effects of the accumulation of small doses, in practice the actual dose is closely linked to weather conditions which affect dispersion patterns and any fluctuations in the composition of incoming waste which may be most marked. As a theoretical analysis of these multitude of factors is impracticable, and the industry operates on such a low cost basis, there is no bank of data which can be utilized to draw valid conclusions. Hence a technique was evolved so that each of the sites visited could be classified with respect to its likely safety rating. In addition some measurements on site were undertaken to discover the feasibility of using relatively straight forward techniques to predict the likely air contaminant concentrations. Use was made of case studies drawn from toxic waste disposal practice. These real world observations were backed up with mathematical models, laboratory experiments and a wind tunnel exercise.

## OUTLINE PARTICULARS

In the present study, due to experience gained earlier, attention was concentrated on the private contracting companies who tended to be least well equipped to deal with complex problems of mixed waste materials. As discussed later, the composition of such materials is sometimes incompletely understood even by the industrialists who consign it. This is typical of the problems faced by the waste disposal industry i.e. not a short fall in the extent of the necessary technical knowledge, but rather the impracticability of applying a rational solution in view of the low cost nature of the exercise. In addition, it had already been established that the accurate assessment of levels of significant contaminants when operations were carried out mostly in the open air is highly problematical (21). Hence an objective assessment of the level of risk was not easy to achieve. Serious additional problems were encountered in the case of solid waste disposal routines, such as uncertainty over the rate of generation of any gases due to inherent fluctuations in the composition both of the deposited waste and the material on to which the deposit occurs. These variations might be compounded by the lack of consistency in the choice of discharge rate exhibited by the operator which might also significantly affect mixing rates. Hence there were real difficulties in drawing valid conclusions from field work. Whilst this did not lessen the significance of the results of on the spot measurements, it did make it unwise to generalize from these results.

A survey of premises and sites was undertaken contemporaneously with a literature survey. The information from these two exercises was analysed to determine the most fruitful avenues for on site measurcments, modelling exercises and case studies.

The object of the measurements and calculations was to quantify the extent of the risk to workmen engaged in certain waste disposal operations from the generation of the air pollutants, particularly when the emissions were due to the mixing of incompatible substances. There are two distinct aspects to the problem viz. the determination of a generation rate for a pollutant and the prediction of a dispersion pattern. Although information is available on simple processes, such as evaporation rates, and the rates with which certain substances react to produce gaseous products, no published data were available on the inadvertent meeting of substances not normally mixed by industry. Very little experimentation has been carried out on the meeting of waste materials.

However, once a generation rate has been ascertained any one of a number of dispersion predictions can be used.

To overcome some of the problems referred to when measuring airborne contaminants on site, consideration was given to a full scale experiment utilizing a tanker, but controlling the emission of the pollutant, perhaps substituting a substance that could be measured more easily. The tanker might have been experimented upon at a controlled location, free from the commercial pressures which dictate the time during which measurements normally have to be taken.

To investigate this possibility a few simple tests were carried out in the open using a private car, instead of a tanker, and with a smoke generator to simulate the gaseous pollutants.

The objects of the mathematical modelling and laboratory experiments were to provide some indication of the level of pollutants that could be anticipated in the air during certain waste disposal routines. The simplest case, that of evaporation of volatile substances and the production of a resulting dispersion field was the most obvious choice. In fact many theoretical models exist derived from duct studies and conversion factors are available to permit these to be used in open air conditions. However, it was found that a study of simple evaporation was planned at Harwell. The prediction of the evolution of gases is not so well advanced for the action of two substances and resulting generation. Although experiments have been carried out on certain commercially relevant reactions, such as those in the petrochemical industry, no figures are published for the mixing of chemically 'incompatible' substances such as acids and sulphides. For any meaningful conclusions to be drawn with respect to the vast majority of reactions it is necessary to carry out experiments, which need not be highly sophisticated. A simple experiment was therefore devised to investigate the rate at which toxic gas is given off when two common industrial wastes meet.

Finally a wind tunnel experiment was devised to generate data on the likely dispersion pattern of gases arising in the discharge zone near a model tanker. The facility was obtained to repeat the experiments with gases having a wide density range.

In respect of the experimentation a decision was made to devote a significant amount of resources to an exploration of the dispersion pattern of gases around tankers discharging wastes, developing laboratory experiments to model the generation rates of airborne pollutants and also to calculate simple evaporation rates, utilizing wind tunnel studies to investigate the actual dispersion pattern and provide figures which could be compared.

In summary, little data are available on the extent of the hazard to workers operating in the changed circumstances of toxic waste disposal in the U.K. Therefore this work comprised an examination of Toxic Waste Disposal techniques utilized in certain parts of the U.K., to assess the extent to which they expose operators to hazards, and included experimentation to determine some guidlines for the safer disposal of such wastes.

## SYNOPSIS OF THESIS

The latter part of Chapter 1 expands certain definitions and provides the criteria by which toxicity is assessed.

Chapter 2 provides information on the composition of toxic waste. Physical and other properties of waste are considered and the particular problems posed by the toxic waste, such as its innate variability explored. The legal position is also explained and brief reference is made to the environmental health implications of toxic waste disposal.

Chapter 3 analyses the common toxic waste disposal methods in detail with some reference to common practice during collection and transport routines.

Chapter 4 includes the identification of hazards and an evaluation of conditions found during the survey.

Chapter 5 consists of an analysis of several codes of practice and an application of quantitative risk critera to toxic waste disposal operations.

The first stage of the practical investigations was to undertake measurements on site and also to enquire into the feasibility of carrying out full scale trials. This is reported in Chapter 6.

Mathematical modelling exercises, undertaken using hypothetical situations similar to those likely to be encountered in waste disposal routines are reported in Chapter 7.

Laboratory experiments were used to predict the likely generation rates of dangerous gases upon the mixing of chemically incompatible substances. These are reported in Chapter 8.

Wind tunnel experiments provided information on the dispersion pattern for gases with a range of densities in the vicinity of the discharging vehicle. These are reported in Chapter 9.

Chapter 10 provides the conclusions and recommendations for further work.

## 1.4 Definition of terms

To delineate the areas of waste disposal and operator hazard covered in this work, the following definitions were adhered to:

HAZARD - A hazard is any condition/event which involves the risk of impairment to health of operators. This encompasses the whole spectrum of chemical, physical and infective agents, and agencies with the main emphasis in this work being on risks arising from the chemical properties of wastes. These include physiological effects, both short and long term, of inhalation; skin, eye and mucous membrane contact; ingestion and accidental injection of biologically active materials.

OPERATORS - Operators are those workers, almost exclusively male, who carry out the tasks involved in disposing of toxic waste. The duties involved are summarized in tables 4.1 and 4.2.

WASTE - is any material which is of no further use to its owner, and the long term accumulation of which on the plant is impracticable or inadvisable.

This study is restricted to Solid Wastes, that is those wastes which do not conventionally leave the point of generation in a pipe or flue. Included are wastes, such as sludges and liquids with a contaminating solids content, usually disposed of in a similar manner to solids. This is in accordance with the convention established by the Key Committee (5). The above definitions include radioactive materials, which have already been separately considered (22), arising from a previous recommendation (13). Operators disposing of radioactive waste were found to have a special position relative to other waste disposal operators. This was due to the benefit they obtained from their membership of a large group of workers already afforded special protection by their employers; hence the problems were fewer in number. Radioactive wastes were, therefore, excluded from this study.

DISPOSAL - involves terminal deposition to air, water or land (whether directly or via pipe, shaft or flue) of toxic waste by processes such as incineration, crude dumping or landfill. It includes any part of any recycling, detoxifying, liquifying or encapsulation process which is actually part of the toxic waste disposal routine. The collection, delivery and unloading of waste, plus any associated process such as dedrumming of the waste at the disposal point, are included.

TOXIC - this term was chosen for the title of the work to emphasize that the study concentrates upon the risk from chemicals rather than all hazards such as fires and explosions. The word poisonous was thought to be too narrow in concept. Although the Key report (5) which was concerned with 'toxic waste' did result in legislation entitled the 'Deposit of Poisonous Waste Act, 1972'. This choice may have been because the legislation was intended to control the environmental health aspects of the deposit of waste, and environmental and public health procedures have traditionally been more concerned with the poisonous aspects of substances; 'Toxic' carries connotations of hazardous gases, as well as poisons, and hence has occupational overtones.

Subsequent developments such as the creation by the Health and Safety Executive of a Toxic Material Working Group, and the preferred use of the word toxic in the Health and Safety at Work Act 1974, and the Control of Pollution Act 1974, have eclipsed the importance of the term 'poisonous'.

A detailed examination of the concept of toxicity follows.

## 1.5 Criteria of Toxicity

It has been argued that all substances are toxic: the right dose differentiates a poison and a remedy (23)

Toxicity is associated with the ability of substances at an appropriate concentration, to interfere with vital processes (24). For example some heavy metals are capable of blocking enzymes e.g. cadmium, mercury, lead and zinc are all commonly regarded as toxic. However, zinc is a material which is required by mammals at trace levels and in its absence deficiency disease becomes apparent (25). Hence care is needed in interpretation.

Toxicity has been described as a property of matter, i.e. a biological property just as mass is a physical property.(26)

The toxicity of a material is not altered by the way it is handled, by its temperature (unless a chemical change occurs) or by its physical state, although the toxic hazard posed by the material may be greatly influenced by these and by many other external factors. The toxic hazard of a material is the likelihood of injury and an evaluation for the purposes of this study must consider, in addition to toxicity, physical and chemical properties, physical state, method of handling and other factors that influence the probability of contact with significant amounts of the material. Relative toxicities are generally described by using $LD_{50}$ and $LC_{50}$ values, which are the levels of the lethal dose for 50% of a population of related test animals, expressed in the first instance as a Dose (usually mg substance/kg body weight) and secondly as a concentration (ppm of the substance in water for acquatic life). Distinctions must be drawn between the acute and chronic effects of the dose and also the oral and dermal effects. However, in common with workers in many other sectors of industry, the solid waste operator is much more likely to be affected by the inhalation or skin absorption of toxic materials. Ingestion is only an important route in cases where the acute or chronic toxicity by that route is very high, which can be so with many biocides, such as the chlorinated cyclodiene insecticides and some chemical intermediaries. In general if the material has an acute oral $LD_{50}$ of 1·0 mg/kg or lower strict precautions are necessary to prevent even minimal oral contact since a lethal dose for a typical worker would be less than one tenth of a gram. However, few substances in common use pose such problems. Table 1.3 shows $LD_{50}$s for some substances of relevance to this study. These figures show that for a typical operator, with a body weight of 75 kg, 1 g of cyanide is needed to form a lethal amount.

TABLE 1.3

Oral (rat) $LD_{50}$s for substances relevant to study (27)

| UNDER 10 mg/kg | 10-99 mg/kg | 100-999 mg/kg |
|---|---|---|
| Dioxin | Arsenic | DDT |
| Sodium cyanide | Lead tetraethyl | Hydrochloric acid |
| Warfarin | Nitric acid | Phenol |
|  | Strychnine | Potassium hydroxide |

Ingestion is therefore not a common problem for operators in toxic waste disposal. With respect to the inhalation risk, however, the surface area of the lungs is so large and the gaseous exchange mechanism so efficient, that relatively low concentrations of some toxic materials, possibly encountered in waste disposal routines, can produce instantaneous collapse and subsequent death in operators even when work is taking place in the open air (28). Accordingly, for the purposes of this enquiry, emphasis is laid on harm associated with substances which are inhaled.

With regard to the chronic effects of inhaling toxic substances, the usual approach with airborne contaminants is to specify time weighted average threshold limit values (TLV-TWA) (29) which refer to a 7 or 8 hour exposure over a five day working week. Integration of inhalation exposures is found by summing the products of individual exposure durations and concentrations and then dividing by the sum of the durations, that is if C = Concentration and t = time, then

$$\text{TWA Dose} = \frac{\sum Ct}{\sum t}$$

Whilst this technique is not without its critics (30) it has the distinct advantage of simplicity and hence finds widespread application. In the official list used in the U.K. (29) excursions are permitted, unless the substance is specifically designated as bearing a 'C' or ceiling notation, on the following scale:

| | | | |
|---|---|---|---|
| TLV | 0 - 1 | ppm or $mg/m^3$ Excursion factor | 3 |
| | 1 - 10 | | 2 |
| | 10 - 100 | | 1.5 |
| | 100 - 1000 | | 1.25 |

Some excursion values appropriate to this study are set out in table 1.4.

TABLE 1.4

Excursion values for relevant substances

| Substance | TLV (TWA) ppm *$mg/m^3$ | Excursion Factor | Max. Concentration permitted for short period ppm (*$mg/m^3$) |
|---|---|---|---|
| Arsine | 0.05 | 3.0 | 0.15 |
| Cyanide CN - Skin | 5.0* | 2.0 | 10,00* |
| bis Chloromethyl ether | .001 | 3.0 | 0.003 |
| Hydrogen selenide | 0.05 | 3.0 | 0.15 |
| Phenol - skin | 5.0 | 2.0 | 10.0 |
| Phosgene | 0.1 | 3.0 | 0.3 |
| Nitrogen Dioxide | C5.00 | Nil | 5.00 |
| Nitric Acid | 2.00 | 2.0 | 4.00 |
| Sulphuric Acid | 1.0* | 2.0 | 2.0* |
| Toluene Diisocyanate (TDI) | C0.02 | Nil | 0.02 |

Table 1.4 demonstrates that the absolute maximum excursion value is 3 x the TLV (TWA). However the concept of Short Term Limits is more appropriate to incidents arising during waste disposal routines, as such happenings are most likely to involve uncovenanted emissions of toxic materials for relatively short periods.

Tentative short term exposure limits now exist in the U.K. and Table 1.5 lists appropriate examples of these TLV (STEL) values, but it should be noted that the American Conference of Government Industrial Hygienists have pointed out (29) that these STEL values do not constitute emergency exposure limits.

TABLE 1.5

Relevant tentative threshold limit values (short term exposure limits) TLV(STEL) or Ceiling Value (CV)(29)

| SUBSTANCE | TLV(STEL)or CV | |
|---|---|---|
| | ppm | $mg/m^3$ |
| Acetic acid | 15.00 | 37.00 |
| Ammonia | 35.00 | 27.00 |
| Ammonium Chloride | - | 20.00 |
| Aniline-Skin | 5.00 | 19.00 |
| Arsine | 0.15 | - |
| C Benzene-Skin | 10.00 | 32.00 |
| Cadmium | - | 0.15 |
| Carbon black | - | 7.00 |
| Carbon monoxide | 400.00 | 440.00 |
| Carbon tetrachloride-skin | 25.00 | 160.00 |
| Chlorine | 3.00 | 9.00 |
| DDT | - | 3.00 |
| Dieldrin-skin | - | 0.75 |
| Fluorine | 2.00 | 4.00 |
| C Hydrogen Chloride | 5.00 | 7.00 |
| Hydrogen cyanide- skin | 15.00 | 16.00 |
| Hydrogen sulphide | 15.00 | 21.00 |
| Lead (inorganic) dust | - | 0.45 |
| Mercury (inorganic) | - | 0.15 |
| Methyl Alcohol-skin | 250.00 | 310.00 |
| Nitric acid | 4.00 | 10.00 |
| C Nitrogen Dioxide | 5.00 | 9.00 |
| Nicotine - Skin | - | 1.50 |
| Parathion - skin | - | 0.30 |
| Perchloroethylene-skin | 150.00 | 1000.0 |
| Phenol-skin | 10.00 | 38.00 |
| Phosphine | 1.00 | 1.00 |
| Phosphoric acid | - | 3.00 |
| C Subtilisins (proteolytic enzyme) | - | .00006 |
| C Sodium Hydroxide | - | 2.00 |
| Tetramethyl lead-skin | - | 0.50 |
| Toluene-Skin | 150.00 | 560.00 |
| C Toluene-2.4-diisocynate (TDI) | 0.02 | 0.14 |
| Trichloroethylene | 150.00 | 800.00 |
| Vanadium Dust | - | 1.50 |
| Warfarin | - | 0.30 |
| Wood dust (non allergic) | - | 10.00 |

Percutaneous absorption is a specific problem with many substances commonly encountered in waste disposal routines such as aniline, phenol and perchloroethylene, all of which have a "skin" notation in the list of TLVs. as shown in Table 1.5. This draws attention to the need to minimise contact with skin and mucous membranes. Whilst the provision of protective clothing might be assumed to provide adequate protection, the mucous membranes and eyes cannot easily be safeguarded without resort to extensive operator protection, such as the use of chemical proof goggles and experience shows that it is very difficult to maintain such a level of protection with a relatively undisciplined workforce. Furthermore an injection injury, in which a puncture wound is contaminated with a highly toxic substance can be a particular problem in those sections of the waste disposal industry where manual dedrumming of highly toxic waste, such as cyanide, is practised. Hence the question of skin contact needs special care in waste disposal operations.

Many materials appear to have no effect after ingestion or gross skin, or eye contact. Such material are regarded as being physiologically inert, not non-toxic, because their toxicity is low. However, if the dose is sufficiently large or if the concentration is sufficiently high, or if the contact is prolonged, some effect will be experienced. This is recognized in the ACGIH category of nuisance particulates (29). Many solid waste disposal operations are in fact inherently dusty.

# CHAPTER 2

# TOXIC WASTE DISPOSAL IN THE U.K.

## 2.1 Statistics

### Amount of Toxic Waste

The overall quantities of toxic waste are only now being accurately monitored. In 1970 the Key Report, quoted the amount produced annually in the U.K. as 'some hundreds of thousands of tons' (5). Four years later the fourth report of the Royal Commission put the 1973 figure at probably three million tonnes (1) whereas a report commissioned by the Department of the Environment in which one quarter of 1972's notifications made under the Act for approximately 50% of the U.K. were analysed and extrapolated, produced an estimate of "possibly five million tonnes" (2). This is currently still the most authorative statement on the amount and constituents of the toxic waste arisings.

An analysis of types of waste was provided. Figure 2.1, is an extrapolation of figures from this latter report to provide a possible annual breakdown for the whole of the U.K. The production of accurate figures must await the publication of information currently being collected by the County Waste Disposal Authorities, under powers provided in Section 2 of the Control of Pollution Act 1974. Appendix VII reproduces a form being used by one County Council in their survey. It contains information relating to a large Electrical Engineering company. The conscientious completion of such enquiries for the whole country, although costly in terms of resources, should provide a valuable data base upon which to plan future waste disposal strategies. Returns from individual companies will also be available for scrutiny so that potential operator hazards will be capable of identification by the enforcement agencies with a much greater degree of precision than at present. Even so, waste is not a homogenous material; it varies in physical state, composition and toxicity, and it is very difficult to accurately assess its likely environmental impact upon either man or the total ecosystem. This is especially so when highly toxic wastes have been bulked with relatively innocuous materials such as floor sweepings, packaging materials and general factory refuse. Consequently little factual information is available on the nature and properties of waste. The Merck Index (31) and similar publications (27, 32, 33) do not list properties of waste materials and when attempting to assess hazards from the mixing of incompatible wastes, no specific guidance is available. The most realistic classification of wastes is that suggested by the Department of the Environment (34) which includes categories such as mixed organic compounds and unidentified chemical

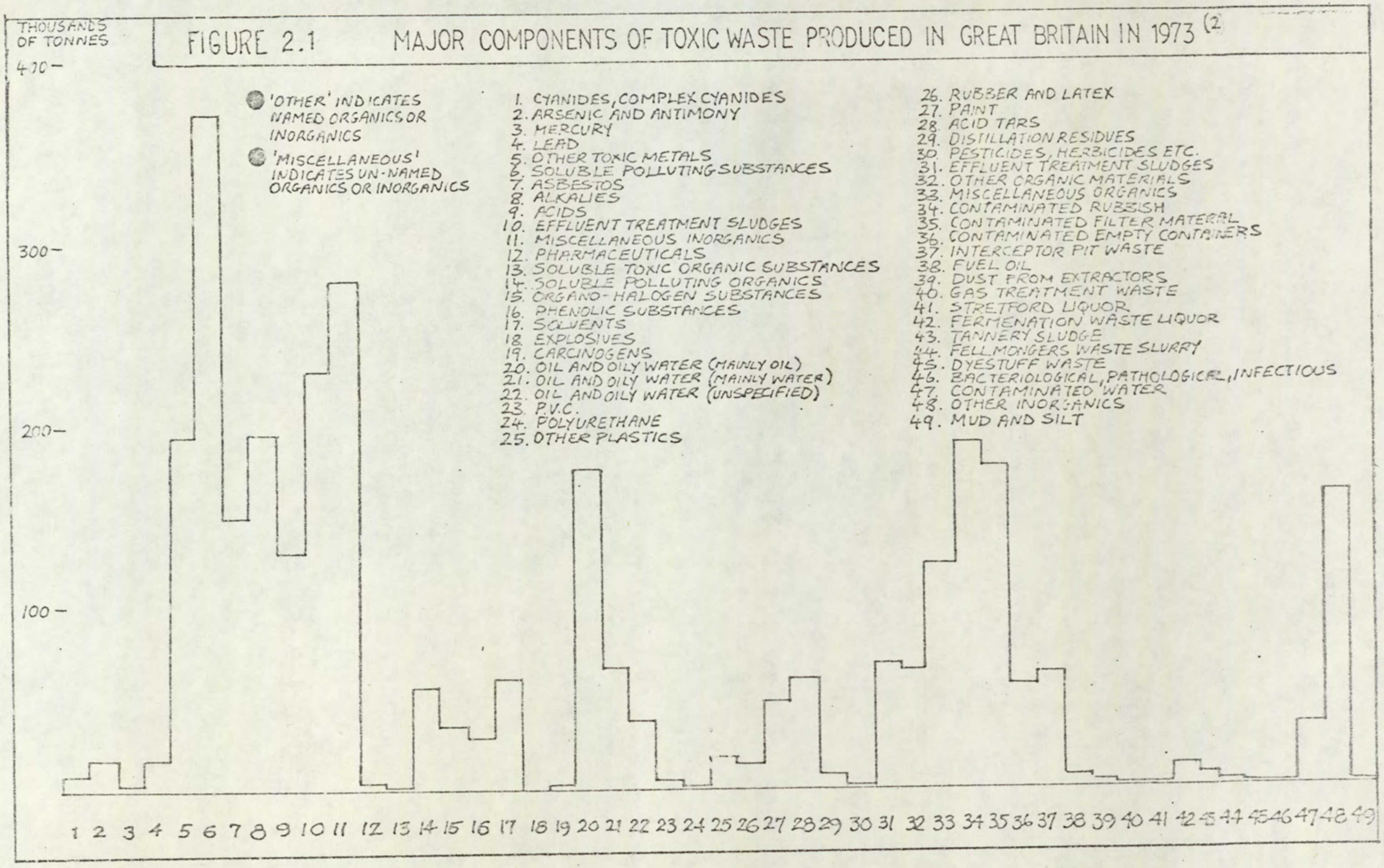


FIGURE 2.1 MAJOR COMPONENTS OF TOXIC WASTE PRODUCED IN GREAT BRITAIN IN 1973 (2

waste and, by means of a group and sub-group coding system, allows items such as empty used containers and used filter materials to be identified. This compares with the Home Office categorization which only lists dangerous substances by reference to the proper chemical name, or any commonly accepted synonym. Hence wastes, being generally mixtures, often heavily contaminated with debris, are not categorized at all (35). Appendix VI reproduces the D.O.E. classification.

The Harwell report demonstrates that the major components are acids, alkalis, asbestos, contaminated rubbish, effluent treatment sludge, filter cake, misc. inorganic and organic oil, soluble polluting substances and toxic metals. It also shows the distances involved in the disposal process with some wastes being transported 750 km for disposal (2).

Finally it provides information on the amounts of waste disposed of at various sites. Table 2.1 is an extract from the report and leads to the conclusion that about 12 sites i.e. less than 5% of the total number, disposed of more than one third of the waste arising in the area studied.

TABLE 2.1

Quantities of toxic wastes deposited on sites for half of the country. (2)

| Number of sites | Percentage of total sites | Amount deposited tonnes/year |
|---|---|---|
| 51 | 17.8 | up to 4 |
| 107 | 37.7 | 4 - 400 |
| 39 | 13.6 | 400 - 1200 |
| 22 | 7.6 | 1200 - 4000 |
| 29 | 10.1 | 4000 - 12000 |
| 26 | 9.1 | 12000 - 40000 |
| 10 | 3.5 | 40000 - 120000 |
| 2 | .6 | 120000 - 400000 |
| Total 286 | 100.0 | |

Wide discrepancies have existed in the past between estimates of waste production and actual waste arisings. This is illustrated by the comments in the report of the Royal Commission on Environmental Pollution (36) in which the Key Committee are criticized for understating the seriousness of the toxic waste disposal problem.

One specific difficulty is demonstrated by comparing the Harwell returns for asbestos waste with information obtained direct from the manufacturers of asbestos products for the same period (22). Table 2.2 summarizes these latter returns and it has been further estimated that total asbestos waste disposal reached about 75000 tonnes in 1974, approximately 45% of asbestos imports for that year. However the Harwell figure for asbestos waste disposal was 150,000 tonnes which approximates to the total amount imported.

The difference may be accounted for by the difference between notifications made for asbestos itself and those for asbestos contaminated waste, but the uncertainty is characteristic of the subject.

TABLE 2.2

Amount of Asbestos Waste arising in 1974 in the U.K.
(Information supplied by the major manufacturers(22))

| CATEGORY | AMOUNT (TONNES) |
|---|---|
| 1) Fine dusts .. .. .. .. .. | 9,493 |
| 2) Loose fibres, floor sweeping etc. | 1,690 |
| 3) Off-cuts, broken pieces and rejects of materials .. .. .. .. | 764 |
| 4) Off-cuts, broken pieces and rejects of high density materials .. .. | 32,813 |
| 5) Sacks and bags .. .. .. .. | 243 |
| 6) Wet scrap, slurries and sludges (20% asbestos) .. .. .. .. | 18,607 |
| 7) Crocidolite .. .. .. .. | 18 |
| | 63,628 |

A most useful yardstick would be toxic waste produced per employee and tentative conclusions can be drawn from other figures which are available in respect of non toxic waste such as the annual solid waste production per man. Table 2.3 shows this relationship broken into SIC classifications for the Upper Mersey Valley Area (37) for 1971.

TABLE 2.3

Annual Waste Production per man employed using standard industrial Classification (S.I.C.) (37).

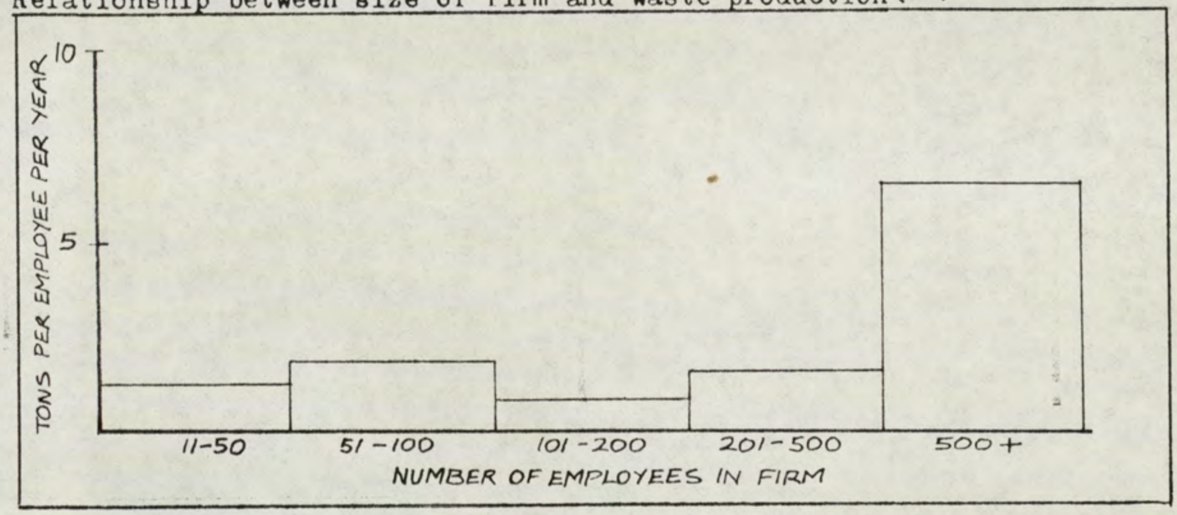
Amount of waste identified divided by number of employees in S.I.C. Order in the sample area.

| S.I.C. Order No. | Solid tons/man | Semi-Solid tons/man | Liquid (tankered) tons/man | Total tons/man |
|---|---|---|---|---|
| III : Food | 0.39 | 0.93 | - | 1.3 |
| IV : Chemicals | 13.2 | 33.1 | 2.71 | 49.0 |
| V : Metal mfg. | 5.3 | 0.1 | 0.48 | 5.9 |
| VI : Engineering | 0.71 | - | 0.1 | 0.8 |
| IX : Other metal goods | 0.92 | 0.1 | 0.1 | 1.1 |
| X : Textiles | 1.17 | - | - | 1.2 |
| XI : Leather | 3.50 | 30.0 | - | 33.5 |
| XII : Clothing | 0.18 | - | - | 0.2 |
| XIII : Bricks | 8.0 | 7.4 | - | 15.4 |
| XIV : Timber | 0.73 | - | - | 0.7 |
| XV : Paper | 6.9 | 0.1 | 0.1 | 7.1 |
| XVI : Other manufacturing | 0.28 | - | 0.1 | 0.4 |

This table shows that waste production per person employed varies markedly between industries. There are also differences between small and large companies within the same industry. Whilst economies of scale encourage large companies both to install costly recycling processes and also to provide for their own disposal of toxic wastes, published data indicate that in terms of general waste, very large companies produce significantly greater waste per man. This is illustrated in Figure 2.2

FIGURE 2.2

Relationship between size of firm and waste production (38)



In view of the markedly higher production of general waste per man in very large companies it may well be that a similar relationship applies to the toxic fraction of waste, although verification of this suggestion must await publication of the County by County returns.

NUMBERS AT RISK

It has already been demonstrated that there is an absence of official information on operators specifically engaged in toxic waste handling. Hence a series of estimates must suffice for the number of workers potentially at risk. If workers concerned with the production of waste are ignored it is necessary to begin with those workers involved in the collection and transporation of toxic waste. Assuming that the amount produced is 5 million tonnes per annum, and that this leaves industrial premises on board vehicles which carry an average payload of five tonnes, then upwards of one million vehicle movements will be involved. To ascertain numbers of drivers involved, it is then necessary to ascertain the disposal pattern. It can be shown that 75% of toxic waste travels less than 50 km ( 2 ) to its disposal point so two hours should suffice for the average round trip. If 30 minutes is allowed for the disposal operation each trip will average 2.5 hours. Assuming drivers work on average 50 hours per week, each will achieve 20 trips per week x 50 weeks/year giving an approximate maximum of 1,000 trips per year.

The majority of toxic waste collections are by specialist drivers, so that if each driver spends his whole working year on such tasks moving five tonnes per trip at a rate of 1,000 per year then 1,000 drivers will be involved ($5 \times 10^6 \div 5 \div 1,000 = 1,000$). To this total number of drivers need to be added the number of operators engaged in the disposal process. As 90% of the toxic waste operations are landfill and it is realistic to allow for one operator per 50,000 tonnes of waste per annum (13), this will result in $5 \times 10^6 \times 0.9 \div 50,000 = 90$ operators being involved. However, it has been shown that in the UK toxic waste is disposed of alongside domestic and commercial waste at an average ratio of 1 to 5 (39). Therefore, the total of 90 needs to be multiplied by 5 to arrive at a corrected figure which is 450. The remaining 10% of toxic waste not landfilled has a much higher proportion of operators to tonnage. Several plants have ratios as high as one operator per five thousand tonnes p.a. (40). Hence these 500,000 tonnes may well require the services of upwards of one hundred operators making the total 550. Accordingly, the total of drivers plus operators handling significant quantities of toxic waste is estimated to be 1,500 approximately.

## 2.2 Health and Safety Development

Concern over occupational health and safety in solid waste management is not new. Ramazzini (the acknowledged father of occupational medicine) described acute and chronic ocular inflammation among 'cleaners of privies and cesspits' in 1713 (41). However, whilst solid waste workers share the general rising expectations of health and freedom from disease, the pattern of work of some of their number has remained similar to that of the "night soil" men who removed solid waste and faeces from houses a century and a half ago. The lack of automation or other significant changes in solid waste collection can unfortunately mean that some solid waste workers still come into intimate contact with the wastes they collect and dispose of. This may be due to some extent to the continuing low cost nature of the entire waste disposal enterprise (13, 40, 42).

The Institute of Solid Waste Management has promoted discussion at four separate annual conferences during the last twenty years (43, 44, 45, 46), and the author's contribution to the debate in the technical press on this issue appears as Appendix VII.

One explanation for the increased current interest is the leeway to be made up in the matter of operator protection since 1974 when the HASAW Act gave many solid waste workers statutory protection for the first time. This Act has required the raising of standards just at a time when the Control of Pollution Act, 1974 was focussing attention on the hazards inherent in certain aspects of waste disposal and make specific reference to the effects of processes on people other than employees, for example, residents adjacent to waste disposal sites. Moreover it has been argued that the latter Act provided protection for the majority of the population at the expense of two minority groups namely the operators involved in handling toxic waste and residents living in the vicinity of waste disposal sites. The author's public contribution to this argument is contained in Appendix VIII.

Section 2.4 shows that the last century and a half has seen the introduction of a wide range of highly toxic materials which eventually appear as wastes and many undertakings have limited knowledge of the composition of their own waste products (47). Indeed material which becomes waste due to malfunctions in a chemical plant may be a substance such as a partial polymer of uncertain toxic properties. For example as a result of the attention focussed on dioxin following its recent escape at Seveso in Italy it was revealed that waste containing dioxin had been dumped on a tip near Clay Cross in Derbyshire in 1968 before its extremely dangerous nature was generally appreciated. (Details in case study 10).

Industry in general has now, however, begun to pay more attention to public concern over its wastes and the waste disposal industry itself has shown evidence of responding to this concern. Occupational health services are now operated by a majority of companies whereas at the commencement of this study they were rare.

A disadvantage under which solid waste management labours is that it does not possess a well established recruitment training and career structure (48)& hence is particularly prone to losing promising recruits at the technical and managerial level who are discouraged by the poor public image of the service. In addition tradesmen and even casual workers can be deterred by the impression of dirty and dangerous conditions. Moreover the morale of the existing workforce can scarcely be improved by the background of public contention and vilification referred to in 2.4, which often surrounds waste disposal operations, especially where toxic waste is handled. However, considerably less attention is focussed upon waste than on the raw materials and the end products of the processes from which it arises. This is understandable since waste has to be disposed of at a cost to the manufacturing facility and generally without any corresponding benefit (49). Although the effect of the Deposit of Poisonous Waste Act 1972 has been to focus more attention on waste, the study of waste still remains a relatively neglected science. For example, the total annual expenditure involved in waste collection and disposal in the U.K. probably exceeds £1 billion but the government's solid waste research budget for 1978/79 amounted to less than £2 million (50). The low priorities awarded to waste disposal by industry are reflected in academic establishments - no university offers an undergraduate course in the subject and only at one Polytechnic is solid waste management a major option on any degree course.

## 2.3 Legal position

### OPERATOR PROTECTION

For the solid waste worker any analysis of the legal position must commence with an examination of Common Law precepts because, as has been shown, statutory reinforcement of these obligations did not occur for most of this group of workers until the advent of the Health and Safety at Work Act 1974.

The reason for the exclusions of the solid waste worker lies in the definition sections of the Factories Acts, most significantly Section 175 which limits the applicability of the 1961 Act to certain classes of operations - namely those taking place on 'premises' and also consisting of specified activities e.g. making, altering, repairing or demolition of articles. Processes solely concerned with the disposal of residues by their release to the general environment are not so covered. For example the Health and Safety Executive have advised: (13)

> "The argument on whether or not a specific waste disposal operation is subject to the Act usually centres around the phrases 'breaking up or demolition of any article' and 'adapting for sale of any article'. Very little guidance has been given in the Courts on the interpretation of these phrases as they relate to disposal operations ....... However, such operations as baling of paper or tins etc., for resale, making of compost etc., are generally regarded as being subject to the Factories Act because this can be loosely termed 'altering for sale'. It can also be argued that breaking up of refuse in a destructor is 'breaking up or demolition', but one

would be on difficult grounds extending such an application to incineration. Similarly, spreading refuse on a tip comes into neither category and is not regarded as subject to the Act. The only exception to the latter would be the limited case of a workshop on site in which say, bulldozers or other plant were repaired or serviced, when employment in the workshops only would be covered by the Act."

Because of the above restriction if a solid waste operator was fatally injured at work before 1974 no subsequent prosecution could have been instituted by the H.M. Factory Inspectorate.

Under the Common Law, it is a fundamental principal that every employer has a duty of care towards his employees. This involves the provision of a safe place of work, safe plant and appliances and safe system of work. These concepts are fully discussed in many standard works of reference (51, 52) but the extent of the duty depends very much upon the circumstances surrounding the individual case. These may involve such factors as the probability of danger, the severity of any resultant harm and the level of competence which can be expected from the workforce. Clearly a supervisor who authorized an unsafe act would be much more likely to be held personally to blame than an operator should any injury result. Employers have been found liable for torts as straight forward as a defect to a tipper lorry (53) or failure to provide a heater in a vehicle (54) but the situation needs careful consideration because employees in their turn have been held to have exhibited a level of contributory negligence up to 100% and thus been unable to recover any damages from a successful action (55).

Furthermore, not only must the system of work adopted be inherently safe (56) but it is also necessary for employers to fully consider any individual susceptibility on the part of their employees, as has been demonstrated by many cases (57 58 59).

The common law concept of a duty of care (which in summary consists of the provision of a safe place of work and the enforcement of a system of comp探tant supervision with provision of substances and equipment which are suitable and if necessary, properly maintained), has tended not to rest very heavily on the employers of solid waste workers in the past because of

(1) the absence of strong unions, due to the scattered employment pattern of the workers.

(2) The ease with which any undertaking which attempted unilateral improvement of the conditions of work could be undercut by a competitor with fewer scruples about operator safety.

(3) The cost conscious nature of the exercise due to the virtual absence of a quality control aspect to operations which has had the tendency to permit the lowest standard to be the most successful.

The problems which employers have faced in respect of their responsibilities to solid waste workers are exemplified by the difficulties encountered when writing the statutory policy statements to comply with Section 2 of the Health and Safety at Work Act. Official guidance (60) stresses that the chain of responsibility has to be clearly delineated, but in practice the supervisory element of this chain cannot easily be extended to cover the single handed worker driving a bulldozer on an isolated landfill site without significantly affecting costs because of the tradition of unsupervised working. Accordingly either the Act has allegedly been ignored (61) or provisions have been made for providing "The best practical means" of protection by measures such as fitting a two way radio into the cab or arranging a regular rendezvous with the supervisor.

When planning systems of work employers should bear in mind that workers sometimes become careless or make mistakes, particularly in circumstances where the dangers are obscured by repetition. This was pointed out in General Cleaning Contractors Ltd. - v - Christmas (56) as follows: "It is .......... well known to employers ......... that their work-people are very frequently, if not habitually, careless about the risks which their work may involve. It is ........ for that very reason that ........ employers should take reasonable care to lay down a reasonably safe system of work. Employers are not exempted from this duty by the fact that their men are experienced and might, if they were in the position of employer, be able to lay down a reasonably safe system of work themselves. Workmen are not in the position of employers. Their duties are not performed in a calm atmosphere with the advice of experts. They have to make their decisions in places of danger and in circumstances where the dangers are obscured by repetition". In making the judgement that it is not for the work force to attempt to devise a safe system and precautions, the following was said:

> "Where a practice of ignoring an obvious danger has grown up ....... (it is not) ........ reasonable to expect an individual workman to take the initiative in devising and using precautions. It is the duty of the employer to consider his men, what they must do, and to supply any implements that may be required".

The Health and Safety at Work Act has already been used in respect of solid waste operations as was demonstrated by the prosecution of Baillie Contracting Co (62) who were working on an industrial waste tip and were fined £800 on indictment for a "woeful lack of foresight" which resulted in the deaths of two workmen due to gases given off during excavation work.

With regard to transportation, powers have existed under the Explosives Act since 1875, to make byelaws governing the conveyance of explosives by road. The conveyance by road of other dangerous substances is controlled under the Petroleum (Consolidation) Act 1928, which specifically governs the conveyance by road of petroleum spirit, and provides that any of the requirements of the Act (including those relating to conveyance by road) may be applied by Order in Council, to other substances.

Whilst the purpose of these statutory controls is primarily to protect the public during conveyance or otherwise they do have the incidental effect of protecting the work force.

In 1965 because of a number of incidents which had occurred in which the emergency services had experienced difficulty in dealing with vehicles carrying dangerous substances, a Standing Advisory Committee on Dangerous Substances was set up to advise on the storage and conveyance by road of such substances and to give special priority to the introduction of controls over conveyance, particularly as regards the marking of vehicles.

Having drawn up an order of priority to ensure the systematic extension of conveyance controls to individual classes of dangerous substances, according to the degree of risk which they offered, regulations were first introduced in 1968 applying certain basic safety requirements and labelling controls to vehicles and packages used for the conveyance of inflammable liquids. These were followed in 1971 by a similar range of requirements for corrosive substances. In 1974 similar controls were imposed in respect of organic peroxides. Regulations are also being prepared which will expand the existing controls over flammable liquids and corrosive substances by laying down requirements as to the construction and operation of vehicles used in their conveyance. Similar controls will be extended to such substances as organic peroxides and dissolved, liquified and compressed gases and toxic substances.

New regulations have recently been introduced for the marking of tankers

These provide that tank wagons and other vehicles carrying certain dangerous substances in quantities above certain specified minimum amounts, must be labelled or marked in such a way that the substance carried is readily identified. The regulations relating to the construction and operation of vehicles are being amended to ensure that all vehicles are fitted with suitable engines, exhaust and electrical equipment, and that tank wagons and their fittings provide an adequate degree of safety. With regard to operation there will be requirements to regulate the conduct of drivers both on and off the road, especially during the loading and unloading, and in emergencies. However, considerable delay has been occasioned in the introduction of regulations governing transporation of waste material. The draft regulations are currently the subject to protracted negotiations between the Health and Safety Executive and interested parties (63)

In order to provide a concise summary of the total legislative position, the author's contribution to a study commissioned by the O.E.C.D. of legislation governing the use, production and disposal of chemicals (64) is reproduced as Appendix IX.

## 2.4 Environmental Health Implications of Toxic Waste Disposal.

The impact which toxic waste disposal has on the environment is largely outside the scope of the present study. However a brief review is included since certain aspects,such as the repacking requirements for sea disposal of cyanide and arsenic do have a bearing on operator hazards.

It can be readily demonstrated from first principles that an ecosystem which does not safely deal with its own toxic wastes is doomed (24,65) Earlier ecosystems successfully evolved ways of dealing with this problem but one result of the Industrial Revolution is that many wastes to which the present ecosystem is not adjusted are being emitted in vast quantities (66). The problems associated with toxic waste disposal are not a modern phenomenon. Mankind has faced those problems ever since he first chose to live in settled communities. The bodies of the dead and faecal material both represent examples of toxic waste with which mankind has had to come to terms; indeed until the isolation of radioactive isotopes, a toxin produced in the body during an attack of tetanus was the most deadly poison known to man (28).

Not until the communal sewage disposal system and regulation of burying grounds became established did a tolerable lifestyle become achievable in the crowded connurbations produced during the industrial revolution. However, the very success of the latter posed new waste disposal problems as the emergent chemical industry began producing significant quantities of toxic waste products and other industries began to operate on a scale that resulted in large waste arisings and severe disposal problems. For example, mining spoil contaminated with heavy metals stockpiled close to mines polluted the rivers of Cardiganshire (67).

Over the years individuals aggrieved by the nuisance and injury that such emissions caused have had extensive recourse to the law to obtain a remedy (68).

The early litigation and subsequent legislation was in the main devoted to the most obvious problems posed by industrialization such as liquid and gaseous wastes. Hydrogen chloride fumes from the classic alkali process were controlled by the early Alkali Acts and other highly offesnive emissions, notably hydrogen sulphide, were pronounced upon by the 1875 Public Health Act. Solid waste disposal was not specifically legislated upon until the present decade, and traditionally has occupied a somewhat neglected position. However, it has now moved to the fore-front of considerations (69).

It is not currently feasible to assess accurately the level of risk to the general public from waste disposal as presently practiced. The difficulty of being objective about such issues has been demonstrated at several Public Enquiries into planning and disposal site licence applications (70, 71, 72). Incidents where toxic materials, especially wastes, are involved tend to be sensationalized (73) e.g. the recent reaction to the reports of unusually high cadmium levels in Shipham due to waste from ancient lead mining operations (74). This trend is particularly noticeable in the case of radioactive wastes.

Any proposals for the location of toxic waste treatment plant will normally meet opposition from local residents, generally based on a combination of the following issues (36):

1. The possibility of a 'grand catastrophe' involving gross air, water or land pollution from the site which may affect a wide area and possibly even involve threats to the water supply of a whole region.

2. Localized danger and/or nuisance emanating from routine operations on the site such as dust, gases, smoke and fumes from fires, smells from odoriferous substances or an increase in pests which are associated with certain wastes (such as those from slaughterhouses). Table 2.4 demonstrates the potential for harm of domestic and general factory wastes or those which are so lightly contaminated as to commonly be regarded as being relatively innocuous.
3. Potential threats posed by vehicles carrying highly toxic materials to persons using, or residing adjacent to, the roads serving the sites.
4. Danger of local residents' children gaining unauthorized access to site (perhaps attracted by the idea of scavenging amongst the waste) and becoming contaminated by toxic material.
5. Miscellaneous issues peculiar to the site in question, such as the destruction of good arable pasture or a habitat for a rare species of wild life.

Clearly of the issues listed above, all but the last, have a bearing on potential hazards to operators. It follows that in response to public pressure, a more rigorous application of the law preventing environmental damage by toxic waste disposal processes must eventually benefit the operators, i.e. :-

For example the full implementation of the letter and spirit of Part I of the Control of Pollution Act (as detailed in Appendix X) could eventually involve the County Waste Disposal Authorities, the Health and Safety Executive and District Environmental Health Departments in collaborative ventures to provide for the waste disposal requirements of entire regions, thereby obviating some of the illogical arrangements which currently exist.

TABLE 2.4

Potential Hazard of domestic and general factory wastes.(75)

| Landfill of: | Process and transportation mode | Pollution potential | Specific Pollutants |
|---|---|---|---|
| Domestic, Catering & Food Industry Waste and General Factory Rubbish | Aerobic and anaerobic decomposition, rusting etc. producing gases which percolate through porous strata and fissures | Air Pollution<br>Fires and Explosions in basements<br>Hazards in Excavations | Hydrogen sulphide<br>Methane<br>Carbon dioxide |
| Offcuts of Plastic, Rubber etc. | Products of combustion and/or pyrolysis escaping into the air or leaching into groundwater | Air Pollution. Contamination of watercourses aquifers and reservoirs | Hydrogen cyanide<br>Carbon monoxide<br>Hydrogen chloride<br>Phenols |
| Dirty Degreasing and Drycleaning solvents | Exposure as free liquid surface or saturated zone giving rise to evaporation leaching into groundwater | ditto | Perchloroethylene<br>Trichloroethylene<br>1.1.1 Trichloro ethane |
| Lightly contaminated Demolition Waste | Provision of unsufficient inert cover or failure to prevent drying out of sludge in the open allows dustborne release of toxic fractions | ditto | Asbestos<br>Mercury<br>Lead |
| Spent Mineral . Acids | Reaction with incompatible substances during disposal process can result in the formation of highly active attack gases | Air Pollution | Hydrogen sulphide<br>Hydrogen cyanide<br>Nitrogen dioxide |

# CHAPTER 3

# DETAILS OF TOXIC WASTE DISPOSAL METHODS

## Disposal Methods in Detail

A classification of waste disposal processes is reproduced as Table 3.1. In practice, not all of these are commercially viable. Figure 3.1 provides a "decision tree" approach to the selection of appropriate disposal techniques.

This chapter is devoted to a brief explanation of the most significant methods found during the site visits, viz landfill incineration, sea dumping and certain others, preceded by a description of the methods adopted for collection and transport of toxic wastes and selected pre-treatment systems.

### 3.1 Collection and Transport

Storage on the premises where the waste is produced varies with the physical form of the waste. Bulk storage provisions range from a simple heap to a reception pit or above ground tank with or without bund. Smaller quantities of waste, either solids, sludges or liquids, are normally stored in metal drums often of 45 gallon (205 litres) capacity. A metal skip, with a capacity from 5 - 20 $m^3$, is commonly employed to store intermediate quantities of solids and sludges or to act as a receptacle for individually drummed wastes.

The collection and transport of toxic waste varies from a fully mechanised process, in which the remotely situated operator actuates a mechanism, to a system completely devoid of any mechanical assistance so that the operator is in intimate contact with the waste, e.g. manually shovelling it.

Liquids and sludges are collected by vacuum tankers which may possibly

TABLE 3.1

Classification of waste disposal processes (76 )

| Physical Treatment Processes | | | | |
|---|---|---|---|---|
| Liquid-solids separation | Removel of specific components | Chemical treatment processes | Biological treatment processes | Ultimate disposal processes |
| Centrifugation | Adsorption | Absorption | Activated sludge | Deep well disposal |
| Clarification | Crystallisation | Chemical oxidation | Aerobic lagoons | |
| Coagulation | Dialysis | Chemical Precipitation | Anaerobic lagoons | Dilute and disperse |
| Filtration | Distillation | | Spray irrigation | Incineration |
| Flocculation | Electrodialysis | Chemical reduction | Trickling filters | Ocean dumping |
| Flotation | Evaporation | | Waste stabilisation | Sanitary landfill |
| Foaming | Leaching | Combination and addition | ponds | Land burial |
| Sedimentation | Reverse osmosis | Ion Exchange | | |
| Thickening | Solvent extraction | Neutralisation | | |
| | | Pyrolysis | | |
| | Stripping | | | |

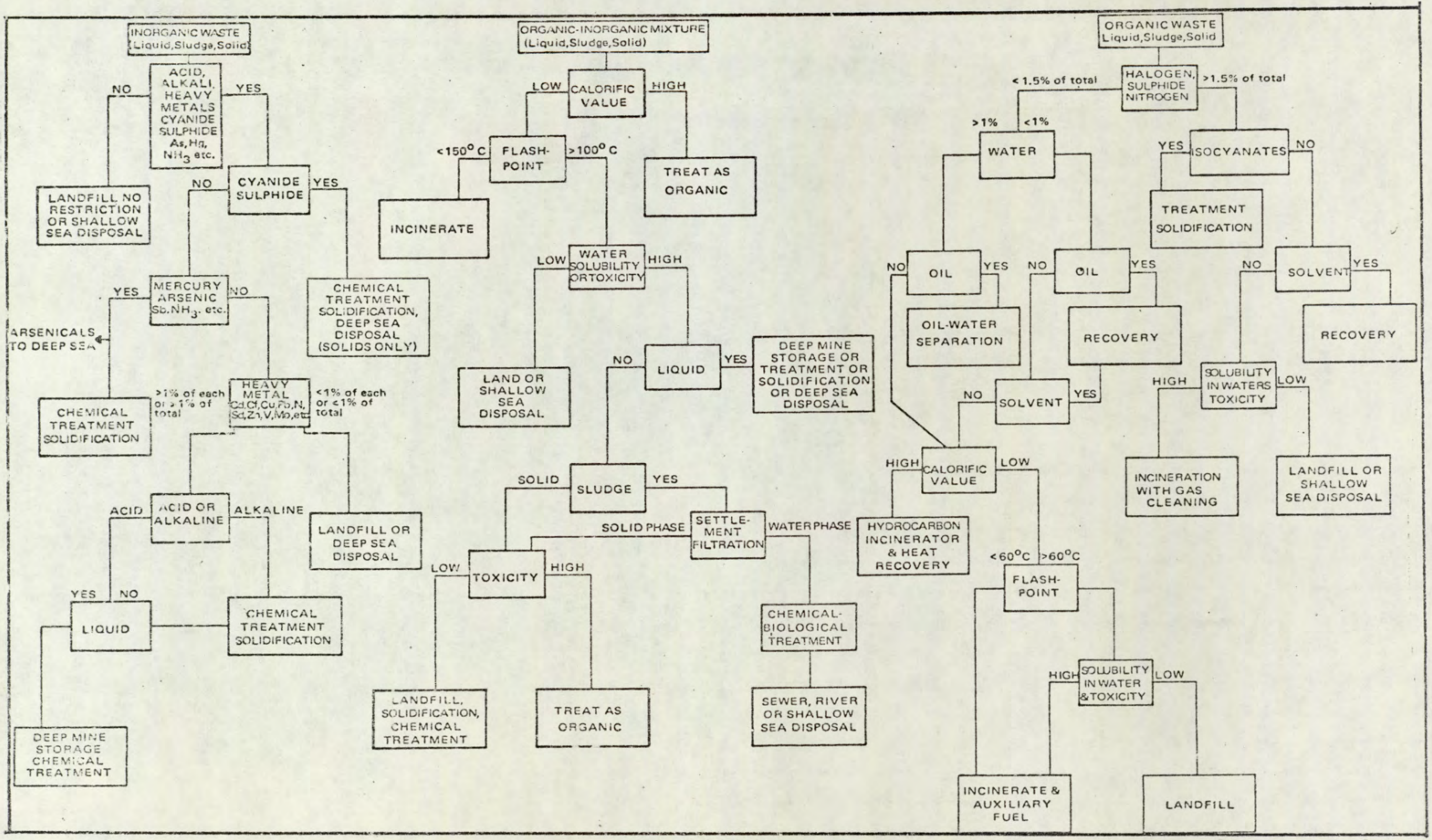


FIGURE 3.1 Waste disposal options in decision tree format (77).

be loaded by gravity, by on site pumps or by suction using the vehicle's drive or auxiliary engine. Discharge is again either by gravity or pump. When a vacuum pump is used the exhausted air is contaminated with the materials being collected & is commonly discharged underneath the vehicle.

A wide variety of vehicles are employed for collection, ranging from simple platform trucks to purpose-built articulated tankers equipped with auxiliary pumping engines, but the two commonest vehicles are the rigid chassis tanker and the skip vehicle.

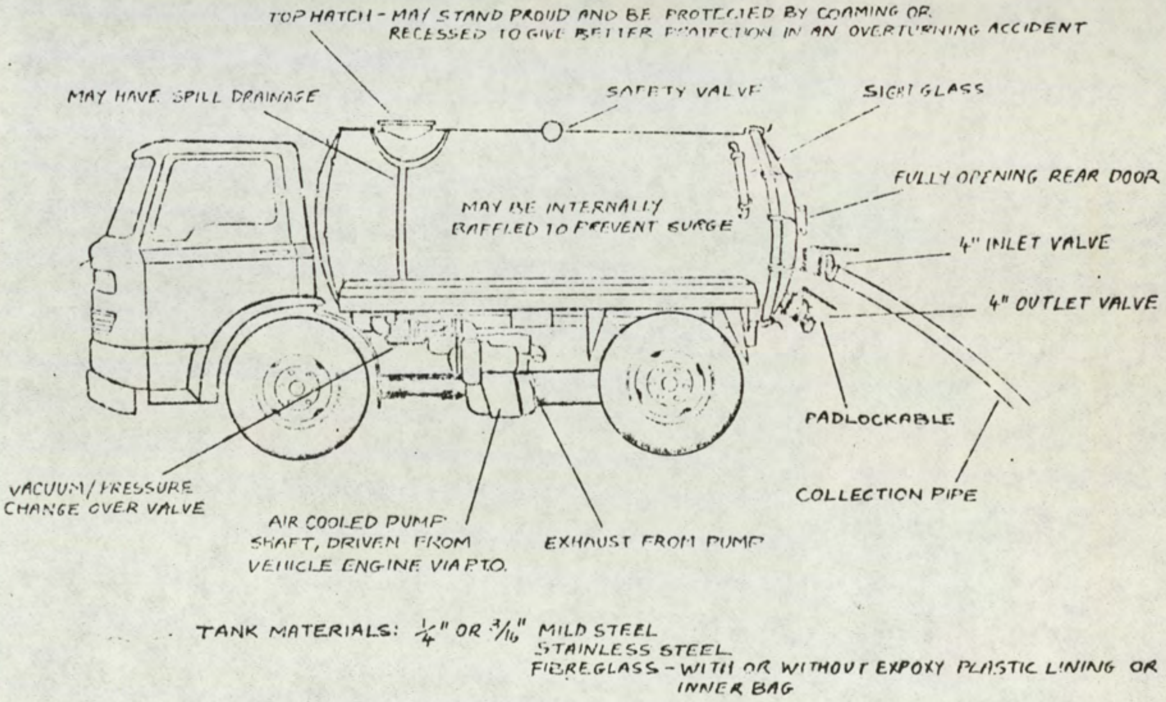


FIGURE 3.2 Details of road tanker used for collecting toxic liquid and sludge

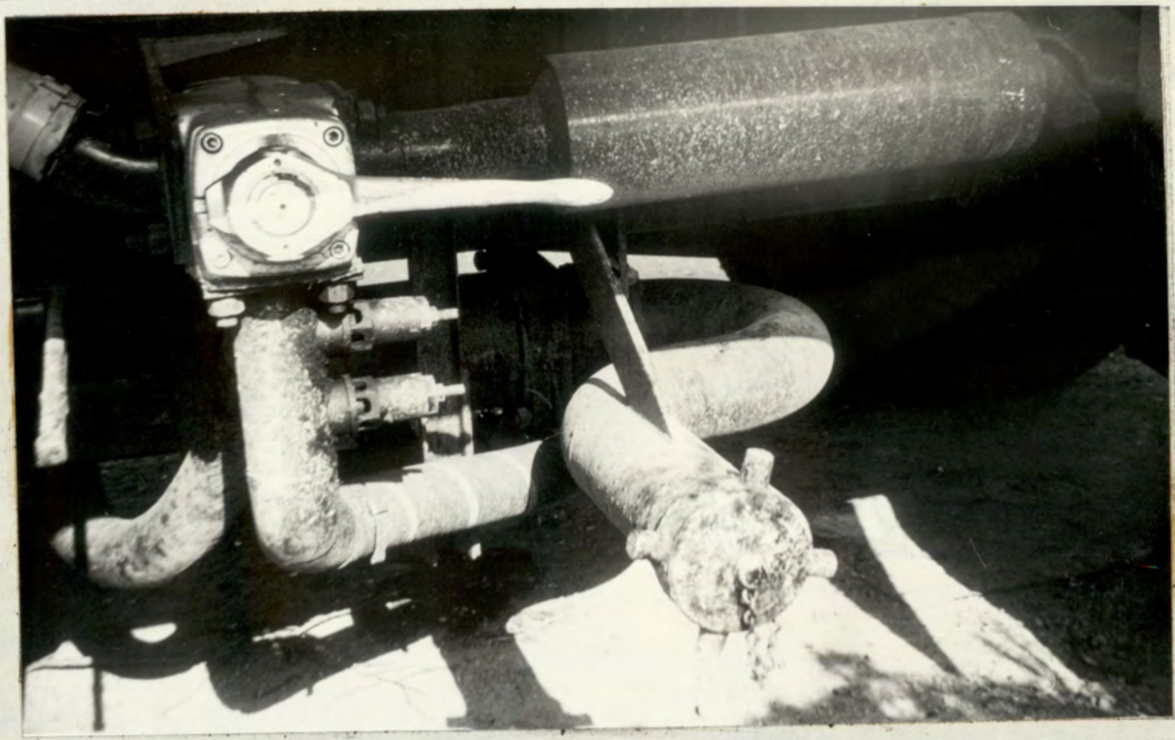


FIGURE 3.3 Change over valve on a tanker pump. This demonstrates the proximity of the exhausted air silencer output (top right) to the operator's position.

FIGURE 3.4 Articulated 4,500 gallon (20,450 litres) tanker Large 14 wheel type with auxiliary engine discharging liquid waste over the face of a tip.

### 3.1.1 ROAD TANKERS

A typical purpose built waste tanker is illustrated in Figure 3.2. This is in HGV Class II, has a 6 wheel chassis and carries about 2,000 gallons (9080 litres) in its steel tank which is commonly 3/16" (4.76 mm) thick mild steel which may be lined with plastic. The hinged rear door can be of full cylinder diameter, with 12-14 fixing clamps, or of slightly less diameter which results in a stronger tank better able to resist being squashed if the tanker overturns. A promising inovation is the provision of a flexible bag liner for the interior of the tank with the vacuum being applied to the space between the bag and the tank so that problems inherent in the exhausting of contaminated air damaging the exhauster pump are avoided, and also benefitting the operator (78).

The 'exhauster' is typically a sliding vane vacuum/compression pump which also acts as a screw pump for discharging contents and will exhaust at 360 cu ft/min (10.2 cu m/min) until the ball valve shuts off the inlet. Loading and discharging times per 1000 gallons (4,540 litres) vary with the viscosity of the waste typically from 2 min for the lowest viscosity to 5 min for the highest. Figure 3.3 demonstrates the change over valve which the operator must control and the proximity of the exhausted air silencer outlet. Figure 3.4 shows an articulated 14 wheel tanker of circa 4,500 gallons (20,500 litres) capacity with a separate donkey engine for filling and emptying the tank. Again the operator's position is close to the exhaust from the pump.

Except in totally unstructured situations such as some landfill sites, tankers discharge their wastes via pipelines. The coupling pipes are carried on board the vehicle in side trays and a certain amount of spillage is inevitable when the pipelines are broken.

Entry into tanker barrels is often required to remove sediments or obstructing material from the outlet valve; this procedure is illustrated in figure 3.5. If the tanker barrel can be tipped by hydraulic means and there is a fully opening rear door it may be possible to perform the cleaning using high pressure water jets without entering the barrel.

FIGURE 3.5 Fully opening rear door. The wide aperture facilitates 'digging out' the residue of the waste.

### 3.1.2 SKIP VEHICLES

These are employed to remove solid and drummed waste which has been accumulated on the producer's premises in metal skips ($3m^3$ - $10m^3$ capacity). The smaller type of container is plain and is tipped to a vertical position to empty. The operator normally stands adjacent to the rear of the cab when emptying the load.

Routine cleaning of the skips is not usually practised, although pressure jetting with water is possible.

## 3.2 Unpacking and Pre-treatment

### 3.2.1 MANUAL UNLOADING

Whilst only a small proportion of toxic solid waste is manually unloaded with a shovel, drummed and bagged wastes may have to be man-handled, if they are not merely dumped from a skip or other tipping vehicle. Drums and bags delivered in skips also require individual attention if they are to be disposed of by any means other than crude dumping.

The discrepancies which occur in practice between the description in the accompanying notification and the actual substances which arrive for disposal, require operators to undertake manual sorting of some toxic waste consignments.

### 3.2.2 UNPACKING

Unpacking is often carried out in the open air, typical conditions are illustrated by figure 3.6 and figure 2 in appendix III. A variety of methods are used to open containers ranging from hand tools, such as knives and axes, to mechanically powered devices such as electric metal cutters and pneumatic chisels.

The empty containers themselves need to be disposed of; this may be by landfill or by incineration or, in the case of metal drums, by sale as scrap. In this latter instance there is a requirement that the drums should be cleaned before being sold.

FIGURE 3.6 Manual Dedrumming. Operators de-drumming solidified spent sodium cyanide salts with the use of axes in the open air.

3.2.3 PRE-TREATMENT

Certain disposal operations are preceded by an unrelated treatment operation such as pH adjustment or oil and water separation. This may take place on a different site.

The layout of a large scale pH adjustment process is shown in appendix XI. Liquid waste, in this case acid, is discharged to the neutralization and pH adjustment pits which are bunded with site clay. Waste alkaline sludge is added by the mechanical grab which is shown in figure 3.7. When the resulting reaction has passed its peak the grab is used to remove part of the retaining bund to allow the neutralized acid to drain into the large lagoon from which it is tankered for final disposal to sea or mineshaft. The precipitated salt is landfilled on the same site.

A somewhat makeshift oil and water separation plant is illustrated in figure 3.8. Suitable waste oils arriving at the landfill site are diverted to the storage tanks and allowed to settle. Waste acids are used to split the emulsion; the separated oil is consigned to a recycling plant and the contaminated water is disposed of on the landfill site.

### 3.3.2 Landfill (including mineshaft disposal)

The 'controlled tipping' of solid waste (a variation of which is termed 'sanitary landfill') is the technique for disposing of solid waste (including some sludges and liquids) on land in such a way as to avoid nuisance or risk to public health during the operation and after its completion (49). The technique is based on the principle of compacting the waste in layers and covering each layer with suitable material as tipping proceeds. The covering material may be excavated for the purpose or consist of relatively inert waste such as builders' rubble. It should

FIGURE 3.7. Large Scale pH Adjustment Process. Mechanical grab feeding sludge into acid lagoon in a pretreatment process.

FIGURE 3.8. Temporary Oil and Water Separation Plant. Constructed in a makeshift manner on a landfill site and not complying with the necessary constructional and operational standards.

form a 'seal' for the more active or offensive waste and act as a fire stop in the case of a conflagration.

The disposal of toxic waste on landfill sites has been officially endorsed by the government in the UK as being capable of making a contribution to the reclamation of land. Attention is drawn to the need for the exercise of particular care in respect of handling and water pollution aspects. The handling considerations are listed as including flammability, volatility, odour emission, toxicity, chemical interactions, corrosivity and physical stability. Water pollution aspects include solubility, absorption, chemical precipitation or degradation, biological breakdown effects of solvents,~~4~~ encapsulation as well as geological and hydrogeological factors. (80) The basic principle advocated is that of 'dilute and disperse', in order to avoid, wherever feasible, long term problems due to concentrated and persistent waste. In the UK the basic operation is currently carried out on land which is often otherwise unusable; covering the deposit is carried out with "inert" material which is usually waste itself. This is in contrast with 'sanitary landfill', as practised in the USA, where an excavation preceeds the deposit and the excavated material is then used as cover for the waste. The term landfill also encompasses the creation of artificial mounds of waste and tipping on low lying estuaries.

Waste disposal is often combined with land reclamation; hence many landfill sites are on derelict land or in worked out mineral extraction locations. The mineral extractive industries consume over 4,500 acres (1,820 hectares) per annum in England and Wales (1). If it is assumed that these excavations are of material at an average depth of 3m (which is a conservative estimate) then over 54 x $10^6$ $m^3$ are potentially available for back filling each year. Hence landfill will continue to provide the major waste disposal method in the foreseeable future (6) even when allowance is made for the strictures resulting from the enforcement of Part I of the Control of Pollution Act 1974, which will have the effect of excluding many potential landfill sites because of possible environmental pollution.

UK practice for the disposal of toxic waste by dumping on landfill sites normally involves an operation in which domestic, commercial and non hazardous industrial waste are used as covering material for the solid and sludge toxic waste which arrives contemporaneously. Alternatively, in the case of liquids the specific excavation of small lagoons or trenches is undertaken into previously deposited waste to facilitate absorption of the liquid. The US practice of excavating very large lagoons for soakage purposes is not practicable in the UK since high rainfall and low temperatures result in a situation where gains exceed evaporative and absorption losses.

Achievement of the 'dilute and disperse' aim advocated by the Department of the Environment is hampered by two factors. Firstly, considerations relating to the water pollution potential rule out many sites (8) so that developers are now employing consultant hydrogeologists to survey potential landfill sites at a very early stage. Secondly, public opinion is an important factor in determining the acceptability of any site; vociferous opposition is common from local residents and opinion leaders over any waste disposal proposal particularly if the proposal is for the disposal of toxic waste (70). Hence the number of landfill sites which eventually receive permission for disposal of toxic waste is strictly limited.

Landfill occasionally takes place into standing bodies of water. figure 3.9 shows a site where a deep pool several hectares in extent was being filled with solid waste.

FIGURE 3.9 Landfill into a deep lagoon Also visible is a vertical storage silo which is leaning out of vertical alignment, probably due to settlement of the tipped materials.

### 3.3.1 MINESHAFT DISPOSAL

Proposals for utilizing abandoned mineworkings for liquid waste disposal often result in unfavourable comment from Water Authorities because of their pollution potential. It has so far not proved financially attractive to excavate complete mines specifically for waste disposal purposes (although this is currently being considered for radio-active waste disposal), and UK mineshaft disposal sites are very limited in number. If the workings have recently been in use as a mine, the facilities such as sanitary accommodation, ablutions, etc. originally provided can be retained and above ground reception facilities added. These may consist of a bunded area with or without intermediate storage tanks and several 100 mm diameter pipes which discharge by gravity directly into the main shaft.

Little is known about the nature of the reactions underground. One shaft which was taking very large quantities of spent mineral acids from the West Midlands became blocked due to such reactions in 1977 and an application for planning permission is under consideration (49) to bypass the bridged section by sinking an alternative 520m shaft which will renew access to the extensive underground workings.

### 3.4 Incineration

Combustion is a simple way to effect a considerable volume reduction in any flammable solid toxic waste. Flammable liquids, which may also be wastes, can be used as secondary fuels for wastes of low calorific value. Unfortunately such processes have sometimes been performed with the minimum of equipment, and makeshift incinerators have been constructed using sections of obsolete plant. Burning in the open air has also been resorted to in the past.

Incineration has recently been the subject of a great deal of research, both with regard to its environmental impact and the economics of operation. Incineration of domestic refuse was popular in the 1960s and was favourably commented upon by the Government 1971 report on refuse disposal. (81) But by 1976 an Official Waste Management

Paper made it clear that waste heat recovery would have to be investigated as incineration on its own was a waste of resource. (80) It also pointed out that the technical problems associated with waste heat recovery encountered in practice would be found to add significantly to total costs. The conclusion in the technical memorandum was that it is unlikely that incineration will play a significant role in municipal waste disposal in the future, although the use of waste as a fuel supplement in conventional boilers is likely to offer a more attractive and less troublesome solution.

Early toxic waste incinerators were conventional furnaces which in a few cases were attached to waste heat boilers. In the case of solid wastes, loading was usually non-automatic, being effected by charging quantities of waste on to a grate containing a quantity of already burning material. Liquid wastes were incinerated via standard injection nozzles designed for the burning of homogenous liquids such as fuel oil. Flue gas cleaning was often absent.

The latest solid waste incinerators make many more concessions to the specific problems inherent in toxic waste, such as the handling difficulties posed by heterogenous solid waste and the grossly contaminated nature of many liquids. (82) Flue gas cleaning in the form of dosed water scrubbers is common but waste heat recovery is rare.

A vessel came into service in the mid 1970s operating out of Rotterdam burning wastes which are unacceptable for landfill in Holland. Because there is no requirement to scrub the tail gases from the incinerator at sea it could offer more competitive rates than land based rivals. This development is particularly appropriate to the Netherlands where the restrictions on landfilling toxic waste have given rise to a greater reliance on incineration and chemical treatment of waste (20).

## 3.5 Dumping at Sea

Sea disposal from dump bottom barges was a popular method of disposal of domestic refuse earlier this century for towns on the coast. Significant changes in the character of such refuse, resulting in decreasing density, and increasing the tendency of debris to float, plus the concern over environmental pollution of beaches resulted in this system becoming obsolete. (81) Over the same period Sea Disposal of liquid, solid and semi-solid industrial and toxic wastes has tended to increase. Concern over the effect of sea disposal, particularly in respect of radioactive waste, resulted in a series of international conventions. (49) The UK is a signatory to the 1972 Oslo Convention on sea disposal and introduced its own Dumping at Sea Act in 1974 (80) which outlawed the sea disposal of certain highly persistent wastes such as mercury and cadmium, but permitted significant quantities of certain others, for example, lead and cyanides, to be dumped under a licensing system operated by the Ministry of Agriculture Fisheries and Food.

Methods of sea disposal of toxic wastes include the use of pipelines discharged relatively close to shore. Such pipes may not necessarily have been purpose-built for toxic waste, but for the discharge of sewage or industrial waste. Floating tanker discharge is a common method for wastes which can be dumped within a few miles of land. Waste requiring deep sea disposal, ie into water 2000 m deep, is carried to the appointed zone by a vessel specifically chartered for the purpose or is 'ditched' from the decks of cargo vessels.

In the case of floating tanker disposal of liquid toxic wastes in bulk, road tankers deliver material to the dockside where it is pumped aboard a sea-going vessel into segregated storage tanks. Caustic solutions are used to neutralise strong acids which might otherwise give corrosion problems. Intermediate storage may be in bunded tanks, or in one case in an unseaworthy vessel permanently moored for that purpose. Discharge of liquids is by the vessels own pumps which force the waste out of pipes at the stern below the water line.

Bulk solid toxic wastes are tipped directly from the delivery vehicle into the hold of a vessel and use is made of a grab when effecting disposal overboard at sea.

Drums are used for the non-bulk disposal of liquids and some solids. These are filled to a predetermined density, stockpiled on the quayside and loaded by stevedores as cargo on suitable vessels. Disposal at sea consists of unroping the drums and allowing them to roll overboard.

Conditions imposed by the Ministry of Agriculture, Fisheries and Food specify dumping zones and commonly stipulate specific discharge rates (such as a maximum of 500 tonnes per hour).

## 3.6 Other Disposal Methods

The wide variety of other methods which are utilized for disposal is shown in Table 3.1; for example chemical treatment, including neutralization, precipitation ion exchange, chemical oxidation, chemical/biological treatment includes spray irrigation and trickling filters. Physical processes include simple filtration, solvent extraction or 'laundering', evaporation and solidification.

With the exception of the latter and neutralization few of the systems are commercially viable except for wastes with very costly components such as silver. A major problem appears to be that the successful operation of such sophisticated plant carries stringent requirements for the quality control of waste arising which are, as yet, achieved by few sectors of UK industry (40). Hence few of these techniques are used regularly on a large scale for the disposal of solid toxic wastes (6).

### 3.6.1 NEUTRALIZATION

A more sophisticated version of the crude neutralization described in 3.2.3 is carried out in a variety of plants where acidic waste is neutralized with lime, specifically purchased for the process, to produce a salt and an effluent which, with consent, can then be discharged to sewer.

Wastes are stored in large tanks and neutralized inside a reaction vessel with neutralizing lime. Such plant is under constant automatic surveillance by temperature and pH sensors and has more in common with modern chemical engineering practice than the crude open air operation described in 3.2.

### 3.6.2 SOLIDIFICATION

Suitably dosed wastes can be mixed with a chemically resistant cement which then reacts to form a hard solid. (83) The proprietors of one patented process claim that the pollutants which are present in solution form a chemical bond with the reactants and the insoluble substances are trapped within the matrix as the mixture sets. A typical plant has storage tanks and bays plus disintegration and reaction vessels which discharge to a weight controlled batching plant. The resulting slurry is pumped to an adjacent lagoon or landfill site and sets in about three days to concrete like consistency.

Wastes consisting entirely of organic waste such as hydro carbon oils, solvents, plastics, etc cannot be solidified, but small percentages of these substances mixed with inorganic wastes are tolerated.

### 3.6.3 WASTE EXCHANGE

Properly segregated wastes can be advertised through the United Kingdom Waste Material Exchange, which enables waste items to be brought to the attention of possible users. A quarterly bulletin divides the available items into categories set out in Table 3.2. Each entry in the bulletin comprises a brief description and the explanation of the frequency and quality of the waste arising. It is not easy to be objective about the financial savings resulting from the service as this information is commercially sensitive. However, a number of reports from companies which have made significant savings are on record. (84)

Table 3.2 - Categories of waste accepted by the Waste Exchange System (49)

| | | | |
|---|---|---|---|
| 1. | Acids and Alkalis | 7. | Minerals |
| 2. | Catalysts | 8. | Miscellaneous |
| 3. | Inorganic chemicals | 9. | Oils and waxes |
| 4. | Organic chemicals and solvents | 10. | Paper and board |
| 5. | Food processing | 11. | Rubber and plastics |
| 6. | Metals | 12. | Textiles and leather |

# CHAPTER 4

# IDENTIFICATION OF HAZARDS AND SITE INVESTIGATIONS

## 4.1 Introduction

The purpose of this chapter is to provide exemplification of the types of hazards encountered and record the impressions formed during the site inspections in an objective manner.

Site visits and a literature search were undertaken as a pre-requisite to the experimental investigations. This enabled a programme to be drawn up of the duties of waste disposal operators. This is reproduced as Table 4.1 and Table 4.2 is a flow chart showing these duties set out on a time scale basis. This demonstrates the sequential relationship between events in the disposal operation.

Use of these charts and a time and motion study produced by a local authority assisted detailed analysis of hazards involved in each event. These analyses have been summarized in the following sections, which correspond with those used in Chapter 3:

4.2 Collection, transport and unloading
4.3 Pre treatment
4.4 Landfill
4.5 Incineration
4.6 Sea dumping
4.7 Other disposal methods

This is followed by a report of the sites visited, a brief comparison of accident records (4.7) and finally a general discussion (4.8).

The case studies which are used to exemplify hazards are referenced when they have been drawn from the literature. Where references are not provided the cases are based on site investigations.

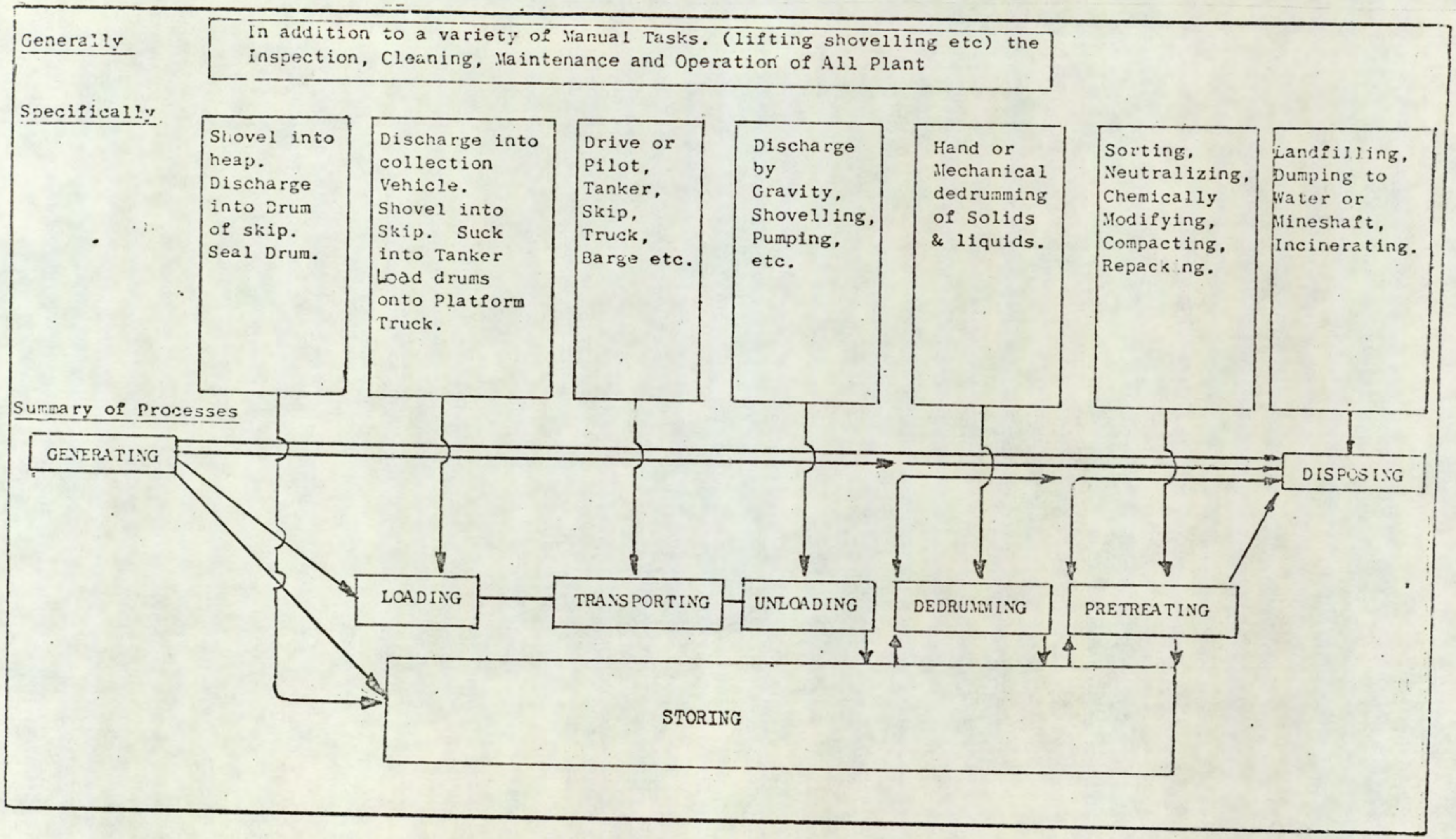


FIGURE 4.1 Operator duties in solid waste disposal

TABLE 4.1

Description and analysis of Toxic Waste Disposal Operator Duties

Loading and unloading
Transporting
Charging and discharging
Chemically Treating
Landfilling
Incinerating
Dumping into water
+ Miscellaneous manual tasks

Analysis of time spent carrying out the following tasks

| Duties | % time spent by operators in the following processes | | |
|---|---|---|---|
| | Landfill | Incineration | Treatment Plant |
| Adding | | 25 | 25 |
| Separating | | 10 | 10 |
| Mixing | 15 | 15 | 15 |
| Crushing and Breaking | 10 | 5 | 8 |
| Compacting | 40 | | 2 |
| Igniting and extinguishing | 2 | 10 | - |
| Excavating | 10 | - | - |
| Covering | 5 | - | - |
| Carrying | 5 | 5 | 5 |
| Unloading, debagging and dedrumming | 3 | 20 | 25 |
| Miscellaneous - tidying etc | 10 | 10 | 10 |

## 4.2 Collection, Transport and Unloading.

### 4.2.1 LIQUIDS

Industrial wastes are amongst the most highly toxic liquids handled by industry (85).

For example, since relatively small quantities of volatile liquids can give rise to unacceptable conditions in an enclosed space, such as a hazardous waste store or a skip bunker, any solid waste worker who enters such a space to remove waste (whether by rolling out drums, introducing a collection hose or digging out) may be exposed to considerable risk. Table 4.2 illustrates the small amounts of various toxic volatile materials needed to exceed the TLV (STEL) in a 38 $m^3$ space, equivalent to that of a store or bunker.

TABLE 4.2

Amounts of liquid needed to exceed TLV(STEL) in a small store assuming complete evaporation and homogenous dispersion (86).

| Substance | Vapour pressure at 25°C (mm Hg) | Threshold Limit Value STEL ppm | Quantity of liquid in ml to give STEL in room of 1000 ft (38 $m^3$) |
|---|---|---|---|
| Acetone | 226 | 1250 | 116 |
| Amyl Acetate | 9 | 150 | 28.5 |
| Benzene | 95 | 10 | 1.2 |
| Bromine | 213 | 0.3 | 0.018 |
| Carbon disulphide | 360 | 30 | 2.1 |
| Carbon tetrachloride | 112 | 20 | 2.4 |
| Diethyl ether | 535 | 500 | 66.3 |
| Ethanol | 50 | 1000 | 74 |
| Ethylene dichloride | 88 | 75 | 7.5 |
| Mercury | 0.0019 | 0.015 | 0.0003 |

In practice the vapour from each of these materials would be denser than air so that, in the absence of extraneous draughts, highest concentrations would be expected at low level.

As demonstrated in 3.2.1, the exhaust from the vacuum pump on a road tanker is contaminated by the waste materials itself and normally discharges close to where the operator must be positioned to control the pump. According to one tanker manufacturer, to reposition the exhaust might introduce the risk of chassis or tank corrosion from any exhausted acids.

Caution is also necessary during loading when the highest vacuum is in use as implosion of the barrel and subsequent rupture can occur if it is not adequately designed, since vacuum relief valves are not commonly provided. Liquids and sludges are discharged either by screw pump or gravity. Pumping is faster but cannot be utilized where the tank has an anti-corrosion lining as the vacuum induced may be sufficient to tear the lining away from the steel tank. Whilst it is possible to obtain an extremely rapid discharge by opening the rear door, this short cut is little used in practice because of the need to first operate the vacuum pump, to hold the door shut whilst the retaining clamps are freed, then release the vacuum whilst keeping well clear of the rear door.

With normal pumped discharge expulsion of the final liquid is followed by a jet of heavily contaminated, compressed air, and this aerosol fog of tank contents may also represent a hazard to the operators.

Liquid drummed wastes pose particular problems. They may need to be manhandled over uneven terrain and due to disrepair, the removal of lids can require excessive force. Alternatively, drums may leak and hence contaminate the operators with their contents. Internal pressure can increase due to physical causes such as deformation of the drum or a significant change in ambient temperature or difference between filling and ambient temperatures and chemical changes such as reactions between the drum and any corrosive contents like a strong acid resulting in gas generation.

Subsequent removal of a bung or even disturbance of the drum may be followed by the forceful ejection of drum contents.

Corrosive materials such as hydrochloric and sulphuric acids, are commonly presented as "spent acids" or "acid tars" and are of the order of 15% (5 molar). Hence the need for caution as, at this strength, such acids are extremely corrosive. In addition to the inhalation, ingestion or skin contact which could be expected to pose problems under some circumstances, the potential for the unexpected presence of a highly dangerous reactant is so large as to give rise to a very significant cause for concern [87, 13].

A number of serious incidents have been reported in which reactions have taken place between the waste being loaded and the existing contents of the tanker barrel. More than one death has been occasioned due to such reactions. One fatality was due to the effects of a violent reaction between wastes which blew the door to a tanker barrel open and struck the driver who was standing close to it.

Apart from violent reactions, admixtures of incompatible chemicals can produce a cloud of attack gas [88]. For example, contact of cyanide solution and an acid produces hydrogen cyanide:

$$2NaCN + H_2SO4 \Rightarrow Na_2SO4 + 2HCN$$

and hypochlorite solution can generate chlorine:

$$4NaClO + 2H_2SO4 \Rightarrow 2Na_2SO4 + 2H_2O + O_2 + Cl_2$$

Table 4.3 exemplifies the toxic gases resulting from the meeting of the incompatible substances listed in the first two columns. The inclusion of the Threshold Limit Values provides some indication of the extent of the risk.

TABLE 4.3

Toxic gases liberated as a result of mixing of certain chemically incompatible substances.(75)

| INCOMPATIBLES | | RESULTING TOXIC GAS | TLV(STEL) or TLV(C) ppm |
|---|---|---|---|
| A | B | | |
| Arsenical Materials | Any reducing agent | Arsine | 0.15 |
| Cyanides | Mineral Acids | Hydrogen Cyanide | 15 |
| Hypochlorites | Acids | Chlorine | 3 |
| Nitrates | Sulphuric Acid | Nitrogen dioxide & Nitrous Fumes | 5 |
| Nitric Acid | Copper, Brass, many heavy metals | | |
| Nitrates | Acids | | |
| Phosphorous | Caustic Alkalies or reducing agents | Phosphine | 1 |
| Selenides | Reducing Agents | Hydrogen Selenide | 0.15 |
| Sulphides | Acids | Hydrogen Sulphide | 15 |

Many factors determine the significance of toxic gas generation when this takes place in the open air (89). The following case studies provide examples with a variety of outcomes.

## CASE STUDY 1 Admixture of Incompatible Wastes due to Spillage

An uncovenanted delivery of tankered plating waste was accepted at a treatment plant without the appropriate notification having been received in advance and on a day which had been assigned for acid deliveries. The tanker driver reported that the waste had arisen as a result of a factory clearance operation and the paperwork indicated that it contained cyanide. It was directed to the appropriate bay where its contents were discharged into the bunded cyanide holding tank. During the pipe uncoupling operation several gallons of waste were spilled on to the yard surface. Several minutes later another tanker was discharging waste phosphoric acid at the same spot and a similar spillage occurred when the delivery hose was uncoupled as illustrated in Figure 4.2. Adjacent to where the spillages were mixing, detector tube readings indicated a level of 5 ppm hydrogen cyanide.

Analysis

The likely course of this reaction is as follows:

$$H_3PO_4 + NaCN \Rightarrow HCN + NaH_2PO_4$$

The acceptance of toxic waste without the requisite statutory notice having been given is illegal. The utilization of the same discharge area for cyanide and acids is bad practice. Enforcement of a different and non-interchangeable pipe end fitting system would lessen the likelihood of even more serious incidents. This site had a regular concreted yard surface with a uniform fall to a drain as figure 4.2 shows. Hence the extent of the problem was less than might have occurred on a site without an impervious yard surface, or one deeply scored with wheel marks where a large pool of the incompatible materials could have formed.

FIGURE 4.2 Discharge pipe connections This shows the drainings from a road tanker being collected subsequent to the dis-connection of the discharge pipeline.

Early in 1975 the driver of a road tanker engaged in discharging toxic waste was fatally gassed on a large landfill site at Pitsea in Essex.

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## CASE STUDY 2 Admixture of Incompatible Toxic Wastes/Faulty System of Work (70)

---

A,the driver of a tanker mistakenly discharged 5 tonnes of waste aluminium sulphide liquor into a soakage pit on the Pitsea site which was reserved for acid wastes. The driver of the next tanker to unload, B, quite properly discharged waste sulphuric acid into the pit; he was subsequently found collapsed in his vehicle cab and was dead on arrival at hospital. Figure 4.3 shows the disposition of the soakage pits and B's tanker.

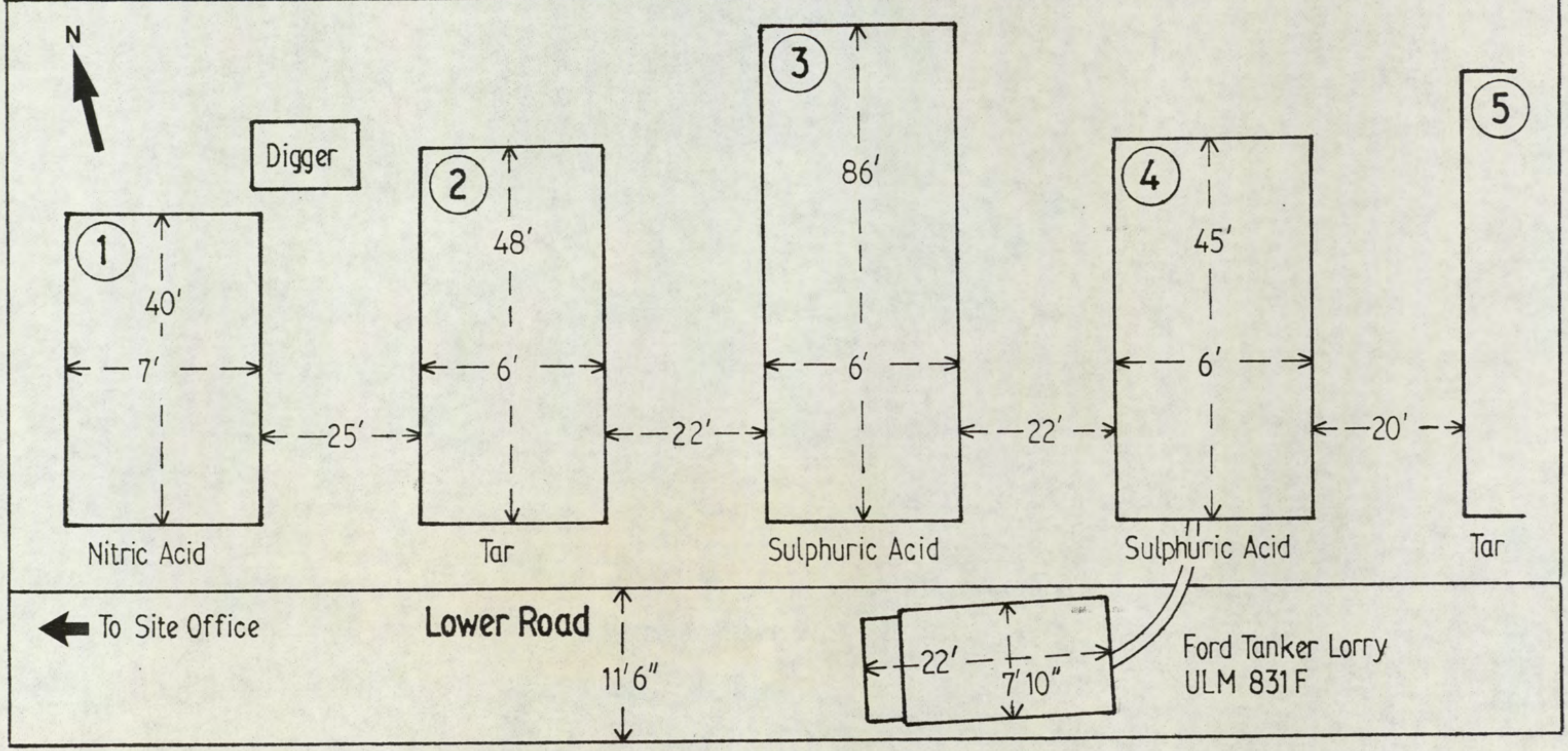
### Analysis

Hydrogen sulphide would have been generated when the two wastes met viz $Al_2S_3 + 3H_2SO_4 \Longrightarrow 3H_2S + 2AlSO_4$. The weather was overcast with slight rain and a light easterly wind; from the relative positions of the vehicle and the pit, this wind would have tended to move the generated gas towards B's tanker. The deceased's movements prior to collapsing are not known but his body was found inside the cab with the doors closed and the window nearest the pit slightly open. The vehicle engine was running.

The TLV(STEL) of hydrogen sulphide is 15 ppm (27 $mg/m^3$). Although the gas has a characteristic, very unpleasant odour with a threshold of less than 1 ppm, olfactory fatigue is rapid and even 10 to 15 ppm is sufficient to inhibit odour sensation completely.(26) Exposure to several hundred to a few thousand ppm results in an increase in frequency of respiration with a decrease in depth of inhalation and after a few breaths, respiration ceases. Collapse either preceeds this stage or immediately follows it. It is significant that hydrogen sulphide exhibits a specific depressant effect on the respiratory process.4 in cases of poisoning heart beats will commonly outlast respiratory movements.(28) The implication that the deceased driver was exposed to a concentration of at least several hundred ppm was borne out by the medical evidence that death followed respiratory arrest although the actual cause was presence of stomach contents in the trachae. (The depression of the respiratory function would presumably also have inhibited the coughing reflex which would normally clear the wind pipe.)

FIGURE 4.3 Disposition of soakage pit and tanker in case study No 2 (90)

| LOCATION OF SCENE | DAY DATE & TIME OF INCIDENT | OFFENCE |
|---|---|---|
| Land Reclamation Company<br>Special Excavation Area<br>Approx. 3/4 mile East of Site Office: Lower Road | Approx. 11·50 am<br>Wednesday 12 March 1975 | Sudden Death:<br>Carroll |



Mixing of the incompatible substances did not apparently result in any risk to the health of driver A. However, the soakage pit was almost empty of acid before the sulphide was mistakenly pumped in. Also, since wastes are innately variable, the residual waste in the soakage pit could have constituted a relatively weak acid incapable of generating a sufficiently large quantity of gas when combined with the uncovenanted load. Furthermore, as driver A left the site immediately and his place was straightaway taken by the deceased's tanker, the time dependant nature of the generation of the gas would work in favour of A and against B, whose load of acid would have accelerated any reaction already taking place.

---

Three years later a somewhat similar set of circumstances occurred in Southern Louisiana, U S A (91). A young driver was fatally poisoned by hydrogen sulphide generated when the waste he was discharging reacted with the contents of an open pit. Subsequent enquiries revealed that the site was one of four being operated illegally and that a permit had been issued for the waste which required disposal in a deep injection well.

---

## CASE STUDY 3 Chlorine Evolution on Landfill Site (18)

A skip vehicle delivered two skips containing drums of waste to a landfill site. One skip was from a school and the other from a chemical works. Both of the skips were tipped to empty and while the bulldozer driver was reversing over the waste he inhaled fumes which made him ill. The foreman and a third man were also affected by fumes. All three were hospitalized and away from work for a week with respiratory congestion.

### Analysis

Investigation revealed that some drums had contained sodium hypochlorite and others acid. The tipping and subsequent crushing had permitted the two to mix. Chlorine gas would be evolved:

$$NaClO + 2HCl \Rightarrow Cl_2 + NaCl + H_2O$$

Chlorine gas has a highly toxic action and has been used as a war gas. Stringent precautions are necessary to prevent the meeting of such incompatible materials and the notification system needs to be rigidly enforced.

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Reactions between chemically incompatible materials, especially liquids, can be speeded up by the agitation which occurs during transit, as the following study demonstrates.

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### CASE STUDY 4 Reactions on Board Waste Tanker During Road Journey.(92)

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A three month old safety tanker built of $\frac{1}{4}$" (6mm) mild steel plate to the latest design was sent to collect a quantity of dilute plating acid waste. In transit, the driver noticed that his safety valve was blowing. He stopped (outside a fire station), summoned help and opened the manual blowdown valve, but could not relieve the exceptionally high presssure in the tank. The fire brigade used water to cool the tank which had become quite hot and eventually the rise in pressure was controlled and the load delivered intact and without spillage. After steam cleaning and inspection the wall of the tank was found to have been heavily attacked by the waste and appreciably reduced in thickness after a few hours exposure.

### Analysis

Examination of the tank contents showed that instead of the dilute dichromate waste listed on the DoPW Act notification a mixture of sulphuric and nitric acids was present with a total acidity of 15 per cent. Further enquiries at the plating company revealed that the mixture had been diluted down to this strength just prior to collection.

The combination of sulphuric and nitric acids is carried out in industry to obtain 'mixed' or nitrating acid. Such a mixture is highly corrosive and its reactivity would have been increased by the elevation of temperature upon dilution. In addition, not only would agitation during the journey have speeded the reaction between the acid and the metal tanker barrel but the reaction is markedly exothermic and also gives off hydrogen. The system of work in operation should have made it impossible for acid of this strength to be collected in a mild steel tanker. For example the storage tank outlet could have been of a specific pattern to prohibit delivery to any tanker other than suitable plastic lined or stainless steel types; a permit system involving a pH check could also have been introduced.

---

### 4.2.2 SOLIDS

Toxic waste containers are rarely designed specifically for that purpose. Drums for example, are frequently reject items unserviceable for further use. The operators task of removing the contents is hampered by the common practice of consigning other items such as scrap metal, broken pallets, etc. along with the waste containers, as figure 4.4 demonstrates.

FIGURE 4.4 Cyanide Waste as delivered to Treatment Plant
This toxic waste described in the manifest as "Sodium Cyanide - hard crystalline material" is grossly contaminated by extraneous objects such as wood, metal and plastic.

CASE STUDY 5 Inadequate Protection from Risk of Cyanosis

Palleted drums of p-toluidine (o-methylaniline) were consigned for processing to a company specializing in the treatment of highly toxic material. They found that the drums were so badly rusted that they could not be de-drummed by conventional methods and hence the contents were dug out by labourers wearing protective clothing who worked under close supervision. At the first sign of cyanosis a worker would be withdrawn from duties and rested.

Analysis

Aniline and many homologues which cause methaemoglobinaemia are easily absorbed through the skin and if airborne are dangerous when inhaled. Although the characteristic blue skin colour will rapidly pass, leaving only a headache, prolonged absorption of small quantities instead of producing cyanosis will result in anaemia (28). Hence the above routine sets a precedent for a dangerous practice on two counts. Firstly, workmen liable to contract cyanosis from this source should be provided with full protection to the skin and respiratory tract. (The penetration powers of this group of substances needs to be allowed for, as a case is recorded of severe cyanosis resulting from contaminated leather shoes (28)). Secondly, it is unacceptable to use the onset of cyanosis as a threshold symptom. A fully mechanised de-drumming routine might have proved a feasible alternative to avoid intimate worker contact with this waste.

---

Hazards in the unpacking of toxic waste from bags, arise from the ease with which dusty materials become airborne and the tendency of bags to burst and spill or disperse their contents.

Finely divided solids which are handled in bulk can give rise to large amounts of airborne dust. For example, when loaded with a mechanical shovel, flue dust can result in large quantities of dust which may contain vanadium, and there is some evidence that polycyclic aromatics may be adsorbed in it. Figure 4.5 demonstrates the intimate contact between workers and waste inherent in some disposal routines. The handling of waste metal finishing and surface treatment salts pose particular problems (93). Of particular concern is the dedrumming of cyanide salts. The implications of hot liquid salts being allowed to solidify inside drums are detailed in 5.1.1.

FIGURE 4.5

Waste Handling. Physical contact with wastes is difficult to avoid in some handling routines such as the cleaning of this hopper which contains residues of silica gel contaminated with arsenic.

In practice operations such as debagging and the opening of drums are often located in the open air to minimize risks to operators. As a result they are sometimes regarded as intrinsically safe from dust and gas hazards. However, experience shows that this provides no guarantee of safety in the case of the emission of attack gases such as hydrogen cyanide or hydrogen sulphide. Concentrations high enough to result in the immediate collapse of workmen have been reported to occur in the open air (74, 28). Kinsey et al have also shown that the threshold limit value for chrysotile asbestos can be reached in the open air during waste disposal operations (22).

In some instances reliance is placed upon the operators sense of smell to give warning of hazardous situations. However, the sense of smell is a notoriously unreliable safeguard against harm from toxic gases. Individual response to smell has a wide variation. Panels of volunteers used to define odour threshold often produce widely varying results. Obviously no protection whatsoever is offered against an odourless toxic substance such as carbon monoxide or mercury and even those operators who do possess a satisfactory sense of smell (and heavy smokers or common cold sufferers for example are often deficient in this respect) are subject to the problems of olfactory fatigue. Furthermore, there are some substances for which the suggested odour threshold is close to or even higher than the TLV(TWA) as shown in Table 4.4

The storage of salvaged articles or 'tot' in driving cabs has given rise to problems and in one case the fumes given off were sufficient to narcotise the driver (96).

TABLE 4.4

TLVs and Odour Detection Threshold Values in ppm

| | TLV (TWA) | Suggested Odour Threshold (95) |
|---|---|---|
| Acrolein | 0.1 | 0.2 |
| Ammonia | 25 | 46.8 |
| Benzene | 10 | 4.7 |
| Carbon Tetrachloride | 10 | 100.0 |
| Chlorine | 1 | 0.3 |
| Hydrogen Chloride | 5 | 10 |
| Tolylene Diisocyanate (C) | 0.02 | 2.1 |
| Trichloroethylene | 100 | 21.4 |
| Sulphur Dioxide | $(2^{\ddagger})$5 | 0.5 |

$^{\ddagger}$proposed ammendment

Transport problems are inherent in the disposal of organic lead waste. The extent of the difficulties in California was so great that toll collectors on a bridge along the route to a reprocessing factory became ill from the vapour escaping from vehicles crossing the bridge (97).

The ultimate disposal of unwanted containers can also give rise to hazards. Metal drums which are unacceptable for reconditioning are commonly flattened before disposal so that they occupy less space during their journey to the final disposal site. Although the flattening operation will often take place in the open air to minimise danger, residues may spill when the old drum is cut or flattened. The danger is increased if an oxy-acetylene flame is used since, depending upon the composition of the residue, heat may rapidly volatilize it and/or decompose it to harmful derivatives and may result in an explosive mixture with the air in the drum. The cutting flame provides an obvious ignition source for any explosion (98).

Few Companies surveyed appear to maintain an accurate inventory of toxic materials used on their premises and only rarely is an attempt made to discover via scrupulous book-keeping of raw material received and goods sold where the materials are disposed of or discharged to. It follows that for waste disposal contractors "one of the biggest problems is the unexpected items which go into industrial waste containers" (99).

The securing of skips containing toxic waste is also such that unauthorized removal might occur. Instances have been disclosed in which items contaminated with mercury and cyanide have disappeared from such skips [100].

In summary, a range of potential hazards arise with manual handling during unloading. Inhalation of dust, fibres, or gases is perhaps the most serious, together with the possibility of skin contact or injection wounds. In the latter case certain routines bring operators into intimate physical contact with wastes and those operators sorting acutely toxic waste contaminated by the presence of extraneous articles such as scrap metal, broken glass etc. are at risk.

## 4.3 Pretreatment

### 4.3.1 NEUTRALISATION

The highly hazardous nature of some wastes present problems in some of the 'detoxification' operations which are utilised to prepare them for subsequent landfill or discharge into water. Table 4.5 summarises the commonest operations in which the chemical combinations are associated with the liberation of hazardous gases.

The death has been reported of a 20 year old workman engaged in stock-piling drums for waste sludge reception near to an industrial waste pond. This man was found collapsed at the wheel of a tractor which he had driven close to the edge of the pond which was in use for treating cyanide-bearing waste from the manufacture of acrylic fibres [101].

TABLE 4.5

Liberation of hazardous gases associated with Selected Pre-treatment Processes (102)

| Process | Associated Problems | Hazardous airborne contaminants liberated (in addition to the principal reagents) | TLV(STEL)/ CV ppm ($mg/m^3$) |
|---|---|---|---|
| Neutralisation of Strong mineral acids from metal finishing trades (sulphide and hypochlorite contamination common) | Fierce reaction Possibility of mixing with water or organic materials | Chlorine<br>Nitrogen dioxide<br>Sulphur dioxide | 3<br>5<br>10 |
| Chlorination/Oxidation of Cyanide wastes from heat treatment plant | Mixing cyanide with acids liberates hydrogen cyanide | Hydrogen cyanide | 15 |
| Separation of oil and water mixtures from engineering and heat raising plant | Emulsion splitting may involve generation of heat, hydrogen and hydrogen sulphide | Hydrogen *<br>Hydrogen sulphide *<br>Phosphine | <br>15<br>1 |
| Detoxification of chromic acid and chromium salts from the plating industry | Use of Sulphite | Sulphur dioxide | 10 |
| Detoxification of by-products from smelting | Water and weak acids liberate attack gas | Arsine<br>Phosphine ▲ | 15<br>1 |
| Treatment of ammonia bearing waste from chemical industry | Liberation of gaseous Ammonia | Ammonium chloride<br>Nitric Acid | (20)<br>4 |
| Removal of sulphides from leather industry waste | Generation of Sulphide gas | Hydrogen sulphide * | 15 |

* Highly flammable ▲ Pyrophoric

Although the principles involved are usually relatively simple, there are sectors of the waste disposal industry lacking the necessary expertise or supervision to guarantee that even straightforward operations such as the neutralization of corrosive waste,will be conducted in a safe manner. This is demonstrated in the following case study.

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## CASE STUDY 6 Nitrogen dioxide evolution (103)

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A demountable tank containing several hundred gallons of waste nitric acid was left at a landfill site which contained an extensive lagoon. An operator was told to connect up pipework so as to drain the acid very slowly over two days into the lagoon. Instead, it was treated as a spent metal finishing acid and discharged in a matter of minutes into a bunded area which already contained a large quantity of such acid. The ensuing reaction resulted in the liberation into the air of a large quantity of nitrogen dioxide. Figure 4.3 illustrates this cloud drifting into the vicinity of adjacent dwellings. Fortunately, no cases of poisoning were reported.

### Analysis

Nitric acid $HNO_3$ is inherently unstable. The reaction

$$2\ HNO_3 \rightleftharpoons 2NO_2 + H_2O + \tfrac{1}{2}\ O_2$$

is promoted by light and catalysts, especially in strong solutions. Reducing agents such as metals and many metal ions will also give rise to oxides of nitrogen, usually nitric oxide NO, sometimes nitrogen dioxide $NO_2$.

$$3\ Fe^{++} + NO_3^{-} + 4H^{+} \rightleftharpoons 3\ Fe^{+++} + NO + 2\ H_2O$$

$$3\ Cu + 8\ HNO_3 \rightleftharpoons 3\ Cu(NO_3)_2 + H_2O + 2\ NO$$

NO is converted to $NO_2$ by air.

Nitrogen dioxide has a characteristic reddish brown hue that varies in intensity with concentration and the length of the light path through which it is viewed. When the thickness of the gas-air mixture is of the order of several metres, as in this case, the concentration must be of the order of hundreds of parts per million for the colour to be seen.

Nitrogen dioxide is capable of inducing a fatal chemical pneumonitis if inhaled at low concentrations (the Ceiling Value is 5 ppm) so that a potentially serious situation was produced by this action. The wisdom of utilizing the 'slow drainage' method of disposal of strong acids on landfill sites is questionable as it is far from easy to guarantee that any site is secure enough to prevent access by trespassers who might interfere with the flow rate.

The large scale operation of crude neutralisation has the potential for also releasing large quantities of strong acids into the air, as given in Table 6.4. A high concentration of hydrogen chloride was reported by the chemist on one of the sites visited and the environs of this site bore evidence of the airborne acid level in that quite new concrete posts and metal fences were heavily corroded on the side which faced the treatment lagoon.

More sophisticated plants where the acids are tanked and the neutralisation takes place inside a reaction vessel, require a correspondingly higher expertise with a laboratory on site to check the composition of wastes as received. Any relaxation of the procedures could result in a highly hazardous situation as exemplified by an incident in which

FIGURE 4.6 Evolution of gas from inadvertent mixing of wastes.
A cloud of nitrogen dioxide liberated during the neutralization of nitric acid at a disposal site drifts in the vicinity of occupied property (103).

a large oil settlement tank 8000 gallons (36,400 litres) split and disgorged its contents over a wide area when it was dosed with several hundred gallons of what had been thought to be spent sulphuric acid. The two operators involved were temporarily overcome in the open by what was probably hydrogen sulphide but after the initial collapse they managed to crawl away to safety.

## 4.4 Landfill

Reference has already been made in chapter 1 to the work of the author in respect of operator hazards during toxic waste disposal on landfill sites. This is summarised in appendices IV and V. The following key issues were identified as of paramount importance to the landfill operations:

1. Deficiencies in training systems.
2. Lack of competent supervision, and prevalence of 'single-handed' working.
3. Deficiencies in personal protective equipment and emergency equipment.
4. Insufficient use of mechanical handling systems to minimize contact between operator and waste.
5. Inadequate site checks on waste as deposited, and the tendency for uncovenanted deposits to be made.
6. Inadequate restrictions on access of the public and totters to the tipping areas.
7. The prevalence of fires in deposited waste.

Serious potential operator hazards existed on many of the landfill sites visited. These hazards stemmed from the nature of the operation and the dangerous materials handled, but were compounded by lack of supervision and ignorance on the part of the operators. As waste disposal was found to be largely regarded as a low priority, low cost exercise, specialized facilities for coping with emergencies on site were rare.

The following case studies illustrate the inadequacy of on site checks referred to in 5 above. Relevant case studies are also set out in 4.2 & 4.3 including examples of fatalities resulting from unsafe systems of work.

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## CASE STUDY 7 Problem due to Airborne Sodium Carbonate

On a landfill site a machine operator who had the task of bulldozing 25 tonnes a day of sodium carbonate found it was necessary to wrap a wet towel around his face in order to lessen the discomfort which followed the inhalation of the airborne material resulting from the operation.

### Analysis

Sodium carbonate is a strong base which upsets the pH balance of mucous membranes in the respiratory tract, and induces marked discomfort. The problem could have been obviated by consigning the material via the Waste Exchange to a Company that needed an alkali for neutralizing acids. Alternatively, it should have been tipped at the bottom of the advancing tip face where bulldozing would have been unnecessary.

---

## CASE STUDY 8 Uncovenanted Consignment of Acid

A skip load of general waste from a port was delivered to a local authority landfill site which had no facilities for handling highly toxic waste. It was subsequently proved to contain a 40 gallon drum of concentrated hydrochloric acid. During the landfill operation the drum which was being crushed by a compactor machine split open and splashed an operator with acid, resulting in the need for hospital treatment.

### Analysis

Although the consigner of the acid was never traced, it presumably originated from the cargo of a vessel using the port. The inclusion of such material without notification contravenes the Deposit of Poisonous Waste Act and random checks on waste as delivered to sites would help to discourage such practice. The HASAW Act requirement for the employer to take all reasonably practicable steps to safeguard employees is difficult to comply with in such a situation where the likelihood of such an occurrence is so difficult to quantify.

## CASE STUDY 9 Inadequate Identification of Toxic Waste

A small chemical company in the West Country consigned a quantity of drums described as "washed carboys" to a local landfill site. The driver who delivered them was questioned by the bulldozer operator on the site because the drums were giving off fumes. The operator was assured that the contents were harmless, but chose to check with his employers, the District Council, who received assurances that the carboys were washed before disposal. The same evening the bulldozer operator contacted the emergency services from home who visited the tip and quickly ascertained that the drums still contained appreciable quantities of concentrated mineral acids.

### Analysis

The fact that no one was injured in this incident does not lessen its importance, and the consigners left themselves open to prosecution under the D.PW Act. The District Council should have provided facilities to check the material on site - litmus paper would have sufficed in this instance.

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The unwarranted assumption that landfill is an acceptable disposal method for even the most toxic of wastes has led in the past to some very highly toxic substances being disposed of in this way. The following case study provides one example in relation to dioxin (TCDD - 2, 3, 7, 8 - tetrachlorodibenzodioxin).

## CASE STUDY 10 Disposal of Dioxin on Landfill Site (105)

A serious explosion on a chemical plant in Derbyshire led to the dumping on a nearby landfill site of the remains of the whole plant consisting of rubble and scrap contaminated with dioxin. No record is apparently available of the precise location of the disposal spot within the site.

## Analysis

Because of this incident of the deposit occurred six years before the introduction of the DoPWA Act 1972, notification was not a legal requirement. However, due to the extremely high toxicity potential of dioxin the disposal personnel would appear to have been at some risk during the operation. Uncertainty over the location of the residues within the landfill site limits its future use. It is being argued that the site needs to be permanently 'sterilized' as unacceptable hazards would be created if, for example, excavations for foundations were ever made into the deposited material.

---

The report of the Mines and Quarries Inspectorate for 1974 refers to landfill sites as "new entrants" and after drawing attention to three accidental deaths and five serious injuries in the twelve months, stresses the problem of gas generation from the mixing of incompatible chemicals. The reaction of acid liquors on alkali earths is specifically mentioned with the warning that the resultant gases will escape at breaks in the cover and concentrated emissions can form a long term hazard.
Open burning is officially discouraged on landfill sites (81), but fires are not uncommon on poorly managed sites for the following reasons. Material which arrives on site may be already burning or at a very high temperature. Boiler ashes and residues from the burning of factory waste are examples; slag from metal refining may arrive at such a high temperature that it will readily ignite other material.

The activities of totters, whether or not they are officially recognised, and trespassers may also cause ignition. Fires are lit to burn insulation off cables, melt non ferrous metals, or just to provide warmth. Furthermore, sites which are unable to deny access to children with matches have problems unless the covering of deposits is rigorously enforced.

Spontaneous combustion due to heat release from uncompacted and unsealed organic refuse which is decomposing, is a possibility, as is ignition from cigarette ends carelessly discarded.

Finally, pyrophoric material (which should not be accepted on landfill sites) could escape detection on a badly organised site. For example, phosphorus has caused tip fires.
Figure 4.7 illustrates the effect of a large scale fire on a landfill site.

FIGURE 4.7 Effects of accidental fire
The products of pyrolysis and incomplete combustion from burning rubber extend to a height of more than 100 m above a small landfill site.

### 4.4.2 MINESHAFT DISPOSAL

Mineshafts are mainly used for the disposal of concentrated mineral acids. Hence operator hazards at mineshaft disposal sites tend to be those in handling operations, such as splashes causing skin burns, plus the potential danger posed by the nature of the reactions proceeding underground.

Classical mining accidents, such as injuries resulting from rock falls, are not encountered because there is no access by workmen to the actual shafts.

However, unexpected reactions have occurred in mineshafts. One serious explosion at a deep mine was caused by methane displaced during the filling operation (107). The explosion vented via the main shaft displaced the roof of a building which enclosed the head of the shaft but did not result in any injuries.

## 4.5 Incineration

Most types of used,or waste,lubricants can be used as fuel but unless the exact nature of the oil is known it is extremely unwise to attempt to use it as a fuel. In many locations the "used oil" tank is used as a general deposition for liquid wastes and it is very common to find used lube oils contaminated with very low flash point or . non-flammable solvents e.g. chlorinated hydrocarbons or other chemicals. Attempts to burn these mixtures in conventional heating apparatus can produce a high risk of explosion or the production of noxious corrosive or poisonous fumes (104).

The earliest incinerators were not generally provided with any flue gas cleaning plant. Hence, if the chimney was at inadequate height the tail gases constituted a potential source of nuisance or hazard. However, the provisions of the Alkali Amendment Act of 1961 brought several operations under the control of the Alkali Inspectorate including the incineration of waste materials. Much more attention is paid to minimizing operator hazards on the latest generation of purpose built incinerators than on earlier multi purpose plant and hence these two classes will be examined separately.

### 4.5.1 PURPOSE BUILT INCINERATORS

Although such incineration plant has some potential for posing a variety of problems for the operator, in a properly designed incinerator the combustion process itself should not be a source of risk unless the physical integrity of the incinerator is threatened by the uncovenanted presence of hazardous (eg explosive) items. Moreover, the retention time within the combustion chamber, coupled with the gas cleaning system and height of the chimney, should ensure that the combustion products present little risk to site personnel. However, serious explosions have occurred in such incinerators.(104) One advantage of the large size of the latest generation of municipal incinerators is that they can absorb the effects of relatively minor explosions, albeit at the expense of a subsequent shut down and partial rebuild of the damaged refractories and grate.

Because solid waste is a heterogeneous material, few automated feeding systems have proved commercially viable. Thus, whilst liquid waste can be pumped directly to the burners, the hazards attendant upon the charging of solid waste into the incinerator appear to be an area of pressing concern. For example, the loading of large waste plastic foam blocks into one such incinerator is achieved using a fork lift truck to grasp the block and push it through the feed aperture as shown in Figure 4.8. However, the radiant heat from the combustion chamber is sufficiently intense to ignite the foam whilst it is still outside the furnace and the resulting products of combustion and pyrolysis pose a potentially severe hazard to the personnel engaged in the operation,

The following case study illustrates the problems presented by a purpose built incinerator.

FIGURE 4.8 Incineration of Solid Waste

Large, multi purpose incinerator being charged with waste plastic foam by means of a fork lift truck. The radiant heat has ignited the foam before it is inside the grate.

### CASE STUDY 11 Fire in Bag Filter House (47)

A rotary kiln furnace was designed by a small contractor to burn alkyl leaded sludge residues consigned from a refinery where several large petrol storage tanks were located. The sludge was shovelled into a small sloping kiln which was fired by waste hydrocarbons. Chimney emissions were minimized by a bag filter fitted at the base of the stack. After a number of months operation, a serious fire originated in the residues retained in the bag filter house and produced an air pollution episode. An extensive shut down and rebuilding operation was necessitated.

Analysis

This incident illustrates the difficulties posed during the design of incinerators by the inate variability of waste. Constraints are imposed which make it exceedingly difficult to correctly specify the design parameters for any incinerators and these difficulties are most apparent on small incinerators where the feed rate is low. In addition, the inability to obtain economies of scale may result in recourse to primitive feeding methods, such as the manual shovelling of leaded sludge.

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### 4.5.2 MULTI PURPOSE INCINERATORS

Plant which has not been purpose designed for dealing with toxic waste but adapted from existing plant such as an obsolete steam raising boiler, may be expected to pose some special problems for workmen. In such circumstances the characteristics of the plant are less likely to have been rigorously examined by a competent design engineer; instead the operation may be proceeding on a trial and error basis with significant on-site adjustments such as ( e.g. with liquid waste)burner pressure and flow rate, being made by personnel possibly unfamiliar with the underlying design theory.

The absence of rigorous analysis of the possible combinations of fuel characteristics may result, for example, in direct flame impingement on the refractory lining of the combustion space which could pose a threat to the integrity of the plant as a whole. Also, the likelihood of emissions of toxic materials from the chimney is increased by trial and error experiments with combustion conditions.

The following case study refers to problems consequent upon the use of plant not specifically designed for the operation in question.

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### CASE STUDY 12 Hazard from Incineration of Plastic

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A Lancashire boiler was converted to serve as an incinerator for plastic sheathed copper cable. The significantly different combustion characteristics of bituminous coal and the plastic resulted in incomplete oxidation and the resulting airborne products of combustion and breakdown products of the plastic constituted a hazard both on the site and in adjacent properties depending upon the wind direction.

Analysis

Incomplete combustion of a typical hydrocarbon plastic can evolve large quantities of carbon as smoke. The generation of Hydrochloric Acid from chlorine containing plastic is illustrated in Case Study 15.

The swift cooling effect on the flue gases imposed by the tortuous path which they take in such a boiler imposes a requirement for either a support fuel or a checkerwork of refractories to ensure complete combustion. In addition, some form of flue gas scrubbing is needed to remove the toxic products of incomplete combustion.

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## 4.6 Sea Dumping

The hazards attendant upon sea dumping commence at the preparation stage. The waste must eventually sink, not to just below the surface, but to a safe depth at which it is no hazard to shipping. This preparation may include the use of a standard drum such as is specified by the disposal company in the case of cyanide waste with the proviso that the drum must be over a specific density. In other cases the waste may require repacking by a specialist company, perhaps in concrete, or in a manner approved by the Ministry who licence the dumping.

Whilst the use of specific drums may have only a marginal effect on operator hazards - in that in the case of cyanide it discourages the use of an automated system whereby molten salts are ladled directly into a skip- if the Ministry requirement includes the provision of corrodible caps on drummed liquid wastes (so that the contents will be released at a known rate) then operators have to replace the mild steel caps with aluminium caps at the dockside just before the disposal vessel sails.

Should the drum contain a corrosive material then splashing due to over pressure following, for example, hydrogen generation could be a problem. Furthermore, the repacking of other wastes in concrete obviously introduces extra handling and hence increases the possible hazard to operators, especially when de-drumming is called for.

### 4.5.1 DUMPING FROM DECKS OR HOLDS

In view of the expense involved in charting vessels to reach the deep sea disposal points, reliance is placed on vessels engaged in other work, and the hazardous wastes are carried as deck cargo. The dumping operation consists of three distinct parts. Firstly, the vessel is slowed down, secondly the securing ropes are removed from the drums, and finally in an operation which may involve some risk to the safety of the entire vessel, the Captain keels the vessel over by undertaking a sharp turn. This manoeuvre results in the drums being catapulted into the sea. Such vessels may sail irrespective of whether, or not, conditions are favourable for the waste disposal operations. If the weather in the authorized dumping area is so unfavourable that the Captain deems it inadvisable to attempt the operation then the vessel steams out of the first dropping zone and hopefully is able to unload in the second. However, it is not unknown for a ship to complete a crossing with its load still present on deck. The deroping operation is very hazardous in bad weather conditions and the manual repacking of any drums burst by heavy seas also presents problems.

In the case of dumping in shallow waters, e.g. 50 miles off shore, vessels are generally chartered specifically and fewer operator hazards should be presented. In practice, however, extra difficulties can arise because the waste may not have been drummed. Loose material (such as soil contaminated with a few ppm of highly toxic waste) can become airborne during the operation of loading and unloading the ships hold. Moreover, the increased availability of dockside cranes means that most vessels are no longer equipped to discharge their own cargo. Hence a jury rigged hydraulic shovel may have to be fitted for this purpose rather than a purpose-designed arrangement.

### 4.6.2 DISCHARGE FROM TANKERS

The dumping of a liquid waste presents relatively few difficulties if it can be simply discharged below the waterline using the vessels own pumps. However, liquid/liquid reactions are likely to be more violent than liquid/solid ones and because of the extensive capacity of the tanks on board a typical ship the possibility of incompatible wastes mixing may be higher. Moreover, the agitation during the sea passage will increase the rate of any undesirable reaction. Clearly the implications of any resulting emergency are related to the close confines of a ship at sea. However, the large size of the tanks should increase the ability to withstand the effects of a relatively small quantity of incompatible waste.

The practice of neutralizing strong acids aboard the tanker to minimize corrosion of the mild steel tanks results in the need for operators to regularly enter empty tanks to manually remove the resulting salts. This operation clearly requires careful supervision and stringent safety precautions e.g. a permit to work system (108).

## 4.7 Other disposal methods

Processes outlined in 3.3.6, e.g. solidification and chemical oxidation, carry a much more onerous requirement for quality control of incoming wastes than crude dumping and operators are often in much closer physical proximity to the wastes during processing. Accordingly, the potential for harm caused by the presence of uncovenanted material is higher, as the following case study demonstrates.

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### CASE STUDY 13 Hazards Caused by the Presence of Uncovenanted Material.

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At one treatment plant, the outlet to the batching device which dispensed weighed quantities of neutralized waste into a mixing unit became blocked. This was not an uncommon occurrence and a workman was detailed to enter the hopper and free the obstruction with hand tools. Whilst digging away the waste he became aware of an unfamiliar smell followed by a tightness in his chest. He retreated to the open air where he was seized by a paroxism of coughing; his discomfort increased and he was hospitalized. He subsequently made a full recovery.

Analysis

Attempts to identify the substance were unsuccessful; there were no constituents entered in the manifesto accompanying the wastes which could have produced such symptoms. The Plant Manager presumed that the material was an organic solvent or isocyanate, neither of which should have been accepted on the site. More rigorous controls on the intake of waste to the plant would have minimised the likelihood of this incident. However, the problem of the uncovenanted arrival of a highly toxic component is a sufficiently common feature of the waste disposal industry to warrant special steps being taken to lessen the probability of harm resulting. In this case the unblocking of the hopper should be achieved by mechanical means which do not involve the entry of an operator.

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In addition, the relatively sophisticated plant needed to treat toxic waste by such methods is much more difficult to maintain, especially in view of the heterogenous nature of the incoming waste. Problems due to high wear on components are common. Flexible hoses for example can suffer because of the high content of foreign objects in the waste.

The Key Committee identified the danger that an excessively expensive waste disposal system would motivate certain sectors of industry to dispose of their wastes in an irresponsible manner (5).

The following case study illustrates the potential for harm presented by the unauthorized disposal of one waste chemical intermediary.

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## CASE STUDY 14 Poisoning Caused by Improper Disposal of Waste Containing Dioxin (109)

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Toxic illness of varying degress affected ten persons in Missouri USA in 1971. The most seriously ill was a young girl who suffered kidney and bladder damage requiring hospitalization and surgery through contact with soil containing traces of dioxin (TCDD - 2, 3, 7, 8 8 - tetra-chlorodibenzodioxin). Several thousand gallons of waste oil sprayed on 3 horse arenas and a farm road was subsequently proved to have contained about 300 ppm dioxin. The economic damages (deaths of 63 horses, loss of trade etc) have been extensive.

### Analysis

The highly toxic properties of the dioxin containing residues from the manufacture of the herbicide 2, 4, 5 - trichlorophenoxyacetic acid were fully appreciated by the Company which accumulated them. However, contractors, who were paid several thousand dollars to incinerate it safely, eventually subcontracted disposal to a small company who specialized in spraying farm roads and horse arenas.

The absence of "mens rea" (guilty intent) does not lessen the significance of this incident, it confirms that some sectors of industry are currently handling very toxic waste, with an extremely high potential for harm if it is not disposed of in a responsible manner. The "dilute and disperse" method is inappropriate for wastes which are still highly active when present at the level of a few parts per millions in soil. It may be that consideration should be given to a licensing system requiring companies to demonstrate that they possess the necessary expertise or resources to safely dispose of such waste before being allowed to generate it.

Figure 4.9 illustrates unauthorized disposal of liquid waste on a landfill site by means of opening rear valve of tanker whilst traversing the tip roadway.

FIGURE 4.9 Unauthorized Routines

Lack of competent supervision permits toxic waste to be used as a means of laying dust on a tip roadway.

## 4.8 Site Visits

### 4.8.1 SELECTION CRITERIA FOR PROCESSES AND SITES VISITED

This study was necessarily limited in its coverage of different types of process; there was also a degree of arbitrariness in the selection of locations. However, an attempt was made to visit a cross section of processes, representing both differing techniques and differing levels of technical expertize. Also the locations were chosen to avoid giving preference to one area of the country. To complement this, representative visits were made to waste producers. Table 4.6A provides a key to the activities and size of undertakings visited.

TABLE 4.6A

KEYS TO ACTIVITIES AND SIZE OF UNDERTAKINGS VISITED DURING EVALUATION STUDY

| KEY TO ACTIVITIES | |
|---|---|
| Activity | Company |
| Generate | |
| Store | A B C |
| Load | D E F |
| Transport | |
| Unload | G H I |
| Dedrum | U K |
| Landfill | (H G U<br>(L O R<br>(P S J |
| Incinerate | (H I A<br>(G P Q |
| Dump into Water<br>(via sewer or ship) | E<br>(D M E<br>(O Q I |
| Deepwell Injection | U |
| Recycle | I N H T |
| Encapsulate )<br>Other Physical )<br>Chemical methods) | K U T |

| KEY TO SIZE* FOR THE PURPOSES OF TABLE 4.6B | |
|---|---|
| Classification | Number of Employees |
| Large | More than 100 |
| Medium | 10 - 100 |
| Small | Below 10 |

*Number of employees was felt to be more relevant for the purposes of this study than total throughput, although an increase in mechanical handling could be associated with increased output.

The processes chosen were representative of the disposal methods in 3.2.2. - 3.2.5 but selection was constrained by the reluctance of some managements to allow research to be undertaken on their premises. This occasionally prevented development of the experimental programme to its logical conclusion, or even precluded work on a promising line of enquiry. For example, during a process to render drummed waste from a de-arsenication process suitable for sea disposal, the bungs on the polythene lined steel drums containing the arsenic trisulphide in hydrochloric acid are replaced by an aluminium cap which corrodes in the sea water and releases the contents. This re-capping process which is carried out at the docks could entail some risk, even though it takes place in the open air. However, permission could not be obtained to monitor operations. Similarly, permission was refused to investigate the incineration of waste oil and solvents in an obsolete steam raising plant originally constructed for the gas tar industry.

The choice of locations provided a geographic spread centred on the industrial Midlands extending to Lancashire in the North West, Wales and Somerset in the South West, Essex in the South East and Peterborough in the East Midlands. The extent of the coverage obtained is shown in Table 4.6B. The groups correspond with the classification used earlier in this chapter.

### 4.8.2 VALIDITY OF RESULTS

The constraints imposed as a result of this study being undertaken on a part-time basis meant that visits to such a large number of premises took much longer to accomplish than desirable. Furthermore it was necessary to have carried out the visits to the waste producers and a selection of disposal companies before an operational plan for the research could be produced so that some time elapsed between some of the visits and the analysis. However, regular contact was maintained with a nucleus of companies and telephone enquiries were made to check the veracity of crucial points relating to the others.

TABLE 4.6B

Key to type, size and location of companies visited during evaluation study.

| CODE LETTER | TYPE | SIZE | LOCATION |
|---|---|---|---|
| A | Drum reconditioner | Small | S.W. |
| B | Motor Vehicle component manufacturer | Large | West Midlands |
| C | General Engineering | Large | Wales |
| D | International Chemical Mfg. Co. | Large | N.W. |
| E | Higher Education Establishment | Large | S.W. |
| F | International Chemical Mfg. Co. | Medium | S.E. |
| G | County Council | Large | N.W. |
| H | Waste Disposal Contractor | Large | S.E. |
| I | Chemical Waste Disposal Contractors | Large | Wales |
| J | Waste Disposal Contractor | Small | West Midlands |
| K | Chemical Waste Disposal Contractors | Small | West Midlands |
| L | Waste Disposal Contractor | Small | S.W. |
| M | International Chemical Mfg. Co. | Large | West Midlands |
| N | Chemical Waste Disposal Contractor | Small | N. Midlands |
| O | Waste Disposal Contractor | Medium | N.W. |
| P | County Council | Large | S.W. |
| Q | Waste Disposal Contractor | Medium | S.W. |
| R | Cement Works incinerating waste | Medium | S.W. |
| S | Waste Disposal Contractor | Medium | S. Midlands |
| T | Waste Disposal Contractor | Small | E. Midlands |
| U | Waste Disposal Contractor | Medium | West Midlands |

Whilst it is not suggested that this inspection scoring system would have general applicability if it was used to draw comparisons between inspections administered by different individuals, it was felt that someone with extensive experience in making inspections under the Factories Act and allied legislation had the ability to produce an objective comparison of the standard which was achieved at a number of sites.

Hence the results of the survey are considered to be suitably representative to allow valid generalizations to be made about the extent of the hazards and specific conclusions to be offered on the differences found between landfill sites and treatment centres.

### 4.8.3 EVALUATION OF SITES IN THE STUDY

To allow evaluation of the results of the inspections, 22 key issues were identified, systematically set out and given an importance rating. Tables 4.7A and B specify the target standards which were deemed to be achievable under each of the 22 headings and identify the chosen significance rating for each item.

To permit quantification, a weighted scoring system as set out in Table4.8 was derived to coincide with the three identified levels of importance.

The weighted scoring system was then analysed and a guided interview sheet produced so that standard questions were asked on the inspections. A copy of the document is reproduced as Appendix XII.

In general, co-operation was forthcoming from two classes of management, those who recognised that they had problems on the operator hazard front and also those who were in large measure ignorant of the extent of the hazards which were present. Those who refused co-operation tended to be aware of the problems but dissatisfied with their own solutions. It is felt that visits have been paid to premises which represent points right across the spectrum of technical competence. Despite some companies refusing to co-operate and allow full inspections, visits and other enquiries have revealed that conditions at such sites appear to be no more hazardous than those at the sites which were surveyed.

TABLE 4.7 Target Standard for Site Management with Significance Rating (Part I)

1. Working Plan — Rating: Primary Importance

The existence of a working plan with full details of safety precautions produced by a competent authority, such as consultant or in-house specialist.

2. Efficacy of Supervision — Rating: Primary Importance

Constant presence of sufficient numbers of properly qualified supervisors.

3. Training of Work Force — Rating: Primary Importance

Appropriate training provided for all workmen. No new recruits allowed to commence work without suitable induction.

4. Employment of Safety Officer and Site Chemist — Rating: Primary Importance

The services of a qualified occupational safety and hygiene professional, available on a regular basis and a qualified chemist retained on site to oversee the disposal process check the composition of waste arriving for disposal.

5. Availability of Full Operating Manual — Rating: Primary Importance

Fully detailed operating manual available to all workmen written in suitable language.

6. Compositional Check on Offered Waste — Rating: Primary Importance

All waste analysed before a contract to dispose is agreed and a decision made as to its acceptability by a competent authority.

7. Veracity Check on Deposited Waste — Rating: Secondary Importance

The composition of all loads checked on arrival at site by personnel other than chemists and detained for verification if necessary.

8. Full Protective Clothing — Rating: Secondary Importance

A complete range of protection available viz boots, overalls, gloves, face shield, hard hat etc.

9. Monitoring — Rating: Secondary Importance

Periodic samples taken of the atmosphere on site to check for hazards such as toxic or flammable substances.

10. Intersite Communication — Rating: Secondary Importance

The presence of appropriate means of communication such as telephone or radio to facilitate relaying instructions and warnings.

11. Site Security — Rating: Secondary Importance

Full security both in and outside working hours to prevent unauthorised access to site.

TABLE 4.7

Target Standards for Site Management with Significance Rating (Part II)

12 Ablutions — Rating: Secondary Importance

Adequate washing facilities with hot and cold water supply and means of hand drying.

13 Water Supply — Rating: Secondary Importance

Adequate piped supply of clean and wholesome water for drinking purposes.

14 Absence of Totters — Rating: Secondary Importance

Total lack of any salvaging or resaleable items from amongst the waste, whether by workmen or third parties.

15 Satisfactory Eating Arrangements — Rating: Secondary Importance

Suitable facilities for the taking of drinks and meals properly located with respect to the clean and dirty sides of the process.

16 Regular Medicals and Occupational Health Services — Rating: Secondary Importance

Adequate arrangements for occupational health monitoring, including routine blood samples if appropriate plus the services of an occupational medical officer or nurse.

17 Emergency Decontamination — Rating: Tertiary Importance

Adequate frost and vandal proof decontamination facilities including eye wash bottles or jets.

18 Breathing Apparatus for Emergencies — Rating: Tertiary Importance

Sufficient fully self contained breathing apparatus sets for rescue in confined spaces, fires etc.

19 Drills and Liaison with Emergency Services — Rating: Tertiary Importance

Regular simulation of drill for dealing with emergency such as fire or serious accident. Proper liaison with emergency services so that full understanding of the extent of the hazard is obtained.

20 Fire Fighting Equipment — Rating: Tertiary Importance

Satisfactory facilities including provision of the necessary extinguishers, hose pipes etc.

21 First Aid, Oxygen, Antidotes etc. — Rating: Tertiary Importance

Adequate arrangements for first aid on site including a fully stocked first aid outfit, stretcher, oxygen bottle and mask and appropriate antidotes for highly toxic materials.

22 Reporting of Accidents — Rating: Tertiary Importance

Fully operational system for recording significant accidents and near misses on site.

It was felt that in the special circumstances which obtain in toxic waste management some significant distinction was necessary between these companies which purposely planned and improved their operations and those undertakings where even if the reality of control existed in a limited sense, this was not due to realization on the part of management but rather the fortuitous result of the individual enthusiasm of a site foreman or perhaps even the district HMFI.

Hence the first 6 items which related to this issue earned twice the score of the secondary safety items. The tertiary safety items scored at a level half that of the secondary items, because whilst their existence may well have limited the severity of any incident in terms of human suffering, they are not truly preventative in nature.

TABLE 4.8.

SCORING SYSTEM FOR IMPORTANCE OF TARGET STANDARDS

| Rating | Topic | Score | % of total |
|---|---|---|---|
| A. Primary importance | Planning and supervision of operations. | 6 items scoring 20 each | 48 |
| B. Secondary importance | Operational procedures and site conditions relative to operational safety | 10 items scoring 10 each | 40 |
| C. Tertiary importance | Operational procedures and site conditions relative to emergencies. | 6 items scoring 5 each | 12 |

### 4.8.3 Results

In table 4.9. the sites were set out in order of the inspection date with a numerical expression of their rating in each of the 22 categories. Comparison of the face value of the raw scores demonstrates that sites visited late in the study scored more highly than those visited early. This is borne out by comparing the totals of sites 2 and 12 which are in fact the same site visited at a two year interval during which period the site had been closed due to the service of a prohibition notice by HMFI and then reorganized and re-opened under new management. Of course, the crude score on its own fails to reflect the differing nature of the sites - landfill for example poses a different set of problems for the workman to those presented by an incinerator or a treatment complex. Hence, in table 4.10. the sites have been arranged in two groups: landfill

TABLE 4.9

Rating scores
on sites in
order of
inspection date

| Standard Number | | Max Score | Site Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | ) | 20 | 5 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 15 | 15 | 20 | 10 |
| 2 | ) | | 5 | 2 | 0 | 5 | 10 | 8 | 10 | 15 | 15 | 10 | 15 | 18 |
| 3 | ) | | 0 | 0 | 0 | 5 | 10 | 10 | 5 | 10 | 10 | 5 | 8 | 5 |
| 4 | ) | | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 12 | 8 | 10 | 10 | 18 |
| 5 | ) | | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 16 | 10 | 20 | 4 |
| 6 | ) | | 16 | 10 | 10 | 20 | 20 | 20 | 20 | 20 | 10 | 20 | 20 | 20 |
| 7 | ) | 10 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 8 | 1 | 8 | 10 | 2 |
| 8 | ) | | 5 | 2 | 6 | 2 | 4 | 8 | 6 | 8 | 8 | 6 | 8 | 8 |
| 9 | ) | | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 2 | 2 | 0 | 5 | 5 |
| 10 | ) | | 0 | 0 | 0 | 10 | 10 | 10 | 8 | 10 | 5 | 10 | 10 | 5 |
| 11 | ) | | 1 | 0 | 2 | 3 | 3 | 5 | 2 | 5 | 1 | 5 | 5 | 6 |
| 12 | ) | | 6 | 2 | 2 | 6 | 10 | 8 | 4 | 8 | 4 | 8 | 8 | 0 |
| 13 | ) | | 10 | 0 | 0 | 10 | 10 | 10 | 0 | 10 | 0 | 10 | 10 | 0 |
| 14 | ) | | 0 | 0 | 6 | 10 | 10 | 10 | 8 | 0 | 10 | 10 | 10 | 10 |
| 15 | ) | | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 6 | 0 | 0 | 10 | 0 |
| 16 | ) | | 0 | 0 | 0 | 0 | 2 | 0 | 4 | 6 | 6 | 4 | 8 | 4 |
| 17 | ) | 5 | 0 | 1 | 0 | 0 | 3 | 4 | 2 | 4 | 0 | 0 | 2 | 0 |
| 18 | ) | | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 4 | 0 | 2 | 4 | 3 |
| 19 | ) | | 1 | 0 | 1 | 2 | 2 | 2 | 3 | 5 | 4 | 2 | 5 | 4 |
| 20 | ) | | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 5 | 1 | 5 | 5 | 1 |
| 21 | ) | | 2 | 2 | 0 | 1 | 3 | 2 | 3 | 4 | 1 | 4 | 4 | 2 |
| 22 | ) | | 2 | 0 | 0 | 2 | 5 | 2 | 2 | 4 | 5 | 4 | 5 | 5 |
| Raw Total | | 250 | 55 | 20 | 33 | 84 | 137 | 123 | 104 | 151 | 122 | 148 | 203 | 130 |

TABLE 4.10

Numerical Assessment and final loaded scores of sites (higher final score equates with safer conditions).

| | TYPE OF SITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. LANDFILL | | | | | | 2. INCINERATORS & CHEMICAL TREATMENT | | | | | |
| | Time | | | | | | Time | | | | | |
| A. Site Number (Table 4.9) | 1 | 2 | 3 | 7 | 9 | 12 | 4 | 5 | 6 | 8 | 10 | 11 |
| B. Company key letter (Table 4.6) | H1 | J | L | H2 | G | U2 | T | K1 | U2 | I | Q | K2 |
| C. Crude Score | 55 | 20 | 33 | 104 | 122 | 130 | 84 | 137 | 123 | 151 | 148 | 202 |
| Overall rank | 3 | 1 | 2 | 5 | 6 | 9 | 4 | 8 | 7 | 11 | 10 | 12 |
| Ranking within group | 3 | 1 | 2 | 4 | 5 | 6 | 1 | 3 | 2 | 5 | 4 | 6 |
| D. Correction Factor: | | | | | | | | | | | | |
| <u>% toxic</u> <u>Factor</u> | | | | | | | | | | | | |
| 1 - 25 4 | 3.0 | 3.0 | 4.0 | 3.0 | 4.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 26 - 50 3 | | | | | | | | | | | | |
| 51 - 75 2 | | | | | | | | | | | | |
| 76 - 100 1 | | | | | | | | | | | | |
| E. Final loaded score (CxD) | 165 | 60 | 132 | 312 | 488 | 260 | 168 | 137 | 123 | 151 | 148 | 202 |
| Overall corrected rank | 7 | 1 | 3 | 11 | 12 | 10 | 8 | 4 | 2 | 6 | 5 | 9 |
| Ranking within group | 3 | 1 | 2 | 5 | 6 | 4 | 5 | 2 | 1 | 4 | 3 | 6 |

and others. This shows that the improvement with time is more apparent within the two groups and demonstrates the wider spread of the landfill group scores. The ratio of best to worst being 6.5 to 1 compared with only 2.4 to 1 for the other sites.

Finally, a multiplier was applied as set out in column D to adjust the crude score so that it reflected the proportion of toxic waste to other wastes disposed of at the site. This served to investigate the suggestion that the existence of an inverse relation between frequency of exposure to hazards and the extent of the care displayed by workers would affect the results. Comparison of the ranking of these loaded scores with the crude totals does not reveal that this correction would significantly alter the conclusions within the two groups because in only two cases was the rank order altered by more than one place and 4 of the rank orders were identical when scored by either method. This indicated that within the groups the rank order correlation was not very sensitive. However comparison of the overall crude and corrected scores does demonstrate a significant change. In only one case (the worst site) was the rank order identical and the mean variation from the uncorrected ranking was 3.5 places. Hence the suggestion made above would seem to be borne out by these conclusions. when the best to worst ratios are compared for the loaded scores these are found to have widened in the case of landfill to 9.4 and diminished to 1.5 for the other sites.

The site visit analysis demonstrated the lack of attention evident on many sites to the formal planning of safe working conditions. Although several very good scores were recorded, four sites were assessed at less than 20% of their optimum capability. Similar deficiencies were apparent in respect of primary safety items whereas there was a greater uniformity of provision of secondary items such as fire extinguishers.

## CONCLUSIONS

The results allow a distinction to be drawn between the level of hazard found at landfill sites and other types of treatment plants. On the basis of the crude total score landfill sites gave the greatest cause for concern on the chosen parameters, and whilst loading for the percentage of toxic waste handled produced no change in this tendency, it did alter the relationships within the groups. At face value it is felt that this modified score more accurately reflects the subjective impressions formed during the inspections.

### 4.8.5 COMPARISON OF ACCIDENT RECORDS

In order to investigate further the conclusion reached in 4.8.4 that significant differences exist between the level of hazard at landfill and other treatment sites, analyses were made of accident records from a small landfill site and a medium sized treatment plant. As these were both operated by the same company and located close together, the differences were thought to be real rather than a function of differences in reporting.

A direct comparison would have been valueless because of the difference in the numbers of persons employed and an accident frequency rate comparison would not have taken into account the differing level of risk. Hence comparison was effected by grouping accidents on each site into severe, or potentially severe and others. The basis of the distinction was the seriousness of the accident or its potential for harm and Table 4.11 demonstrates a cross section of the type of accidents classified into the first category. In cases of doubt over classification, additional information was obtained from the respective site supervisors. A comparison of the ratio of severe or potentially severe accidents to all accidents revealed that the treatment site ratio was 1:2 whereas the landfill site ratio was 1:3.

These findings agree with the results of the hazard rating inspections reported in 4.8.4 which show a significant difference between the scores of landfill and other treatment sites. Table 4.11 also permits the conclusion to be drawn that workers on the treatment site come into more intimate contact with the waste than the machinery operators on landfill sites, although the single handed unloading of a dangerous liquid at the tip face does possess the potential for a very severe incident and the unstructured nature of the tipping operation results in a greater proportion of simple slips and falls due to the untidy conditions.

TABLE 4.11

Severe or potentially severe accidents in a twelve month period at a treatment plant.

| | |
|---|---|
| 1. | Cut finger while discharging cyanide from container. |
| 2. | Burnt hands when contaminated gloves were mistakenly worn. |
| 3. | Cut arm on cyanide drum. |
| 4. | Eye contamination from toxic dust. |
| 5. | Burns to chest whilst emptying acid carboy. |
| 6. | Corrosive burns whilst charging caustic into sump. |
| 7. | Splash in eye with caustic liquid. |
| 8. | Injured foot on projecting nail in toxic waste skip. |
| 9. | Splashed with corrosive liquid whilst debagging waste. |
| 10. | Coughing attack triggered by fume inhalation whilst clearing hopper. |
| 11. | Splashed with corrosive liquid whilst moving drum. |
| 12. | Cut finger with glass contaminated by mercury. |

## 4.9 General Discussion of Hazards and Site Visits

Methods of collection can involve operators coming into intimate contact with the wastes. The use of the skip container has improved the lot of certain drivers but liquid waste collection presents problems, notably inhalation of toxic fumes exhausted from the tanker barrel during vacuum loading. The practice of combining part loads to avoid uneconomic journeys obviously increases the chances of inadvertent mixing of chemically - incompatible substances.

The likelihood of skin contact with toxic material is increased if hand debagging or dedrumming is practised.

Certain pretreatment routines give cause for concern, especially those where other wastes are used for neutralization or similar purposes. However, chemical expertise is often available on such plants thereby lessening the likelihood of gross errors.

Landfill of toxic waste poses a high risk potential which is usually compounded by the remote location of the operation and a corresponding paucity of secondary safety features. Whilst locating the operation in the open air maximises the benefits of natural dispersion of toxic substances, gases given off during reactions which are occasionally violent between incompatible wastes, can pose severe problems. Moreover, the vagaries of the British climate must be contended with and the continuance of operations during the hours of darkness is an additional factor in winter months. The lack of easy access can also make the task of the emergency services more difficult and finally, the absence of security fencing on some sites can increase the problems caused by vandals and totters, including the lighting of fires.

Incineration of waste involves operators coming into close contact with waste during the firing process and hence presents an increased potential for harm over crude dumping. This is especially true if the waste handling aspects of the incinerator design are somewhat rudimentary, as is the case on several designs. Control over the quality of feedstock is vital and it is questionable whether industry is sufficiently well motivated to be able to offer adequate guarantees as to the precise composition of its flammable waste arisings.

The hazards of sea disposal are those associated with conventional marine operations, plus any additional hazards associated with the particular operation. These include de-roping of drums on decks in inclement weather, the digging-out of salts precipitated within storage tanks and recapping or repacking wastes before disposal.

Other disposal methods generally carry an onerous quality control requirement to ensure that unwanted or dangerous reactions do not occur. The accidental polymerization of a waste had, for example, necessitated shut down and digging out on one plant.

Analysis of the site visit record demonstrates that the question of quality control of incoming waste did not, in practice, command a high priority, despite the references to this problem in some literature (15, 16, 26, 27, 104).

Both the Key Committee (5) and the Royal Commission Reports (1) concentrated on the environmental pollution aspects of toxic waste disposal and made very few references to operator hazards.

The new media regularly suggest that toxic waste disposal in the UK is unsatisfactory and poses environmental hazards (110-115). The impression is that, although there have been some improvements, much remains to be achieved. The site visits produced clear evidence of the existence of hazards for the work force and some evidence of an improvement in conditions during the period of the survey. It was noticeable that the emphasis on environmental protection had, in some cases, resulted in increased hazards to operators.
Indeed, codes of practice commonly encouraged management to view environmental protection as their principal aim with little, if any, emphasis being given to the protection of the operator.

Accordingly, it was decided that this matter warranted further attention. This is described in Chapter 5 which also applies quantitative risk criteria to the operation of a toxic waste disposal facility.

# CHAPTER 5

# CODES OF PRACTICE, SAFETY TRAINING AND HAZARD ANALYSIS

## 5.1 Analysis of Codes of Practice

Toxic waste disposal operations require the establishment, and enforcement, of a proper method of working. It is part of an employer's common law duty to ensure that such systems of work are provided and maintained. Therefore it is necessary to foresee the hazards that can arise in any waste disposal operation and to devise a safe system which will prevent injury or loss.

A System of Work should include:

A Selection and supervision of personnel

B training and instruction of the work-force

C planning and co-ordination of all activities, in particular those involving collaboration between sections

D provision of operating instructions and procedures. These must cover start-up, shut-down, steady-state operation, and procedures for dealing with various breakdowns or emergencies.

E Procedures for inspection, testing, maintenance and where necessary replacement of equipment.

F Maintenance of satisfactory general conditions of work e.g. specification of periodicity of clear-up operations, responsibility for good housekeeping, site tidyness etc.

In the U.K. this is also a statutory duty under S.2 of the Health and Safety at Work Act, 1974. In fact some work routines are closely prescribed by legislation e.g.eye protection regulations made under the Factories Act, 1961. However the Robens Report on Health and Safety at Work (116) argued that in unstructured areas where the framing of effective statutory regulations had proved difficult, codes of practice had been found to be highly effective.

The aims, purposes and structure of these Codes may differ according to the requirements of the situation and to whom the information is directed. (117)

In its simplest form a Code of Practice may be a few pages containing simple advice. (118) Alternatively, it may contain detailed information to enable decisions to be made on the installation and maintenance of plant and the provision of a safe working environment. (119) For waste disposal operations these should be a recognised safe working procedure for each task to eliminate the risk of an unexpected emission, or to minimize the hazard of any emission. Safe working procedures should be based upon the most effective method of carrying out the work but with operator safety as the pre-eminent criterion. For example, the possibility of a health hazard from dispersing dust, gas or vapour clouds, or the existence of sheltered zones adjacent to obstructions wherein these may accumulate are important factors to be considered in formulating safe working procedures for outdoor situations.

Whilst there is no strict legal obligation to abide by the advice contained in a Code of Practice, any infringement of a Code approved by the Health and Safety Commission may, by virtue of Section 17 of the Health and Safety at Work Act, be used as evidence in a prosecution taken under that Act. Currently none of the waste disposal codes have been approved by the commission and, on present evidence there is little likelihood of such approval in the near future.

At the commencement of this study, few codes of practice existed with respect to toxic waste disposal; a working party set up to produce a general code for all wastes commenced late in 1971 (120). The major concern in the early 1970s was environmental pollution and this code was produced in a provisional form with ambitious proposals for the marking of wastes but few references to operator hazards.

The need for a specific code for landfill operations dealing with operator hazards was identified by the author in 1975(13). Several private companies and at least one trade association had produced their own codes by 1975 but these generally related to one group of wastes. An example is the code for asbestos waste produced by the Asbestosis Research Council (121) in 1973.

Since 1975 several other codes have been produced, notably by the Department of the Environment's Working Group on Waste Disposal legislation who have produced several different codes for various hazardous wastes (a selection of which are reviewed in Section 5.1) and the National Association of Waste Disposal Contractors (77).

It is significant that the latest codes contain many more references to operator hazards. Although a direct comparison is difficult, the National Association Waste Disposal Companies publication which has virtually the same number of pages although rather less text, than the I. Chem. E. Code contains roughly four times as many specific references to operator hazards. Even so, operator hazards are still dealt with cursorily in some cases and significant omissions occur. For example, the problem of gas generations from the mixing of incompatible chemicals, now specifically mentioned in the 1978 Mines and Quarries Inspectorate Report (106), is not referred to at all in either

the I. Chem. E. or N.A.W.D.C. codes.
It is not possible to be certain of the reasons why the Health and Safety Executive have not identified toxic waste disposal as an area needing concerted action to produce an authorative code of practice which stresses operator protection. It can be argued that such emphasis on safety in waste disposal might conflict with industry's need for inexpensive waste disposal facilities. Alternatively it might be feared that such a code would hinder the satisfactory achievement of safety performance by industry as a whole & foster unsafe disposal practices by certain companies in their attempts to avoid higher disposal charges levied by contractors.

Sections 5.1.1 to 5.1.7 are drawn from a representative cross section of sources and exemplify the lack of emphasis on operator protection apparent in many codes of practice.

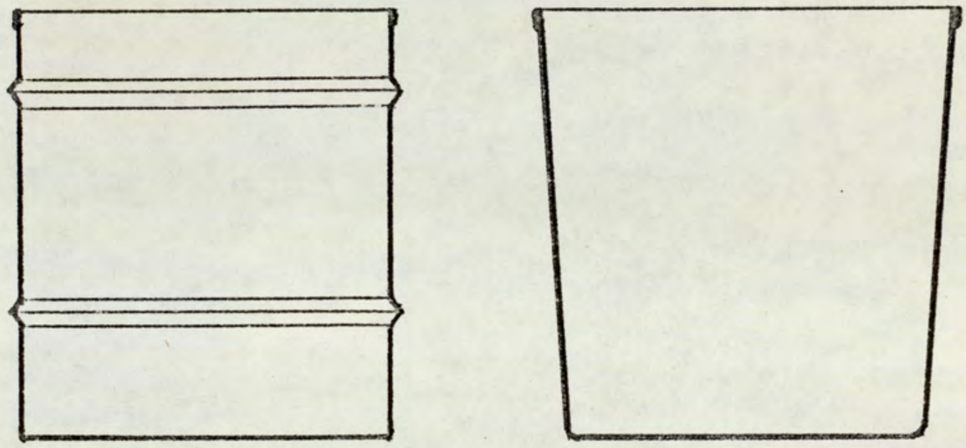
Table 5.1 is a brief analysis for comparative purposes of the salient points from selected codes.

### 5.1.1 Cyanide Wastes

Waste Management Paper No 8 (93) deals with the disposal of heat-treatment cyanide wastes. Although it includes a code of practice, little attention is paid to operator hazards. Reference is made in the memorandum to the Safety Health and Welfare Cautionary Notice on Cyanide Poisoning (12 ) but as that guidance is for the benefit of the worker engaged in traditional handling methods it makes no mention of the specific hazards of waste disposal such as danger of puncture wounds from cyanide contaminated scrap or from the sharp edges of the metal drum during emptying.

For example, the usual trade practice of accumulating molten cyanide from spent salt baths in mild steel drums is described. The drums which are used for this purpose are traditionally the same ones in which the cyanide was delivered. (In fact a major producer operates a sea dumping service and insists upon the use of these drums (122)). The code reproduces a concentration standard deemed as acceptable for landfill purposes which ranges from 1-100 $g/m^3$ of cyanide within a landfill site. As each drum contains about 50 kg of spent (i.e. 15% concentration) cyanide salts, it is clearly necessary to de-drum the waste so as to dilute it to an acceptable level. In any event, de-drumming is necessary for all of the other treatment methods with the exception of sea dumping. In practice de-drumming is a difficult operation to undertake safely as the drums used to contain the salt are parallel sided and provided with

two circumferential reinforcing bulges as shown in Fig. 5.1. Because the molten salt solidifies inside the drum it cannot be removed by conventional methods and the drum has to be cut open. Various drum opening techniques including the use of axes are used as demonstrated in Fig. 3.10 and Figure 2 in Appendix III respectively.
The use of a tapered drum as at B in Fig. 5.1 would facilitate the removal of solidified salts, albeit at a slightly increased drum cost (necessitated by the absence of reinforcing bulges). As alternatives mechanized drum emptying is technically feasible, or all the waste could be dumped at sea thereby obviating the need for any de-drumming operations.



A) Section through drum presently in use with reinforcing circumferential bulges.

B) Section through suggested drum tapered to facilitate removal of contents.

FIG. 5.1 Configuration of drums used for return of spent cyanide salts (not to scale).

The code of practice might usefully have drawn attention to the hazards presented by chronic exposure of operators to cyanide even at levels below the TLV (TWA) (123).

### 5.1.2. Halogenated hydrocarbon solvent wastes

Waste Management Paper No 9 (125) deals with halogenated hydrocarbon wastes from cleaning processes and Chapter 6 refers to landfill disposal. The discharge of metal cleaning wastes should be undertaken with care due to the anaesthetic and toxic nature of the solvent vapour. Waste should normally be deposited at the foot of the working face not less than two metres from the flanks. At least two persons should be present

during the discharge of a tanker and should be positioned upwind of the discharge and well away from the tanker.
The usefulness of the initial warning is somewhat diminished by the reassuring nature of the reference to operators being positioned upwind and well away. This advice is also badly worded; a literal interpretation would involve the excavation of a 2m deep hole where the working face advances over the existing surface. The waste should in fact be deposited at the foot of the face and be so covered as to be left a minimum of 2m from the nearest surface. What distance constitutes upwind of the discharge is not qualified; since it is unrealistic to expect workmen to control discharge valves, start and stop an engine etc. if they are in fact any appreciable distance away from the tanker this will tend in fact to be no more than a few metres. Such a small distance may prove to be inadequate when strong insolation is causing upwind diffusion. Finally, the suggestion that tankers should be positioned at the foot of a working face, which will be a minimum average of two metres in height and sometimes much higher, could prove hazardous as the solvent vapour is much more likely to be pocketed due to turbulence in the space between the tanker and the face and result in high local concentrations, than if the tanker was positioned at the top of the face and discharging the waste over it. Difficulty in obtaining access to the foot of the face means that tankers normally would discharge over the advancing face notwithstanding the greater hazard of reversing over the edge of the tip.

### 5.1.3. Offensive Trade Wastes

Waste Management Paper No 17 (126) deals with wastes from tanning, leather dressing and fellmongering. It urges a policy of 'dilute and disperse' for such wastes and suggests within any landfill site strict segregation from other industrial wastes including acids capable either of solubilising chromium compounds present, or reacting with residual sulphides to liberate hydrogen sulphide. A part of the site not used for other industrial waste, and where there is no risk of acidic leachate reaching the disposal area, should be employed. However, no reference is made to the dangers inherent in the assumption that general factory waste or even domestic waste, will not on occasions be acidic enough to generate troublesome quantities of hydrogen sulphide in contact with sulphide bearing waste. The inherent variability of wastes and the widespread use of strong acids for purposes such as cleaning (127) make it inadvisable to rely upon any guarantees about the freedom of almost any waste from the possibility of the presence of a significant quantity of acid.

### 5.1.4. Fine Chemical Waste

Waste Management Paper No 19 (128) provides guidance with respect to wastes from the manufacture of pharmaceuticals, toiletries and cosmetics. The approach is not consistent with other Waste Management Papers since, although specific advice is given on disposal methods, including landfill, operator safety considerations are not detailed. Instead, reference is made to the National Assocation of Waste Disposal Contractors code of practice ( 77 ) which is discussed in 5.1.7.

Paragraph 5.8.1 of Waste Management Paper No 19 contains a statement which might lead to a misguided sense of complacency on the part of any waste disposal contractor who heeds the advice that 'reject finished products and returned goods may be considered non-hazardous in terms of flammability, reaction with water, self reaction, corrosiveness to skin or eyes or the production of hazardous vapours'. Although the memorandum goes on to contrast the problem presented by wastes from primary manufacture by organic synthesis which are acknowledged to present the potential for a 'considerable short-term handling hazard' insufficient weight is given to the problems posed by the rejects and returns. A separate Government Report (5) has drawn attention to some dangers posed by such wastes. Animal health products,which are conventionally sold in a much more concentrated form,may particularly offend in this respect although certain pharmaceutical preparations, for example linaments may be both flammable and exceedingly irritating to the eyes, as is shown in Table 5.1 which gives the contents of Sloan's linament as listed by the manufacturer on a bottle label.

TABLE 5.1

Active Constituents of Sloan's linament (vv) (129)

Ol. Pini Aromat. 6.74%, Methyl, Salicyl. 2.66%
Ol. Terebinth 48.50% Ol. Camph. 3.35%
Oleores, Capsic 0.72%

Table 5.1 reveals that the principal constituent of this linament is 'Ol. Terebinth' (turpentine), a substance rated in Sax (27) as having a high toxic hazard rating via the inhalation route, with a TLV(STEL) of 150 ppm and the potential for causing serious eye and kidney irritation.

### 5.1.5 Asbestos Waste

A revised code of practice was prescribed in 1973 for the handling and disposal of asbestos waste material (121). Operator hazards do receive some consideration, for example it warns that approved respirators and suitable protective clothing must be worn when changing bags on a dust collector. However, no advice is given on whether or not respiratory protection is advisable during actual disposal operations.

A preliminary study of the level of asbestos fibres during disposal operations on landfill sites (22) reproduced as Appendix V demonstrated that concentrations can reach the TLV (TWA) in the open air.

The reference to accidental spillage should have included a direct warning of the need to consider breathing protection for operators engaged in any cleaning up operations, and the necessity for a high standard of cleanliness inside vehicle and tip machinery cabs should have been stressed. This latter point is especially relevant to bulldozer cabs which are often fitted with air heaters of the recirculating pattern, hence providing a dusty micro environment for the disposal operator.

The advice that, after use, all vehicles and containers should be cleared of loose fibre or dusty by "vacuum cleaning or other dustless method" fails to recognize the virtual absence of any such facilities at most landfill sites.

No specific mention is made of operator protection during this recommended operation, and it is unlikely that battery power could provide the necessary level of vacuum cleaning performance. Hence the outcome of this operation could be a decrease in the general environmental level of asbestos, but an increased exposure to the operators.

### 5.1.6 Landfill Operations

One example of a sound manual produced by a company for its own waste disposal operations is provided by the I.C.I. manual of guidance for the safe disposal of wastes on land (130).

This points out that segregation of incompatible wastes is vital, because wastes, which are in themselves relatively innocuous, may on mixing cause additonal problems. It emphasises that the location of wastes within the tip site needs careful consideration, and provides several examples such as oxidising agents not being allowed to mix with flammable materials, and pyrophoric materials such as used catalysts, which have not been adequately stabilised by oxidation before discharge. Reference is also made to finely divided metals, e.g. aluminium, and residues which might contain traces of alkali metals, e.g. sodium, or other materials which can react violently with water and/or air e.g. aluminium alkyl compounds or lime present similar problems of location on disposal, because of their tendency to ignite or cause high temperatures. Further specific examples include residues containing an unsaturated ketone which must not be mixed with wastes containing sulphides or sulphide precursors, because of the probability of the production of a persistent, strong and unpleasant odour e.g. 'cat smell'.

Advice is given on the deposition of flammable solvents on inert parts of the tip although incineration is referred to as the preferred disposal method for such wastes.
The manual underlines the need to warn the tip operator of all such hazards and to provide advice on the degree of segregation needed, bearing in mind the inadvisability, in the event of fire, of having a large concentration of any one particular type of material in a particular area of the tip. The keeping of adequate records of the location of material is thus seen as essential.
This code identifies fires as a very significant hazard for operators and recommends strict precautions to minimize this risk. It insists that emergency action must be instituted immediately upon the discovery of any fire in, or on, tipped waste.

### 5.1.7 N.A.W.D.C.

This code provides, in outline form, the operation standard to be achieved by members of the National Association of Waste Disposal Contractors (77). The review of legislative standards is weighted in favour of environmental protection and road traffic legislation with a total of 53 entries, against solely the Health and Safety at Work Act under the "Acts affecting the safety and welfare of the public and employees". The Factories Act 1961 for example is not even listed.
In certain areas the code goes into fine detail with provisions such as the requirement for the use of tarpaulins to prevent waste being blown off vehicles transporting waste. However, the approach is not consistent. For example no advice is tendered on the emergency equipment to be carried on such vehicles or practical problems of carrying loose drums in large skips with doors which have to be subsequently opened. There is also a very significant omission from the landfill site guidance with respect to the presence of totters, whose activities can be highly

disruptive of good discipline. Guidance is not issued on the problem of providing a safe system of work for the single-handed bulldozer operator working on a remote tip face.
The code can be criticized for failing to require the production of detailed operating manuals to encourage a safe system of work and for not emphasing the "permit to work" approach which is necessary in certain operations such as road tanker barrel entry.

### 5.1.8 Comment

In the absence of uniformity of presentation between the codes a valid comparison is difficult. However, certain tentative observations are offered as follows.

Environmental considerations, rather than operator welfare implications dominated the texts. Table 5.2 demonstrates that the ratio of numbers of measures to protect the environment, compared with measures to protect the operator, ranged from 1.2X, to 3X as many with a mean of 2.1X. Several of the procedures, designed to safeguard the environment, could result in increased risks for the operators. The 'dilution' of spent cyanide salts to a level acceptable for landfill provides one example. Authoritative guidance on the appropriate overall strategy was absent. The need to structure routines so as to avoid obvious operator hazards was not stressed and although details were sometimes quoted for specific routines, this advice was not provided as exemplification of an overall safe system of work but on a somewhat ad hoc basis.

The comprehensive approach which characterises authorative codes was absent. Many pressing issues such as the control of totting on landfill sites, the prevention of contamination of food, tobacco and personal supplies of drink, and the achievement of safe sampling of hazardous loads did not receive a mention. An unfavourable comparison can be drawn with the extensive detail provided on precautions in the lead industry by the HSE Guidance Note (130) (which was produced as a code of practice until 1976 when it was renamed to avoid confusion over its approved or non-approved status).

TABLE 5.2 - Summary of a representative cross section of codes of practice.

| TITLE | PRODUCED BY:- DATE | APPROX. NO. OF WORDS |  | DIAGRAMS | TABLES | RATIO OF ENVIRONMENTAL TO OCCUPATIONAL PROTECTION MEASURES | COMMENT |
|---|---|---|---|---|---|---|---|
|  |  | TOTAL DOCUMENT | OPERATIONAL CODE |  |  |  |  |
| Disposal of heat treatment cyanide and related wastes. | Department of the Environment<br>1976 | 2000 | 500 | Nil | Nil | 2 : 1 | Claims to be a code of practice but does not provide details of dispersal procedures at operational level. Emphasis is on environmental impact. |
| Manual of guidance for the safe disposal of waste on land. | Imperial Chemical Industries<br>1972 | 5000 | 750 | Nil | Nil | 2.5 : 1 | Claims not to be a code of practice but provides details of landfill operations and some practical advice. |
| A Provisional Code of Practice for Disposal of Wastes | Institution of Chemical Engineers<br>1971 | 7400 | 2400 | One | Two | 3 : 1 | Detailed code, with emphasis on legal approach. No practical operational details of safe disposal. |
| NAWDC Code of Practice | National Association of Waste Disposal Contractors<br>1976 | 3000 | 2000 | One | One | 1.2 : 1 | Comprehensive listing of legal provisions - biassed towards environmental protection. Some practical details are provided but important omissions occur. |
| Recommended Code of Practice for the Handling and Disposal of Asbestos Waste Material | Asbestosis Research Council<br>1973 | 3000 | 1100 | Nil | Nil | 2 : 1 | Emphasis on environmental Implications. Operator protection is not stressed. |

A valid defence against a charge of failing to comply with Section 2 of HASAW Act is the demonstration that the provision of any higher standard was not reasonably practical. The overall emphasis on environmental protection measures and lack of comprehensive operator protection detail in these codes might prove to be highly significant if such codes were produced as evidence in the court proceedings.

## 5.2 Analysis of Safety Training Systems in use

The training provided for solid waste workers prior to the commencement of the Health and Safety at Work Act 1974 was surveyed in a previous study (13). For the sample investigated 4% had attended an appropriate training course, 37% had been given rudimentary instructions in handling toxic waste and the remaining 59% had received no formal instruction whatsoever. As the provisions of Section 2 of the Act now make it an offence not to provide such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of all employees, it was decided to concentrate upon the training offered by a representative selection of companies. The following sample compares six training programmes offered during the period of the survey by the following companies:

(A) A large manufacturer of chemicals.
(B) A medium sized transport company who provide a service for the transportation of toxic waste.
(C) A small specialist company who provide training for transport drivers who handle toxic substances (not specifically wastes).
(D) A large contracting firm who dispose of toxic waste produced by other companies.
(E) A medium sized firm who dispose of toxic waste produced by other companies.
(F) A small firm who dispose of toxic waste produced by other companies.

TABLE 5.3

Comparison of six representative training programmes for toxic waste disposal operators

| Comparison ↓ | Company → | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 1. | Exclusive attendance at Training Centre? | No | No | Yes | No | No | No |
| 2. | Exclusive "On the job" instruction? | No | Yes | No | No | Yes | Yes |
| 3. | Combination of 1 & 2? | Yes | No | No | Yes | No | No |
| 4. | Duration and Mode of attendance at course (if any) | One $\frac{1}{2}$ day for 6 wks | Nothing formal | 1 Week full-time | 1 $\frac{1}{2}$-day for 2 wks | Nothing formal | Nothing formal |
| 5. | Taught by: | | | | | | |
| 5.1 | Specialist Training Officer | Yes in part | No | Yes | No | No | No |
| 5.2 | Supervisor with other responsibilities | No | Yes in part | No | Yes in part | Yes | Yes |
| 6. | Methods used: | | | | | | |
| 6.1 | Formal Lectures | Yes | No | Yes | Yes | No | No |
| 6.2 | Hand-outs | Yes | Yes | Yes | Yes | No | No |
| 6.3 | Demonstrations | Yes | Yes | Yes | Yes | Yes | Yes |
| 7. | Form of assessment: | Informal Continuous assessment | None | Formal Written examination | None | None | None |
| 8. | Extent of emphasis on the special problems of waste | Slight | Slight | None | Slight | Slight | Extensive |

COMMENT

None of the courses provided satisfactory instruction within the meaning of Section 2 of the HASAW Act for workers in the toxic waste disposal industry. Courses A and C were the nearest to the standard required in the HASAW Act but neither provided sufficient emphasis on the special problems posed by waste such as its variability of composition, possible absence of labelling and specific tank cleaning requirements.

Examples were encountered of the under-emphasis of dangers e.g. the 'in house' course provided by the large chemical company sought to put the problems experienced with the company's products into perspective by drawing comparisons with dangers inherent in substances encountered in everyday life, such as aspirin. This could leave employees with an underestimation of the dangers involved. It also suggested the use of cannister respirators for a driver when trapped in the cab of a tanker as a result of an accident. This was justified as follows: "Self contained breathing apparatus requires a lot of equipment weighing about 45 lb and only an experienced man can by himself fit and control such equipment. We don't want to fit you out for a moon walk!" In fact, one of the substances regularly handled has a TLV(STEL) of 0·3 mg/m$^3$ which puts it in the extremely toxic class and self contained respiratory protection would be a vital requirement for effective operation in the event of an emergency not the least reason being that the emergency services could tend to base their own protective measures on that seen to be provided for the driver.

The syllabuses which were in use should have been written in behavioural objective terms - so that instead of just listing topics such as "breathing apparatus, its use and maintenance", specific goals should have been stated. In this example it might be "Drivers shall be capable of:

(a) Selecting the correct respiratory protection to provide adequate protection for an appropriate time against the toxic substances likely to be encountered.

(b) Donning the respiratory protection unaided under all conditions (including darkness).

(c) Carrying out a representative variety of tasks wearing appropriate protection within the time for which respiratory protection is provided.

(d) Cleaning and maintaining the respiratory protective equipment in proper order."

Parallels have been drawn between certain waste disposal operations and the construction industry (46) and the construction site supervisor does have some duties resembling those of a landfill site supervisor.

Research has been undertaken into the safety training needs of the former group (131) which shows that these needs are inextricably bound up with the total management of the site. No evidence was discovered that any waste disposal company had actively undertaken research to discover safety training needs of their workforce, or whether these needs vary from one site to another.

## 5.3 The application of Quantitative Risk Criteria to Toxic Waste Disposal Operations

Ideally this study of operator hazards should include accident frequency rates related to the number of workers at risk in toxic waste disposal and a comparison of these with other industries with similar patterns of employment. It has already been demonstrated that no official figures exist for toxic waste disposal. However, it has been argued that UK solid waste workers in general suffer from a serious accident frequency rate that is several times greater than the expectation of the average UK worker (46). For example, figures have been produced relating to refuse collectors in one city for the 12 months up to June 1976 of 19 'serious' injuries (i.e. lost time injuries with an average of 15 days absence each) from a workforce of 130 (132). This gives a serious accident frequency rate of 146 per 1000 compared with the national average incidence which is less than 10 per 1000 (133).

The International Labour Organisation has drawn attention to the problem faced by solid waste workers and the World Health Organisation pointed out in 1971 that their accident rate is one of the highest for any industry (134). A survey published in 1969 suggested that the USA solid waste workers' injury records tops all others in the country (135). A report on the health of sanitation workers in New York (136) found that these workers who included solid waste operators, had an extremely high injury frequency rate, exceeding that of all other occupations previously studied except logging and it was suggested that refuse collectors suffered worse occupational hazards than any other public workers.

In comparative studies between industries, the fatal accident frequency rate (FAFR) has its uses (137). This figure expresses the number of fatalities occurring in $10^8$ working hours (and also the deaths from industrial injury in a group of 1000 men during their working lives). The overall FAFR for UK industry covered by the Factories Act is 4, which encompasses a range from 0.15 to 67 as shown in table 5.4. (138)

TABLE 5.4

Fatal Accident Frequency Rates for Various Occupations and Activities

| | |
|---|---|
| British Industry (i.e. all premises covered by the Factories Act) | 4 |
| Chemical Industry | 5 |
| Clothing and footwear | 0.15 |
| Vehicles | 1.3 |
| Timber, furniture etc | 3 |
| Metal manufacture, shipbuilding | 8 |
| Agriculture | 10 |
| Coal mining | 40 |
| Railway shunters | 45 |
| Construction erectors | 67 |
| Staying at home (men 16-65) | 1 |
| Travelling by train | 5 |
| Travelling by car | 57 |

To provide grounds for a comparison between deaths from industrial disease and those due to industrial accidents, table 5.5 gives a representative cross section of FAFR's from the former cause.

TABLE 5.5

Estimated Rates of Fatality (or incidence of Disease) attributed to Types of Chemical or Physical Exposure(139)

| Occupation | Cause of Fatality | FAFR |
|---|---|---|
| Shoe industry (press and finishing rooms) | Nasal cancer | 6.5 |
| Printing trade workers | Cancer of the lung and bronchus | 10. |
| Workers with cutting oils | Cancer of the scrotum | |
| Birmingham | | 3. |
| Arve (France) | | 20. |
| Wood machinists | Nasal cancer | 35. |
| Coal carbonizers | Bronchitis and cancer of the bronchus | 140. |
| Viscose spinners (ages 45-64) | Coronary heart disease (excess) | 150. |
| Asbestos workers | | |
| Males, smokers | Cancer of the lung | 115. |
| Females, smokers | Cancer of the lung | 205. |
| Cadmium workers | Cancer of the prostrate (incidence values) | 700. |
| β-Naphthylamine manufacturing | Cancer of the bladder | 1200. |

Many of these figures are high compared with accident rates and would justify high priority and urgent action. However, because industrial disease takes many years to develop the data may relate to past working conditions and it is common experience that working conditions in general have improved markedly in the past 15-20 years. Little data is available on the incidence of disabling diseases associated with toxic waste disposal, however Markham(44) has shown that in respect of a 10 year period ending in 1965 the ratio of early retirements due to bronchitis in Bristol was 70% higher amongst solid waste workers than a control group. Although it has been shown that the numbers involved are not high, studies of cohorts of workers entering UK toxic waste disposal industry would permit valid conclusions to be drawn as to the extent of risk from disease in this occupational group.

THEORETICAL QUANTIFICATION OF RISK

In the absence of factual information relating to accident frequency a theoretical approach based on probability is worthy of consideration. The quantification of risk from technologically based activities has been attempted by many researchers, some of whom have extended the analysis to the comparison between natural and man-originated risks (140, 141, 142).

Any attempt to provide guidance as to the likelihood of a hazard developing on a waste disposal site should be based on a full analysis of the procedures adopted and a working knowledge of the likely aberations which may develop.

The starting point in this approach is the construction of a flow chart for the whole process. Figure 5.2 is an example for part of a waste disposal routine and would need to be augmented with details of the reagents and incoming wastes. A series of fault trees can be constructed from this chart to demonstrate the various combinations of circumstances from which operator hazards may arise. Figure 5.3 shows some of the circumstances which might result in an emission of toxic gas from the conditioning vessel. The fault tree shown is in outline only; to be fully effective it would be necessary to exhaustively analyse each operation, perhaps producing a series of smaller fault trees for each, until specific items could be identified against which a numerical value of likely occurrences per year could be entered. For example, the extreme variability encountered in the composition of the waste which actually arrives for disposal presents one example of such a category. Table 6 in Appendix III provides information obtained by the author on a number of samples taken of waste material which had the potential for harm under this category, hence quantification should begin with an investigation of records to discover a figure for the relationship between correct and incorrect consignments. Similarly past experience will indicate that for a certain percentage of all consignments the theoretically obligatory veracity check will itself be neglected or improperly executed. An estimate of the number of times that incorrect material will be drawn from stock can also be arrived at, as can the number of times that incorrect operating instructions will be used. Hence a combination of estimates can be used to predict the number of times that any one of these possible malfunctions is likely to arise during a specific operating period. Furthermore, the superimposition of the automatic pH control, which warns of an incipient

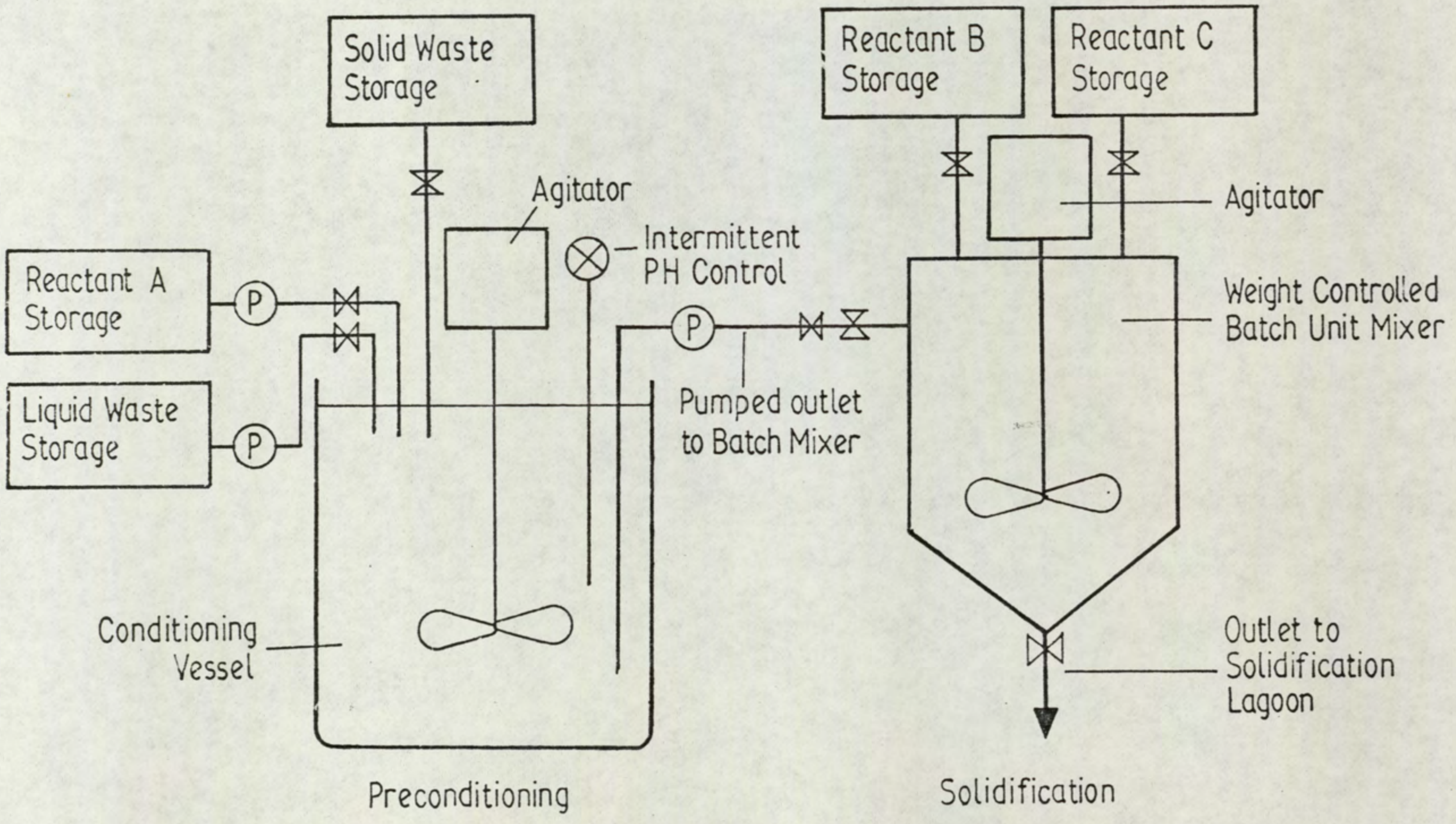
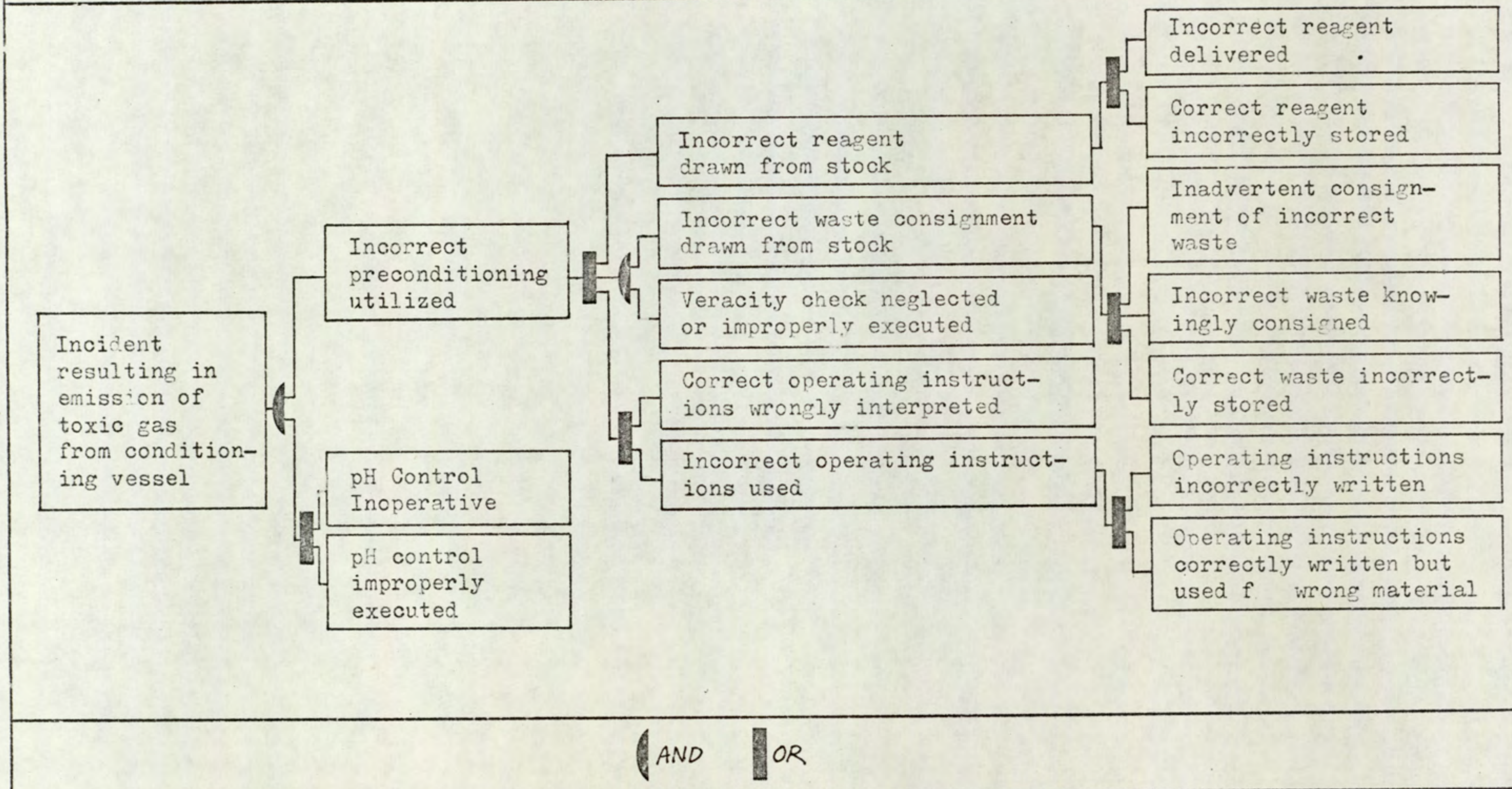


FIGURE 5.2 Flow diagram for part of a waste disposal routine

FIGURE 5.3

Fault tree for one aspect of a waste disposal routine.



incident may itself be inoperative for say 1% of the critical process time, hence 1 in 100 of the potential fault situations so far postulated will be incapable of being arrested in this section of the fault tree. The synthesis of all these factors allows a hypothetical annual probability rate for a plant which undertakes 5000 neutralizations per year to be postulated as follows:-

| | | |
|---|---|---|
| Number of times incorrect neutralizing material will be drawn from stock (0.5% of total). | 25. | I |
| Number of consignments arriving which are sufficiently 'off specification' to give rise to a hazard (0.5% of total). | 25. | II |
| Number of veracity checks improperly executed (0.5% of 25). | 1.25 | III |
| Number of times that correct operating instructions will be wrongly interpreted. | 25. | IV |
| Number of times that incorrect operating instructions will be utilized. | 25. | V |

Hence an estimate of the number of times per year that incorrect preconditioning may be utilized is I + III + IV + V = 76.25. As the pH control may also fail to detect 1% of these reactions, then 0.76 actual incidents can be predicted per year. In addition the control will be improperly executed for 0.1% of operators (adding a further 0.076) giving a total of 0.83 incidents per year.

At this stage an estimation of the extent of the hazard can be attempted - perhaps 1% of the 0.83 incidents per year would prove sufficiently serious to result in the potential for loss of life, resulting in the number of incidents with fatality potential being set at .0083 ($8.3 \times 10^{-3}$) per annum.

To quantify the risk to a specific operator from such a hazard, it is necessary to analyse his movements to predict the proportion of his working day for which he would be close enough to the conditioning vessel to be overcome by a sudden emission of toxic gas. If this amount is for example 2% then his personal liability immediately reduces to $8.3 \times 10^{-3} \times \frac{2}{100} = 1.6 \times 10^{-4}$. Additionally in a three shift situation the operators chance of being on the shift in question, further reduces the probability by one third as follows:-

$1.6 \times 10^{-2} \times \frac{1}{3} = 5.3 \times 10^{-5}$

to convert this to FAFR it is necessary to change this yearly rate into an hourly one by dividing by 2200:

$5.3 \times 10^{-3} \div 2200 = 2.5 \times 10^{-8}$

then multiply by $10^{8}$ to obtain the FAFR

$2.5 \times 10^{-8} \times 10^{8} = 2.5$

This particular value for one operation only of a waste disposal complex is very high. However, it does depend upon the validity of the assumptions which have been made on the frequency of various aberations. Should the value of these basic assumptions be changed significantly, then the final FAFR will also significantly alter - for example, if the estimate that 1% of the incidents would prove sufficiently serious to result in fatalities was incorrect by the value of one decimal place in either direction then the FAFR would similarly alter in the same fashion, the values ranging from .25 to 25.

THEORETICAL ANALYSIS

It is also possible to extend such an analysis to an area greater than the plant, thereby encompassing workers on adjacent sites (and also the general public). One such analysis of a fire on a landfill site follows.

It has been shown that fires constitute a common problem on landfill sites (143) and also reported that many relatively innocuous materials produce toxic degradation products on pyrolysis (144). Amongst the most common are halogenated hydrocarbons which may produce acid chlorides and carbon monoxide which is also produced by the incomplete combustion of hydrocarbons. Several polymeric substances also pose a threat when heated. Table 5.6 identifies qualitatively some important toxic gases produced during combustion of a selection of polymers and lists their TLV (STEL) values.

TABLE 5.6

THERMAL DEGRADATION PRODUCTS OF POLYMERS (145)

| POLYMER | TEMPERATURE °C | TOXIC PRODUCTS | TLV(STEL or CV ppm |
|---|---|---|---|
| Polychloroprene | 377 | Hydrogen chloride | 5 |
| Polytrifluoroethylene | 380-800 | Hydrogen fluoride | 3 |
| Polyvinyl fluoride | 370 | Hydrogen fluoride | 3 |
| Polyvinyl chloride | 225 | Hydrogen chloride | 5 |
| Certain polyamides/urethanes | 250-500 | Hydrogen cyanide | 15 |

Polyvinyl chloride (PVC) plastics commonly occur in waste material. It has been demonstrated that the yield of hydrogen chloride is 505 milligrams per gramme of decomposing PVC (146). The following case study analyses the possibility of harm arising from a fire on a landfill site when waste containing PVC is involved.

---

CASE STUDY 15 Fire on Landfill Site (71)

---

A serious fire on a landfill site was estimated to be consuming the tipped material at a rate of approximately 2 tonnes/hour. The landfilled material at the seat of the fire included quantities of polyvinyl chloride plastic.

Analysis

If an assumption is made that PVC constitutes 5% of the waste then the generation rate of hydrogen chloride will equal:

$$5\% \text{ of } 2 \text{ tonnes/hour} \div \frac{505}{1000} = 20 \text{ kgm/hour or } 5{\cdot}5 \text{ gm/second}$$

If the fire occurs at a time when average meterological conditions prevail then Leutzke's equation (see section 7.1.3) can be used to predict the relationship between the windspeed and the critical distance downwind on the centreline of the plume. This relationship is displayed in table 5.7 for distances relating to the workforce.

TABLE 5.7

Critical distances downwind from a 5.5 gm/sec release of hydrogen chloride (at various windspeeds in 'average' meteorological conditions) applicable to workforce TLV (STEL) 7 mg/m$^3$.

| Wind speed m/s | Critical Distance m |
|---|---|
| .125 | 843.1 |
| .25 | 575.9 |
| .50 | 393.5 |
| .75 | 314.7 |
| 1 | 268.7 |
| 2 | 183.5 |
| 3 | 146.8 |
| 4 | 125.3 |
| 5 | 110.8 |

Should it be desired to extend the analysis from the workforce to the general public. It is necessary to examine the way that public and occupational exposures are related. The traditional approach of the Alkali Inspectorate is to use approximately 1/30th of the TLV (TWA) value (147), using the assumption that a member of the public is likely to be exposed for 3 times as long as the average worker and using a further divisor of 10 to allow for hypersensitive individuals who would be screened out of occupational exposure. If this logic is pursued into the TLV (STEL) values then the first divisor of 3 is unnecessary because the public and the workers are exposed for the same period hence a straight forward reduction by a factor of 10 becomes appropriate. Justification exists for applying this higher standard to office workers who will likewise not have been occupationally screened. Table 5.8 displays the appropriate relationship when the much more onerous standard of 0.7 mg/m$^3$ is used as the TLV (STEL).

TABLE 5.8

Critical distances downwind from a 5.5 gm/sec release of hydrogen chloride (at various windspeeds in average meteriological conditions) applicable to the general public TLV (STEL) 0.7 mg/m$^3$.

| Wind speed m/s | Critical Distance m |
|---|---|
| .125 | 2991.7 |
| .25 | 2043 |
| .50 | 1377.2 |
| .75 | 1101.4 |
| 1 | 940.4 |
| 2 | 642.2 |
| 3 | 520.9 |
| 4 | 438.5 |
| 5 | 387.8 |

COMMENT

The utilization of theoretical computation of risk based on data collected within the industry has drawbacks. The low cost nature of most waste disposal enterprises makes it questionable whether the industry is sufficiently advanced to supply data which is accurate enough for any predictions to be made with confidence.

When extrapolating such data in order to evaluate the risk to residents adjacent to sites, it is worth noting that public authorities tend to include a very high margin of safety into their calculations (148) and in terms of major hazard potential, waste disposal sites would not be expected to rank very high in their list of priorities when compared with other high risk, major hazards.

## 5.4 General Summary and discussion

Section 5.1 has suggested that there appears to be an unfulfilled need for an authoritative code of practice which emphasises procedures which are necessary to minimize hazards to operators.

Section 5.2 compared six training programmes and demonstrated shortcomings which were apparent.

Section 5.3 concluded that despite obvious shortcomings, the use of risk analysis can have some value in focussing attention on the constituent parts of each operation analysed.

Whether such a low cost industry as toxic waste disposal could collect the necessary base data cheaply enough for the rational allocation of scarce resources so as to obtain maximum benefit and the greatest achievable safety performance within the budget must remain an open question.

However, the statutory duty of the Waste Disposal Authorities will eventually result in more reliable data becoming available (as evidenced in Appendix V).

In view of the importance which might attach to on-site measurements of airborne contaminants it was decided to devote some resources to exploring this issue. This is reported in Chapter 6. However, limitations imposed by the nature of the enquiry dictated that a fully theoretical approach could be more rewarding; accordingly mathematical modelling was investigated in Chapter 7.

In order to predict the likely value of generation rates of toxic gases laboratory experiments were undertaken and are reported in Chapter 8. Finally, a wind tunnel exercise was utilized to test the validity of certain assumptions concerning the dispersion patterns of gases liberated at ground level. Particulars are set out in Chapter 9.

# CHAPTER 6

# ON SITE AND FULL SCALE MEASUREMENTS

## 6.1 On site and full scale measurements

### FULL SCALE DISPERSION

The experimental data used to verify Suttons' classic dispersion formula (149) were obtained by relatively crude hand sampling methods. Therefore the dispersion field around a vehicle was initially investigated by correspondingly simple methods.

These tests involved liberating smoke upwind of a car on a basically flat site but with minor surface irregularities corresponding to the terrain of a typical landfill disposal site, as illustrated in fig.6.1. Smoke was generated by a smoke test candle with an approximate discharge rate of .8 gm/sec and in separate tests by a proprietary smoke machine which burnt cotton waste at an average rate of .5 gm/sec. The liberation point was 1 metre from the rear of the vehicle which was placed with its longest axis parallel with the direction in which the wind was blowing. The mean wind speed was recorded. Two air samplers, as specified in Table 63a,were located one on the inside face of the open vehicle drivers door and the other at the front edge of the bonnet on the centre line of the vehicle. An evaluation of the smoke collected during the test was obtained by means of an EEL smoke stain surface reflectometer of the type used in the National Air Pollution Survey.
The results are set out in 6.2.

### ON SITE MEASUREMENT OF AIRBORNE CONTAMINANTS

Reference has already been made to the difficulty of accurately measuring the levels of airborne contaminants immediately adjacent to a disposal point. Even with more sophisticated facilities, accurate estimation of the likely short term atmospheric concentrations at a particular downwind position close to a pollution source has been found difficult (21). Accordingly, the on site measurements were kept to a minimum, and limited to locations where the presence of a particular pollutant was most likely to be capable of being demonstrated.
Equipment to monitor on site concentrations was selected on the basis of experience in previous surveys on landfill sites. Details of the instruments chosen are set out in Table 6.1. The emphasis was laid upon

TABLE 6.1

Equipment used in on-site and full-scale measurements

| | | | |
|---|---|---|---|
| A For on the spot measurements | | | |
| Conditions Investigated | Equipment Type | Make & Model | Remarks |
| Concentration of specific gases in the atmosphere | Bellows type Hand Pump and air quality tubes | Standard Draeger pump and tubes | Major difficulty with waste was knowing which gases to test for |
| Concentration of combustible gases in the atmosphere | Catalytic filament and wheatstone bridge explosimeter | Sieger Gas Alarm Calibrated for Toluene | Although specific for Toluene, results given with any combustible gas |
| Wind speed | Hot wire anemometer | Wallac type GGA 23S | Working range 0–5 m/s |
| B For monitoring and subsequent laboratory analysis | | | |
| General concentration of airborne toxic & non toxic dust | Mains powered fixed position air pump and filter holder | Rotheroe Mitchell 301/min with remote 60 mmdia head using GFA paper | Papers dried and preweighed<br>Analysis (if appropriate) by Atomic Absorbtion Spectrophotometry |
| Specific dust concentration in breathing zone of operator | Battery powered personal monitor and plain filter holder | Casella & Rotheroe Mitchell 2 lit/min samplers using 25 mm heads and GFA paper | |
| Airborne Smoke Concentration | - do - | - do - | Evaluation of darkened filter surface achieved by Relfectometer |

instruments which gave results on the spot, which facilitated the movement of the instrument around the disposal location to the point of maximum concentration.

Difficulties of accurately monitoring airborne concentrations of hazardous dusts and gases on landfill sites have already been identified (13,22) Appendix XII reproduces the results of an on site assessment of hazards to operators engaged in the disposal of asbestos waste.

## 6.2 Results of on site and full scale measurements

FULL SCALE DISPERSION EXPERIMENT

Results are displayed in Table 6.2

TABLE 6.2

Results of full scale smoke dispersion experiments.
Wind Speed 1.5 m/sec mean. gusting 0.5 - 5 + m/sec

| Smoke generation type | Time minutes | Location of sampler | Percentage reflectance | |
|---|---|---|---|---|
| | | | 1st | 2nd |
| Candle | 7 | Door | 85 | 80 |
| | | Bonnet | 93 | 97 |
| Smoke machine | 11 | Door | 81 | 89 |
| | | Bonnet | 97 | 95 |

ON SITE MEASUREMENT OF AIRBORNE CONTAMINANTS

The results of the on site gas and dust sampling are given in Tables 6.3 6.4 and 6.5 respectively.

With the on site monitoring of toxic dust, problems were encountered with respect to detection limits. Because of the need to utilize personal monitors restricted to a maximum sampling rate of two litres per minute it followed that a ten minute operation only resulted in 20 litres or so passing through the filter paper. Hence in order to be able to demonstrate whether the TLV (STEL) for arsenic of 0.5 $mg/m^3$ was exceeded, it was necessary to show whether there were more than 0.5 x .020= 10 $\mu g$ present which was very close to the detection limit of the analytical facilities available.

Accordingly it was decided to record the gross amount of dust and simply express the toxic element as an appropriate percentage of that amount.

On one waste treatment plant ammonia was present at a very high level (estimated by the author at not less than 50ppm). Unfortunately verification of the level by the use of sampling equipment was not permitted.

Access was obtained to results of a sampling exercise carried out by a major chemical manufacturing company (150) on a small disposal site operated by contractors. The principal constituent of the waste being dumped into a lagoon was toluene and measurements taken with an indicator hand pump are reported in Table 6.4 which also shows the measurement of mercury in air recorded during a government sponsored enquiry into the pollution potential of landfill sites. (8).

## 6.3 Discussion of full scale and on site measurement results

FULL SCALE DISPERSION

The simulated field trials with an actual vehicle reported in 6.1.1. confirmed that the concept of full scale working were sound, and that significantly different airborne concentrations can occur at less than one metre apart. However this type of test bears heavily on resources,

Figure 6.1 'Full Scale' Dispersion Testing

The generators used in the smoke dispersion experiment appear in the foreground and a measuring instrument is visible inside the door.

TABLE 6.3A

Results of gas sampling during waste collection or disposal routines.

| SITE KEY | SAMPLING POINT LOCATION | TYPE OF ROUTINE | SUBSTANCE | AMOUNT IDENTIFIED | CEILING OR STEL VALUE |
|---|---|---|---|---|---|
| A | (a) Head Height in drum emptying area. | Semi-mechanized drum emptying process. | Toluene Diisocyanate | Nil | .02 ppm |
| | (b) | | Non specific flammable gas. | 20% of lel for toluene | |
| | (c) | | Perchloroethylene | 15 ppm | 150 ppm |
| | (d) | | Toluene | Nil | 150 ppm |
| E | (a) Head height in print room. | Waste disposal operation on dyeline copier | Ammonia | 33 ppm | 25 ppm |
| | (b) Workers head height in laboratory. | cleaning mercury spillage. | Mercury | 0·30 mg/$m^3$ | 0.15mg/$m^3$ |
| I | (a) Head height in cyanide treatment area. | General atmosphere during the de-drumming of cyanide with pneumatic chisel. | Hydrogen cyanide | 1 ppm | 15 ppm |
| | (b) Head height in cyanide treatment area. | | Hydrogen cyanide | 5 ppm | 15 ppm |
| | (c) Head height near incinerator. | During manual loading of TDI residues. | Toluene Diisocyanate | Nil | 0.02 ppm |
| | (d) Head height on storage deck. | General atmosphere. | Hydrogen cyanide | Nil | 15 ppm |
| J | (a) 1 m inside access hatch of road tanker barrel. | Cleaning of tank interior surface (removing deposits) | Ammonia<br>Hydrogen Chloride | 40 ppm<br>55 ppm | 35 ppm<br>5 ppm |
| | (b) 1 m inside access hatch of road tanker barrel. | | | | |

TABLE 6.3B

Results of gas sampling during waste collection or disposal routines (continued)

| Site Key | Sampling point location | Type of routine | Substance | Amount Identified | Ceiling or STEL value |
|---|---|---|---|---|---|
| K | a) Head height in tanker discharge bay | General atmosphere during tanker discharge | Hydrogen cyanide | 5ppm | 15 ppm |
| | b) Operators breathing zone inside neutralizing tanks | cleaning of tank interior surface (removing deposits) | Hydrogen cyanide | Nil | 15 ppm |
| | c) - do - | - do - | Ammonia | 10ppm | 35 ppm |
| | d) - do - | - do - | Chlorine | Nil | 3 ppm |
| | e) Head height within bund | general atmosphere | Hydrogen cyanide | 1ppm | 15 ppm |
| | f) adjacent to storage tanks | during processing | Ammonia | Nil | 35 ppm |
| | g) - do - | - do - | Hydrogen sulphide | Nil | 15 ppm |
| | h) Head height in drum opening area | During the manual dedruming of cyanide with axes | Hydrogen cyanide | 2ppm | 15 ppm |
| | i) Head height on process desk | General atmosphere during processing | Mercury | Nil | 0.15mg/m$^3$ |
| L | a) Head height adjacent to | General atmosphere during | Hydrogen Sulphide | Nil | 15 ppm |
| | b) tanker discharge pit | tanker discharge | Phenol | 3ppm | 10 ppm |
| | c) | | Non specific Flammable gas | 10% of lel for toluene | - |
| U | a) Head height adjacent to | General atmosphere during | Hydrogen Chloride | 15 ppm | 5 ppm |
| | b) tanker discharge pit | tanker discharge | Phenol | 2 ppm | 10 ppm |
| | c) | | Ammonia | Nil | 35 ppm |

TABLE 6.4

Results of gas sampling carried out by other organizations (150)(8)

| SITE KEY | SAMPLING POINT LOCATION | TYPE OF OPERATION | SUBSTANCE | AMOUNT IDENTIFIED | CEILING OR STEL VALUE |
|---|---|---|---|---|---|
| L | (a) Head height adjacent to tanker discharge area. | General atmosphere during tanker discharge. | Toluene | 250 ppm | 150 ppm |
| | (b) Head height adjacent to tanker discharge area. | General atmosphere one hour after discharge. | Toluene | 50 ppm | 150 ppm |
| | (c) Head height adjacent to gatemans cottage 50 m from discharge point. | General atmosphere during tanker discharge. | Toluene | 50 ppm | 150 ppm |
| Not visit. during this Survey | (a) Head height adjacent to excavation area. | Excavation of trenches into previously deposited mercury bearing waste. | Mercury | 0·01 $mg/m^3$ | 0·15 $mg/m^3$ |
| | (b) Head height above smouldering waste. | General atmosphere where waste containing mercury was incinerated in the open. | Mercury | 0·7 $mg/m^3$ | 0·15 |
| U | (a) Head height adjacent to neutralization lagoon. | General atmosphere during acid neutralization. | Hydrogen Chloride | 50 ppm | 5 ppm |

TABLE 6.5A

Results of dust sampling during waste collection or disposal routines

| Site Key | Sampling point location | Type of operation | Time(min) Monitor Operated | Total dust $mg/m^3$ | Toxic dust $mg/m^3$ | Ceiling or STEL value $mg/m^3$ |
|---|---|---|---|---|---|---|
| K | Personal Monitor | | | | | |
| | a) Loading shovel driver | Loading silica gel containing 15% arsenic | 39.5 | 12.8 | Arsenic 1.9 | 0.5 |
| | b) | | | | | |
| | b) - do - | Loading flue dust containing 3.5% vanadium | 6.5 | 8.7 | Vanadium 0.3 | 1.5 |
| | c) - do - | Loading dried sludge containing 1.5% inorganic lead | 14.0 | 14.7 | Inorganic Lead 0.2 | 0.45 |
| | d) General Labourer | Cleaning residues of flue dust containing 3.5% vanadium from hopper | 25.3 | 22.4 | Vanadium 0.8 | 1.5 |
| | Fixed Monitor | | | | | |
| | a) Head height, open air 10m downwind of disposal plant | Processing silica gel containing 15% arsenic | 143.7 | 0.7 | Arsenic 0.1 | 0.5 |
| | b) Head height, Open air 10m upwind of disposal plant | - do - | 144.5 | NIL | NIL | - |

TABLE 6.5B

Results of dust sampling during waste collection or disposal routines

| Site Key | Sampling point location | Type of operation | Time(min) Monitor Operated | Total dust $mg/m^3$ | Toxic dust $mg/m^3$ | Ceiling or STEL value $mg/m^3$ |
|---|---|---|---|---|---|---|
| Q | <u>Personal Monitor</u><br>General Labourer | Yard duties (sweeping etc) waste incinerator | 46.2 | – | Inorganic lead .05 | 0.45 |
| P | <u>Personal Monitor</u><br>General Labourer | Deck duties (sweeping etc) on domestic and industrial waste incinerator. | 45.0 | 1.3 | see text | – |
| G | <u>Personal Monitor</u><br>a) General Labourer | Deck duties (sweeping etc) on transfer loading station | 390.5 | 11.9 | see text | – |
|  | b) Bulldozer driver | Landfilling domestic and industrial waste | 88.1 | 16.6 | see text | – |
|  | c) Bulldozer driver | - do - | 42.2 | 183 | see text | – |
|  | d) Bulldozer driver | - do - | 39.9 | 187 | see text | – |
|  | e) Incinerator operator | De-ashing operations on | 36.5 | 555 | see text | – |
|  | <u>Fixed Monitor</u><br>Underground vehicle loading bay | Loading of compaction vehicles with domestic and industrial waste | 345.5 | 475 | see text | – |

and it was also discovered that a Government Research Establishment was planning research of this nature. (151). Hence these investigations were not taken further.

ON SITE MEASUREMENTS

Experience during the gas measurements reported in 6.2 on site also demonstrated the short-comings of the chosen methods of making 'real' measurements. In particular the results of the gas sampling routines were probably not representative of actual conditions. For example, the limitations of the hand pump air quality sampling tube system were evidenced on several occassions by the presence of strongly offensive solvent odours, although no readings were obtained on the chosen sampling tube. However, the amounts discovered in some sampling routines provided unequivocal indication of the existence of problems. For example, comparison of the TLV(STEL) and the amounts measured shows that in some cases operators were exposed to concentrations of a hazardous substance such as hydrogen chloride at levels five times greater than the recommended ceiling values.

The on site dust measurements were inherently likely to be more truly representative of actual conditions. Total dust results were unacceptably high; two samples being in the region of 50x the recommended values.

Since the results were based on single measurements they are of unproven accuracy. However they are indicative of the levels to be anticipated.

The limited analytical facilities meant that the values of hazardous dusts were simply extrapolated from the total dust standard i.e. when arsenic was reported as a contaminant at a level of 15% in a particular substance, then the arsenic in air result was taken as 15% of the recorded total dust in air level. Whilst this system has obvious drawbacks it did provide some indication of the level of dangerous constituents without the need for extensive analytical facilities.

Measurements reported from two other sources do provide further reinforcement of the conclusions, although doubt arises in the case of the mercury vapour results as the readings were taken using an ultra violet type mercury meter, and there may have been an obscuring effect due to smoke particles from the smouldering cells.

In summary, whilst the limitations which were imposed by the chosen sampling system were very apparent during the tests, the results obtained serve to underline the suggestion that a potential hazard exists for solid waste workers from the airborne concentrations of gases and dust to which they are exposed. This suggestion was confirmed by the test results from other undertakings to which access was obtained.(8.150)

However these findings emphasised the problems which are faced by any low cost enterprize which is attempting to monitor levels of airborne contaminants. It is very difficult to provide a comprehensive picture without access to sophisticated monitoring equipment. Simple hand pump readings may mislead,and hence give rise to a false sense of security.

# CHAPTER 7

# MATHEMATICAL MODELLING

## 7.1 Mathematical Modelling

### 7.1.1 GENERAL PRINCIPLES

The principles of mathematical modelling of certain natural phenomena are given in several texts (152, 153, 154) and it is necessary to treat the mathematical modelling of the generation or evaporation and subsequent dispersion of gas clouds as two separate issues. However in the case of vapour cloud dispersion from a volatile liquid there is an interrelationship between wind speed and evaporation rate.

EVAPORATION

The principles involved in simple evaporation of liquid from surfaces of known dimensions have been extensively explored (155) and extrapolation is possible from measurements in evaporation studies. Some deviations may arise in practice however from variations in surface geometry and in ambient conditions.

GENERATION

As explained in Section 8.1 generation rates of toxic gases as a result of the meeting of chemically incompatible substances cannot be mathematically modelled in the same fashion. Hence no calculations have been advanced for such occurences. Results of laboratory experiments to model generation rates are reported in 8.2

DISPERSION

Mathematical modelling of the dispersion of gases, dust and fumes is inherently difficult (156). However such approaches are commonly used to predict the likely concentrations of airborne contaminants following accidental release of hazardous substances (157, 158, 159, 160). These predictions, if used with caution, can provide indications of the possible extent of certain hazards.

The evaporation and subsequent dispersion of air pollutants from waste disposal operations will now be dealt with sequentially. ( NOTE with respect to units, the System International is used except where, as in Equation 1, the units are established in CGS and in such a case a simple conversion of the data from S1 to CGS has been undertaken. )

### 7.1.2 Evaporation from Free Liquid Surfaces

It can be argued that studies of simple evaporation are of limited value with regard to landfill disposal of toxic wastes, because the liquid is allowed to soak into previously deposited waste; hence a free liquid surface does not commonly exist for an extended period. However, the modelling of evaporation from the surface of liquid impregnated waste is much more complicated since, once a free surface is lost, it depends upon diffusion through a heterogeneous solid.

Accordingly, for the present investigation, the fact that flooding of the discharge pit or trench can occur during the discharge cycle (and may well persist for a substantial time period afterwards was considered to provide sufficient justification for the mathematical modelling of these circumstances. The validity of this approach was borne out in discussion with Harwell Hazardous Waste Service who have subsequently published results of their own research programme (161).
A very comprehensive formulae is offered by Gray (155) for evaporation in ducts, but as this study is concerned with releases in the open air where precision is unachievable, the simpler approach of Clancey (162) is preferable. Using an average value for the turbulence factor of 0.25 which ignores the possible extremes of turbulence and hence involves a maximum error of 10%, then the evaporation rate from a pool will be given by:

$$E = 1.2 \times 10^{-10} \times \frac{M.p}{T} \times \bar{u}^{0.78} \times a^{0.89} \times b \qquad (Eq1)$$

Where $E$ = evaporation rate (gm/sec)
$\bar{u}$ = mean wind velocity (Cm/sec)
$a$ = downwind dimensions of surface (Cm)
$b$ = crosswind dimensions of surface (Cm)
$M$ = molecular weight of the diffusing vapour
$p$ = vapour pressure (dynes/cm$^2$)
$T$ = absolute temp $^{\circ}$K

Results of the use of this formula for selected volatile substances which are likely to be encountered in substantial amounts on landfill sites are set out in 7.2 The choice of perchloroethylene and trichloroethylene allows subsequent computation of 'worst possible' circumstances because their high densities relative to air (5.83 and 4.53 respectively) do not facilitate rapid dispersion.

### 7.1.3 Estimates of dispersion

INTRODUCTION

The wide variety of factors involved in the dispersion field of any given pollutant released into the air are briefly summarized below. In unstable atmospheres, usually encountered in the day-time frequent and random variations in wind direction occur. The magnitude of these variations is related to the prevailing atmospheric conditions and affected by turbulence induced by roughness elements on the ground on a microscale, such as buildings and trees, & on a macroscale such as topographical features. Thus dispersion direction under these conditions will be less predictable from moment to moment. A wide range of wind speeds may exist with most conditions of stability of the atmosphere. Hence there is no direct co-relation between wind speed and the stability or instability of the atmosphere.

As wind speed increases the vapour or dust from a continuous source is introduced into a greater volume of air per unit time interval resulting in increased dilution of the effluent. However the concentration at any point along the centre line of mean wind direction from a continuously generated cloud is not inversely proportional to the mean wind speed because of the concentrating effect which results from the less meandering path taken by the higher speed wind.

The effect of turbulence in mixing the vapour cloud with other air is much more significant than molecular diffusion. The extent of mixing will depend on the frequency and magnitude of turbulent motions in the wind. If these are composed of a wide variety of fluctuations of varying size and frequency, mixing with ambient atmosphere and thus dispersion, will be rapid. However small scale motions within the general direction of the wind are unlikely to promote rapid dispersion because of the interaction of these small motions with each other. In a field of extensive slow eddy motions the vapour cloud may follow a tortuous path complying with the various influences of successive motions without effecting rapid dispersion.

Density of a gas or vapour is an important physical factor. A cloud of gas or vapour of density very much greater than air, not only tends to settle beneath the air by gravitational force, but in view of its high density gradient, also exerts a damping effect on air turbulence thus significantly lowering the rate of dispersion compared to a cloud of gas of similar density to air. Gas density is also very dependent on the relative temperature of its constituent parts, thus hot gases are displaced upward in the air and cool gases tend to spread at low level.

If the particle size/density relationship is not such that settlement by gravity occurs then the rate of dispersion of airborne material is not significantly affected by whether it is gas, liquid or solid. Wind speed, turbulence and particle size all determine whether a pollutant will settle under gravity. However, it has not been conventional practice to allow for the extent to which gravity settlement affects airborne concentration, hence satisfactory theoretical treatments have not been widely available for cases where density differences exist and this factor has been ignored in the classic dispersion theories (152, 153, 154).

## DISPERSION MODELLING

Sutton developed the basic equations for dispersion and these were subsequently amplified by field diffusion tests (163). Various modifications have been suggested normally in the direction of simplification and the treatment which appears to find greatest favour (164) is that used in a workbook by the United States Department of Health Education and Welfare (165).

## TURNERS WORKBOOK OF DISPERSION ESTIMATES

The workbook method utilizes a system of X, Y and Z axes. For a ground level emission the origin is at ground level with the X axis extending horizontally in the direction of the mean wind. The Y axis is in the horizontal plane perpendicular to the X axis and the Z axis extends vertically. The plume travels along or parallel to the X axis as shown in Figure 7.1

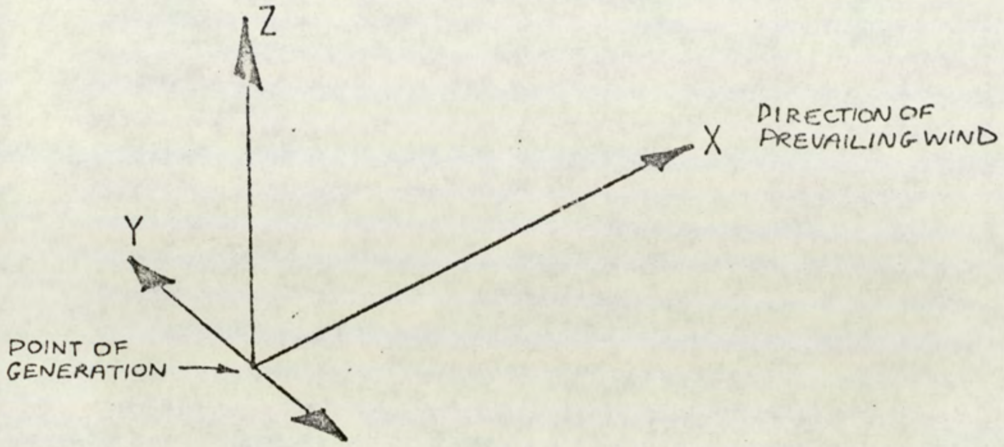


FIGURE 7.1 System of axes used in Turner's Workbook (165)

The concentration X of gas or aerosol at XYZ from a continuous source is then given by a point on the centreline of the plume

$$X = \frac{Q}{\pi \sigma y \sigma z \bar{U}} \qquad \text{(Eq2)}$$

Where X = Concentration at distance X (M)
Q = Generation rate of substance (gm/sec)
$\sigma y$ = Horizontal dispersion factor (from tables) (m)
$\sigma z$ = Vertical dispersion factor (from tables) (m)
$\bar{U}$ = mean wind speed (m/sec)

The values of $\sigma y$ and $\sigma z$ vary with:

1. turbulent structure of the atmosphere
2. height above the surface
3. surface roughness
4. sampling time over which the concentration is to be estimated
5. wind speed
6. distance from the source

The following are assumed:

The dispersant is a gas or aerosol less than 20 µm in diameter, the plume spread has a Gaussian distribution in both the horizontal and vertical planes with standard deviations of plume concentration distribution in the horizontal and vertical of $\sigma y$ and $\sigma z$ respectively. The sampling time is ten minutes approximately

Height is confined to the lowest several hundred meters of the atmosphere, surface to relatively open country.

The emission rate of pollutants is uniform and total reflection takes place at the earth's surface.

The turbulent structure of the atmosphere and wind speed are considered in the stability classes presented and the effect of distance from the source is considered in the graphs determining the parameter values. Values for $\sigma y$ and $\sigma z$ are estimated from the stability of the atmosphere which is in turn obtained from the wind speed at a height of about 10m and during the day, the incoming solar radiation or, during the night, cloud cover.

As the workbook is written for environmental rather than occupational health purposes, it does not provide predictions nearer than 100m from pollutant sources. Hence for the purpose of this exercise it was necessary to extrapolate from the tables $\sigma y$ and $\sigma z$ to provide values for distances within 5m of the source.

## CLANCEYS DISPERSION EQUATION

Simpler approaches have been suggested. One such treatment (162) only provides for average meteorological conditions which incurs a possible error of 30% in extreme conditions. The equation is:-

$$X = \frac{32\ Q}{\bar{u}.x\ 1.75} \qquad \text{(Eq3)}$$

Where X = concentration on X axis direction of mean wind at distance xm from the source ($gm/m^3$)

Q = source strength (gm/sec)

$\bar{U}$ = mean wind speed (m/sec)

Results of calculations utilizing both the workbook approach and the above approach are compared in 7.2.

## BENAIRES' RULE

Provided that the emission can be regarded as such a point source then an interesting development in the evolution of a rule of thumb approach has been suggested (166) It is argued that the following two formulae cover all cases:

$$D = 7.3 \times x^{-2} \text{ (day)}$$

$$D = 25 \times x^{-2} \text{ (night)}$$

Where $D$ = Dossage, normalized to unit emission

$x$ = Downwind distance in metres

The familiar inverse square law for decay of various isotropic phenomena with distance is used and the factors of 7.3 and 25 take account of the much greater stability of the atmosphere encountered during the absence of the strong heating action of the sun. (Clearly a transition period will occur as the sun is setting and rising but no guidance is issued on procedure during this period).

Results using the above equation are set out in 7.2.

## LUTZKES' CRITICAL DISTANCE COMPUTATION

A prime concern of this study is in the location of the maximum allowable airborne concentration in relation to the source and it has been suggested that Sutton's classic formula can be modified to provide a simple prediction of the downwind distance at which a certain limiting concentration will be located (167). Assuming average meteriological conditions then :

$$X_{max} = \frac{K.Q^{(c)}}{S.\ \bar{U}} \qquad \text{(Eq5)}$$

Where X max = critical distance

K = a constant (9.23)

C = a constant (0.55)

Q = generation rate (kg/hour)

S = critical concentration such as TLV or LEL ($g/m^3$)

$\bar{U}$ = average wind speed (m/s)

The results of a micro computer programe (displayed in Appendix XIV) using the above equation are set out in Tables 7.5 and 7.6.

## AREA OF SOURCE

The treatments above are for a point source but it has been shown earlier that the source is not a point, but an area, and that the extent of the area is important when estimating generation rates. However area release will behave in the same way as a point source which is located upwind of the actual source - see figure 7.2.

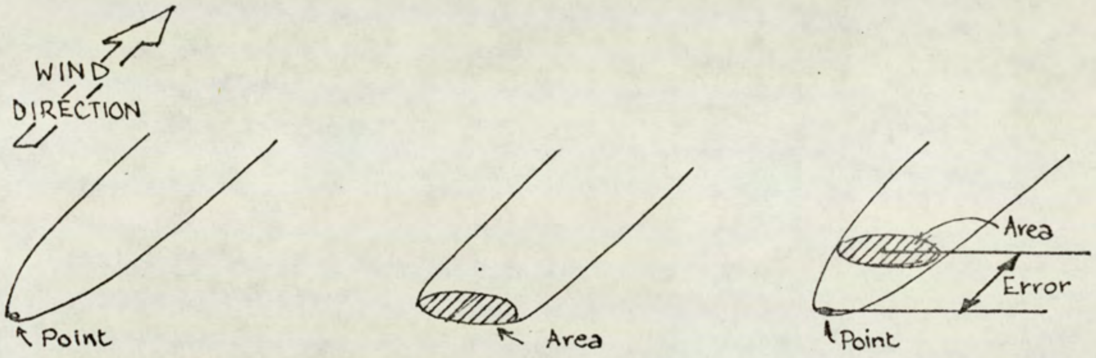

(a) theoretical model
(b) Actual situation
(c) Combination

FIGURE 7.2 Error due to difference between point and area sources

A method has been suggested for the estimation of the "virtual point source" position. However since little is actually known about the size of the dispersing cloud at the time of release and the error is on the side of safety it is prudent to disregard this difference (162) and not introduce a spurious impression of accuracy.

## 7.2 Results of Mathematical Modelling

### 7.2.1 EVAPORATION FROM FREE LIQUID SURFACES

Using equation 1 as an initial example, this provides the prediction that if perchloroethylene was discharged so as to flood a soakage pit which was 10m x 10m in size at an air temperature of $27^{0}$C in the presence of a 1m/sec wind, the evaporation rate would be in gm/sec:

$$1.2 \times 10^{-10} \times \frac{166 \times 26.4 \times 10^{3}}{300} \times 100^{(0.78)} \times 1000^{(0.89)} \times 1000 = 29.7$$

This result accords reasonably well with the findings of a research project into evaporation rates in the field (161).

The parameters likely to affect the generation rate of a given substance within the terms of the equation are:-

i) Area of pool
ii) Dimensions of pool relative to wind direction
iii) Wind speed
iv) Temperature

The following exercises investigate the predicted effects of each of these parameters in turn:

i) Area of Pool

If the surface area of the pool is altered, but all other parameters kept constant then the results set out in Table 7.1 are obtained.

TABLE 7.1

Variation in evaporation rate with changing area of perchloroethylene as predicted by Clancey's equation.

| Square Pool Area in $m^2$ | Evaporation rate in gm/sec for a 1/m/sec wind |
|---|---|
| 200 | 57.28 |
| 150 | 43.65 |
| 100 | 29.75 |
| 75 | 22.67 |
| 50 | 15.45 |

These results are plotted in Figure 7.3.

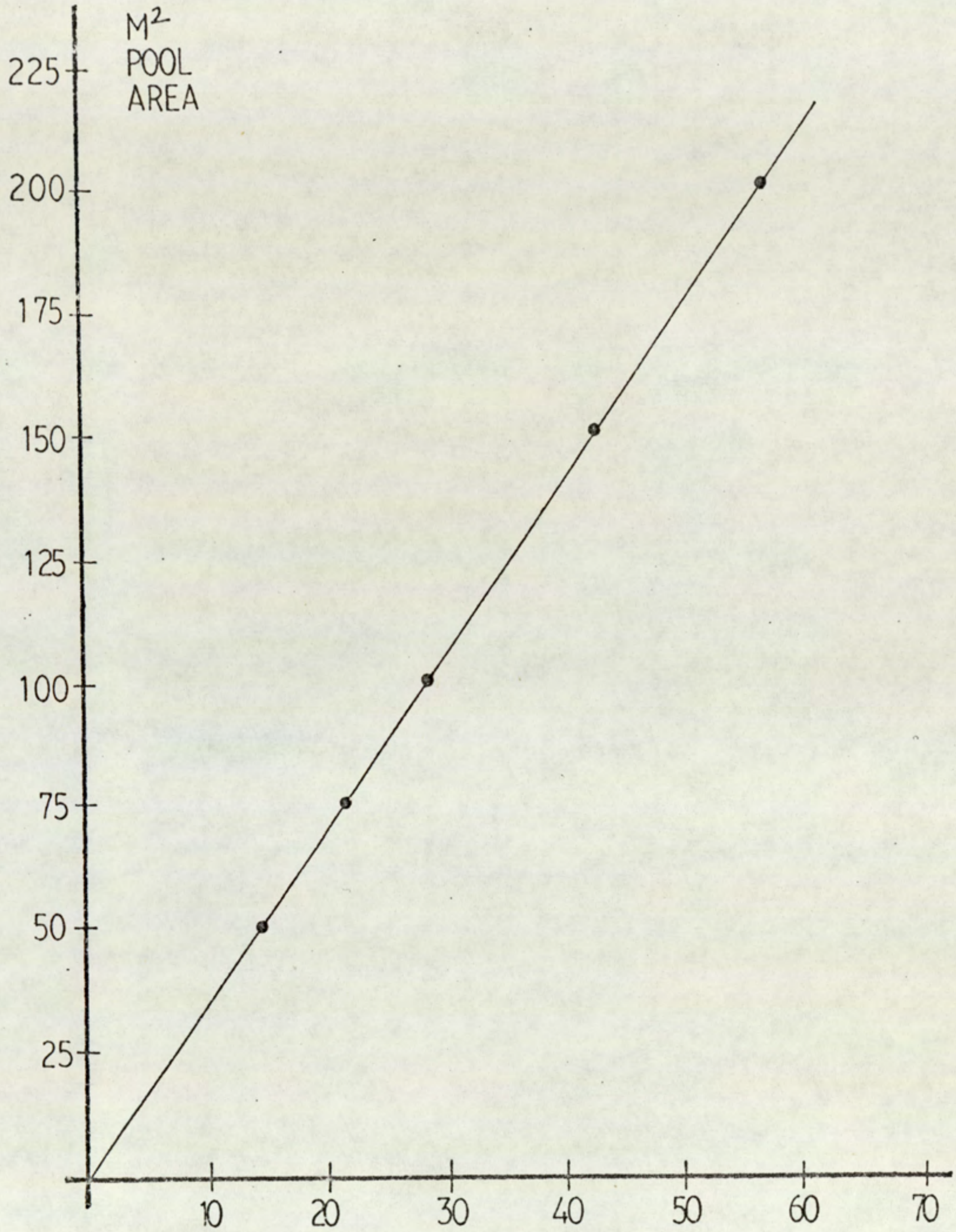
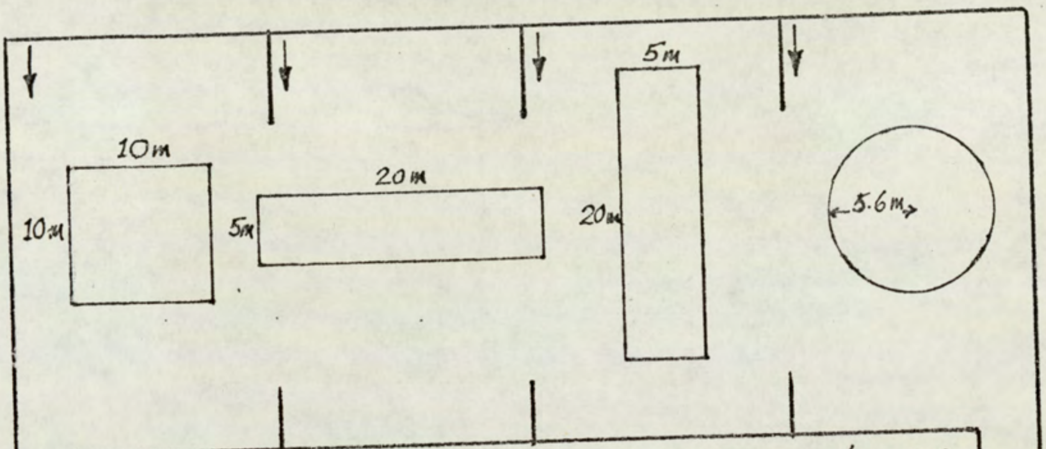


FIGURE 7.3 Variation in evaporation rate with changing area of perchloroethylene as predicted by Clancey's equation.

(ii) Dimensions of pool relative to wind direction.

If this exercise is repeated for pools of a constant area but with differing dimensions relative to the wind direction then the results will appear as set out below: (wind direction shown by ↓ ).



Evaporation rate in grams per second for a 1m/s wind:

| (a) | (b) | (c) | (d) |
|---|---|---|---|
| 29.7 | 32.1 | 27.6 | 30.2 |

FIGURE 7.4 Effect on evaporation rate of changing pool dimensions

Inspection of the evaporation rates reveals that a doubling in length of the edge of the pool which is at right angles to the wind directions (Case b) produces a mere 7% increase in evaporation rate and likewise halving this dimension (Case c) produces a similar decrease.

The calculation for a circular pool shows less than a 2% change with respect to evaporation from the square pool.

(iii) Wind Speed.

If the square pool dimensions are held constant and the wind speed is varied, then the same equation predicts that the generation rates would be as shown in Table 7.2.

TABLE 7.2

Relationship predicted by Clancey's evaporation equation between wind speed and evaporation rate of a pool of perchloroethylene of $100 m^2$ area.

| Wind Speed metres per second | Evaporation Rate grams per second |
|---|---|
| 4.000 | 87.7 |
| 2.000 | 51.1 |
| 1.000 | 29.7 |
| .500 | 17.3 |
| .250 | 10.0 |
| .125 | 5.9 |

Inspection of these results indicates that doubling or halving this parameter has a marked effect upon the evaporation rate. This is demonstrated in Figure 7.5.

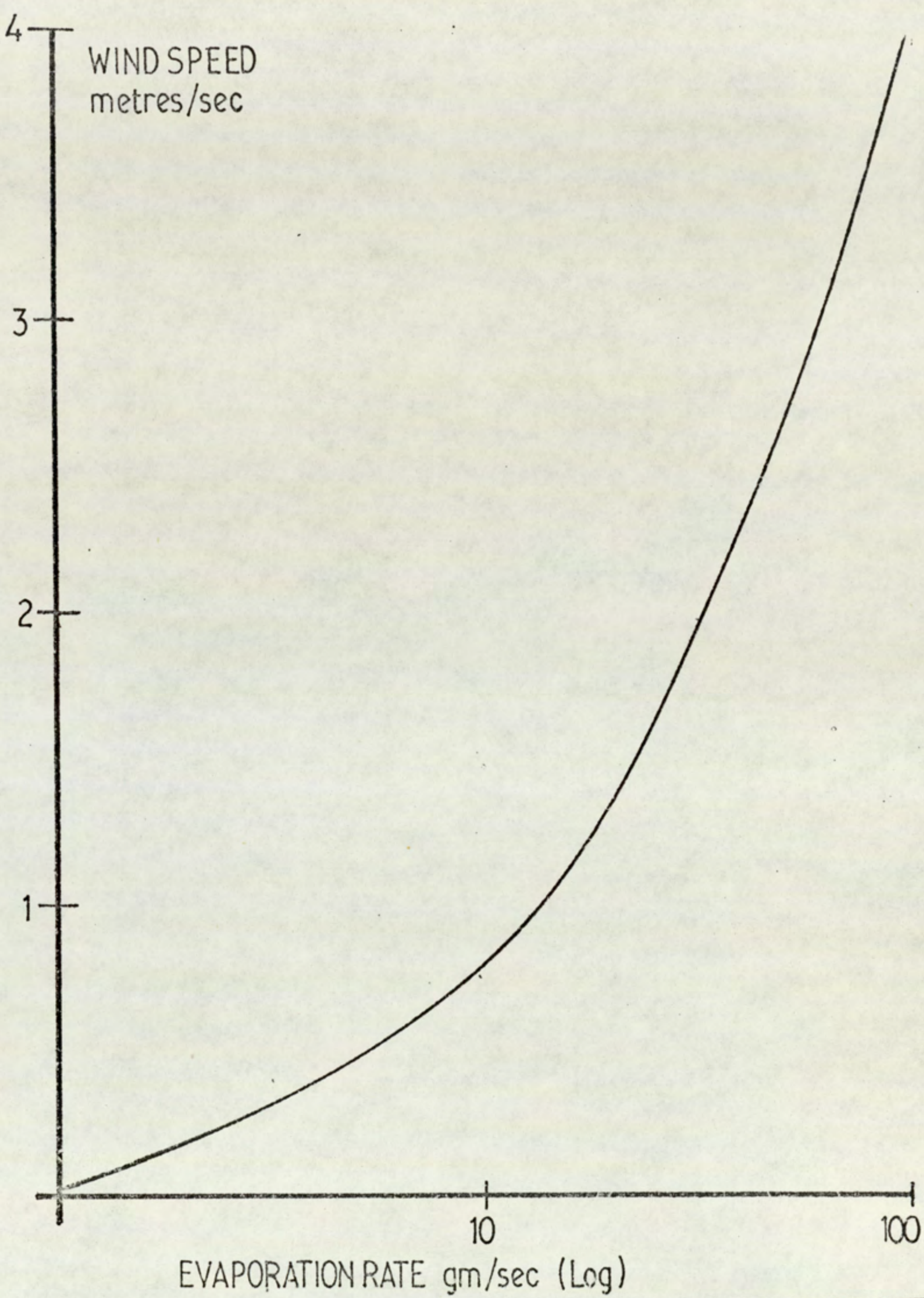


FIGURE 7.5 Display in Log/Normal format of the relationship predicted by Clancey's evaporation equation between windspeed and evaporation rate of a pool of perchlcroethylene of 100m$^2$ area.

iv) Temperature

It can be shown that the effect of varying the temperature is not large. A 10°C difference in temperature from 30°C merely alters the generation rate by 1 gm/sec (3.3%).

## TIME FOR COMPLETION OF EVAPORATION

In order to determine the significance of any particular airborne concentration, it is necessary to know the length of time for which that concentration will persist. In the case of a pool 100 $m^2$ in area as the contents of a typical 1000 gallon (4,540 litre) tanker of perchloroethylene would weigh 22,200 kgm. The use of equation 1 predicts that it would take the time set out in Table 7.3 for complete evaporation at the stated wind speeds.

TABLE 7.3

Time taken to evaporate 22,200 kgm of perchloroethylene at various windspeeds from a pool 100 $m^2$ in area

| Wind speed metres/secs | Evaporation rate grams per second | Time for complete evaporation (hours) |
|---|---|---|
| 4.00 | 87.7 | 70.2 |
| 2.00 | 51.1 | 120.6 |
| 1.00 | 29.7 | 207.5 |
| .50 | 17.3 | 356.2 |
| .25 | 10.0 | 616.2 |

## 7.2.2 RESULTS OF DISPERSION ESTIMATES

Four methods of estimating dispersion were described in 7.1. These were:

1. Turner's workbook method (Eq2), which provided a comprehensive coverage for all possible variations of weather conditions and involved the use of tables from which values of $\sigma y$ and $\sigma z$ were obtained.
2. Clancey's simplified version (Eq3), in which an average value was submitted for the weather variation.
3. Lutzkes' critical distance computation (Eq5), which was a rearrangement of Eq3 to predict the point at which a critical value such as the TLV(STEL) or LEL, would be located in a dispersing cloud.

4. Benaires approach (Eq4) which provided a rule of thumb method in the form of two very simple equations.

Table 7.4 sets out a comparison between methods 1(Eq2) as extrapolated and 2 (Eq3) for predicted concentrations at various positions downwind from a 10gm/sec source on the plume centreline. Method 3 (Eq5) is utilized in Figures 7.6 and 7.7 to demonstrate the relationship predicted between windspeed and furthest location of a concentration above the TLV(STEL) for perchloroethylene and trichloroethylene respectively.

TABLE 7.4

Comparison of two methods of calculating downwind concentration expressed in gm/$m^3$ on the centreline of a plume for a gas evolved at a constant rate of 10 gm sec.

A = Clancey B = Turner (extrapolated)

| Wind Speed m/s | Method | Concentration in gm/$m^3$ at various distances from source | | | | |
|---|---|---|---|---|---|---|
| | | 5m | 10m | 50m | 100m | 500m |
| 2.5 | A | 7655 | 2276 | 136 | 40. | 2.4 |
| | B | 3536 | 1061 | 64 | 21. | 1.2 |
| Ratio | A/B | 2.1 | 2.1 | 2.1 | 1.9 | 2.0 |
| 1 | A | 19138 | 5690 | 340 | 101 | 6.0 |
| | B | 8841 | 2652 | 162 | 53 | 3.1 |
| Ratio | A/B | 2.1 | 2.1 | 2.1 | 1.9 | 1.9 |
| 0.5 | A | 38277 | 11300 | 680 | 202 | 12.1 |
| | B | 17683 | 5305 | 322 | 106 | 6.2 |
| Ratio | A/B | 2.1 | 2.1 | 2.1 | 1.9 | 1.9 |

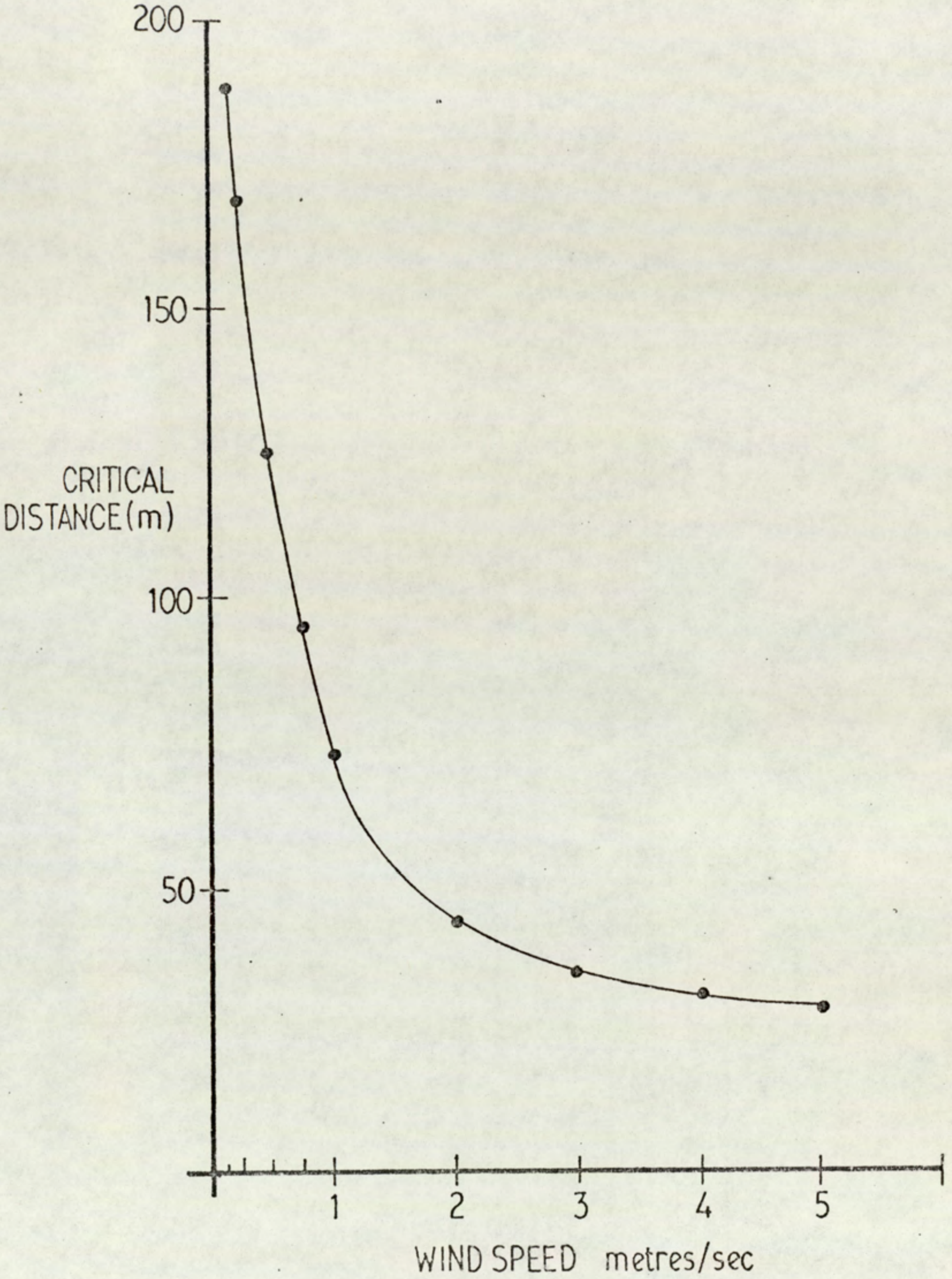


FIGURE 7.6 Distance in metres downwind at which the critical concentration of 1000 mg/m$^3$ is located for perchloroethylene dispersion from a source strength of 51 gm/sec at various windspeeds.

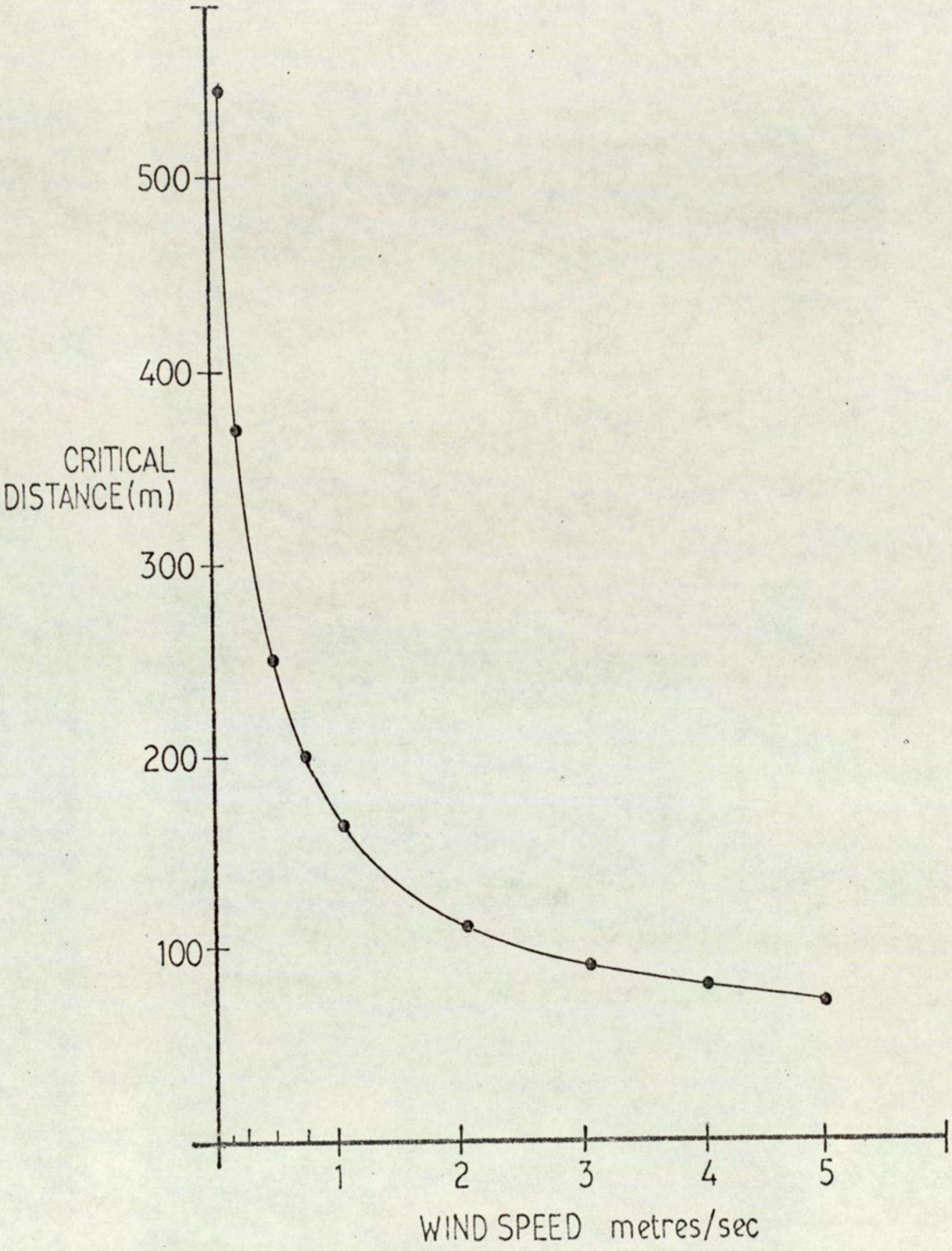


FIGURE 7.7 Distance in metres downwind at which the critical concentration of 800 mg/$m^3$ is located for trichloroethylene dispersing from a source strength of 276 gm/sec at various windspeeds.

Using Method 4 (Eq4) if a gas is being generated at 10 gm/sec. then at 10m downwind, the predicted dosage will be:

Day $D = 7.3 \times 10^{-2} = 7.3 \times \frac{1}{10} 2 = 10 \times \quad = 0.73$ gm/sec

Night $D = 25 \times 10^{-2} = 25 \times \frac{1}{10^{2}} = \quad 10 \times 0.25 = 2.5$ gm/sec

i.e. at 10m from a 10 gm/sec release, dose will be 0.73 gm/sec daytime and 02.5 gm/sec at night on the plume centreline directly downwind.

## 7.3 Discussion of results of mathematical modelling

### EVAPORATION FROM FREE LIQUID SURFACES

The results of the theoretical exercise on generation rates of volatile solvents reported at 7.2.1. predict that the size of the pool and the wind speed are the most significant parameters when determining likely downwind concentrations adjacent to areas of evaporating solvents.
In practice the use of pools with extensive surface areas is necessary to avoid extended disposal periods and of course no control can be exercised over the wind speed. The results of the dispersion calculations displayed in Figures 7.5 and 7.6 demonstrate that the TLV(STEL)s for common solvents which are disposed of in tonnage quantities (125) can be exceeded for extensive distances downwind.
Although few authoritative field studies are available to provide verification of these predictions, publication of the results of the government sponsored preliminary enquiry (151) now suggests that theoretical calculations work reasonably well for relatively involatile solvents, although heat transfer effects do need to be taken into account for volatile solvents(161).
In addition, this study indicates that the evaporation rate from solid waste onto which solvents have been poured is initially two to five time higher than from a pool of liquid of corresponding size. Although the study also shows that the inter-relationship between simple and 'wicked' evaporation is not amenable to theoretical treatment, it does, at face value, allow the conclusion to be drawn that the short term risk hazards to workmen and local residents would be at least twice as high if waste solvents were dispersed onto domestic waste, than if they were lagooned. Recognition does however need to be given to the form in which the wastes are presented. If extensive contamination with other substances is present, then allowances will need to be made. For example water retards evaporation whereas oil increases it (161).

With regard to the length of time which the evaporation would take, Table 7.3 predicts that for a $100m^2$ pool, under typical meteorological conditions evaporation could persist for several days.

## COMPARISON OF DISPERSION FORMULAE

Table 7.4 demonstrates that downwind concentrations predicted by Clancey's method are approximately twice as great as those predicted by the use of Turner's workbook. The simplified approach favoured by Clancey using a standardized neutral atmosphere does however require a built-in safety factor and examination of the basic formulae on which these treatments are respectively based reveals a difference in the size of the generation term Q. Sutton's basic formulae, which was used by Clancey, has a 2x multiplier applied to Q, whereas the Pasquill formula which was used by Turner in his workbook does not. In deciding whether the Turner (Eq2) or Clancey (Eq3) approach is most appropriate to the circumstances of waste disposal, consideration must be given to the uncertainties due to the inherent variability of waste itself. Hence the advantage of Clancey's simpler approach with its inbuilt factor of safety would seem to outweigh the potential higher accuracy which would follow from the use of Turner's workbook. Using the same argument, Lutzke's equation is the quickest way to find the downwind location of the critical distance. However the application of Benaires rule which provides an extremely simple approach, presents difficulties both because its use is handicapped by uncertainty over the appropriate factor to use during the transition from day to night time conditions, and because it merely provides a dosage normalized to unit emission of the source; a concept with which occupational hygienists are not familiar.

In addition the Benaire approach seems unduly simplistic, even if cognisance is taken of the compensating factor affecting plume center-line dose concentrations due to the path of high winds meandering less around their mean direction (this directional stability having the effect of compensating for the stronger longitudinal diluting effect of high velocities). In practice the effects of a change in wind velocity differ with the mechanism of release of the pollutant. For most substances down-wind concentration will tend to decrease with a higher wind speed and hence be capable of being corrected in the manner suggested above, however significant changes in the stability of the atmosphere are capable of causing unrelated changes and in the case of volatile liquids, vapour concentration downwind is markedly dependent on wind speed, because this factor actually regulates the rate of evaporation.

## SUMMARY

Mathematical modelling of evaporation from free liquid surfaces and the subsequent dispersion of airborne pollutants, were shown to be relatively straight forward techniques, and the small amount of verification which is available, suggests that these approaches have their uses, providing they are treated with caution. Benaires rule, however, seems to possess serious limitations.

# CHAPTER 8

# LABORATORY EXPERIMENTS

## 8.1 Generation of gases from mixing of chemically incompatible substances.

It is not possible from a simple examination of the stoichiometry of a reaction to predict the rate at which it will proceed (168) For example, many of the substances familiar in our environment are unstable from a thermodynamic viewpoint - the fossil fuels, coal, petroleum and natural gas should according to thermodynamic calculations be converted to carbon dioxide and water upon exposure to air. Although this reaction does indeed take place, it occurs so slowly that it can be ignored in virtually every situation (the case of coal in very large bunkers being one exception).

In fact a chemical change will only proceed spontaneously if the "free energy" $\Delta G$ is negative and the kinetics of the reaction are favourable (169).

Consider thermodynamic and kinetic aspects of the following reaction:-

$Na_2S(S) + 2\,HCl(aq) \Rightarrow H_2S(g) + 2Na\,Cl\,(aq)$ (Reaction 1)

If the enthalpy of this reaction is calculated a decrease will indicate that the reaction is exothermic.

Enthalpy of reaction can be calculated from molar enthalpy of formation of the products minus the molar enthalpies of formation of the reactants. (These values can be taken from thermodynamic tables)

| | | | |
|---|---|---|---|
| $\Delta Hf\ H_2S(g)$ | $-\ 20.5\ kJmol^{-1}$ | $\Delta Hf\ Na_2S(s)$ | $-\ 372.4\ kJmol^{-1}$ |
| $2\Delta Hf\ Na^+(aq)$ | $-480.2\ kJmol^{-1}$ | $2\ \Delta Hf\ H^+(aq)$ | 0 by definition |
| | $(-\ 500.7\ kJmol^{-1}$ | - | $(-\ 372.4\ kJmol^{-1}$ |

$\Delta$ Hf reaction = $128.3\ kJmol^{-1}$

$\therefore$ reaction is exothermic.

If the free engergy $\Delta G$ is similarly calculated a negative $\Delta G$ will indiate that the reaction is thermodynamically favourable:-

$$\Delta G_f H_2S(g) - 33.4 \text{ kJmol}^{-1} \qquad \Delta G_f Na_2S(s) - 361.5 \text{ kJmol}^{-1}$$

$$2 \times \Delta G_f Na^+(aq) - \underline{523.8 \text{ kJmol}^{-1}} \qquad 2 \times \Delta G_f H^+(aq) \quad \underline{0 \text{ by definition}}$$

$$\underline{\underline{(-557.2 \text{ kJmol}^{-1})}} - \qquad \underline{\underline{(-361.5) \text{ kJmol}^{-1}}}$$

$\Delta G_f = - 195.7$ kJmol$^{-1}$ Therefore the reaction is thermodynamically favourable.

Thermodynamic principles can be used to show whether the reaction is likely to proceed to completion thus:-

$\Delta G = -2.303 \text{ RT} \log K$ where K = equilibrium constant

R = Gas constant

T = Temp°K

substituting the values obtained so that

$$- 195.7 \times 10^3 = - 2.303 \text{ RT} \log K$$

$$\frac{195.7 \times 10^3}{2.303 \times 8.314 \times 298.15} = \log K$$

$$34.2 = \log K$$

$K = 1.9 \times 10^{34}$ that is $\dfrac{H_2S \quad Na^{+\ 2}}{H^{+\ 2}} = 1.9 \times 10^{34}$

hence the reaction goes virtually to completion.

(Assumes presence of solid $Na_2S$ which concentration is therefore unity, and chloride ions have been ignored as they appear on both sides of the equation)

Having determined that the reaction is favourable on thermodynamic grounds and goes to virtual completion, kinetics will reveal if the reaction will actually proceed.

Kinetics is largely an empirical study and provides a method for studying what happens at molecular level in chemical reactions.

The rate of a reaction J can be expressed as the rate of appearance of products or disappearance of reactants (170).

$$J = \frac{1}{u}\frac{d(\mathrm{Prod})}{dt} = \frac{1}{u}\frac{d(\mathrm{React})}{dt}$$

where

u = stoichiometric number + for products - for reactants.

In general for a reaction $A + B \rightarrow$ products, a rate equation will show:

rate $(J) = k_R \left[A\right]^{n_1} \left[B\right]^{n_2}$

where

$k_R$ = rate constant $n_1$ and $n_2$ are orders of reaction with respect to A and B.

(The powers to which the concentrations of A and B are raised are not necessarily integers and may, or may not, be the stoichiometric numbers). Reaction 1 tends to a first order with respect to HCl within concentration limits and the rate of such a reaction can be measured by the production of $H_2S(g)$ which will produce a considerable increase in the volume of the system (168). A similar argument can be advanced with respect to the meeting of HCl and liquid ferrous sulphide:

$FeS\ (aq)$ and $2HCl(aq) \rightleftharpoons Fe\ Cl_2(aq) + H_2S\ (g)$(Reaction 2)

In summary, a potential energy/reaction co-ordinate diagram for an exothermic reaction will have the form shown in Figure 8.1

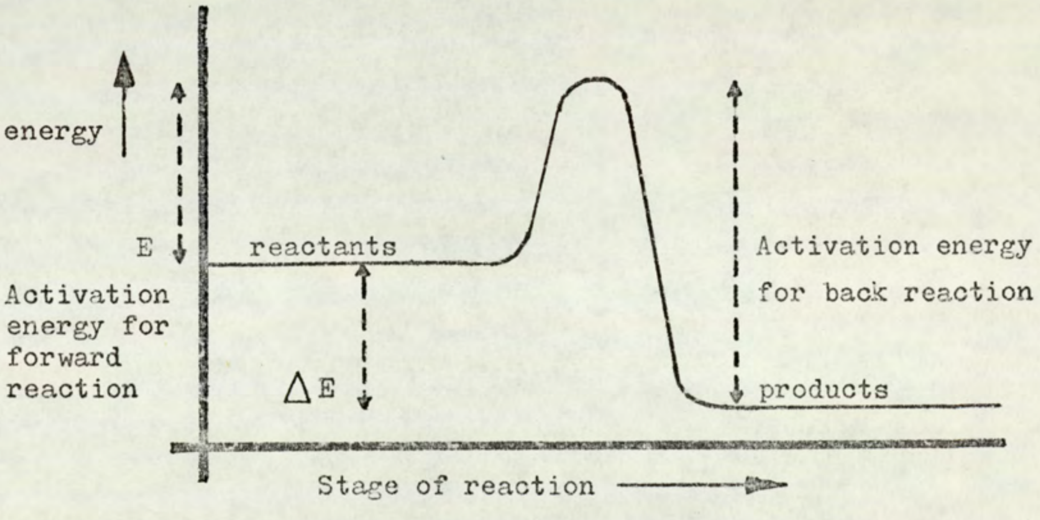


FIGURE 8.1 Potential energy/reaction co-ordinate diagram for an exothermic reaction.

As the rate of hydrogen sulphide production is proportional to the progress of the reaction an experiment was devised which allowed acid and a solid or liquid sulphide to meet in a closed system which had facilities for accurately measuring its increase in volume as a function of time. Details of the experiment appear below in 8.2

## 8.2 Experimental method

A double limbed reaction vessel was connected via tubing to a 100ml Gas Syringe mounted on a vibrating bed. The syringe plunger held a pen which produced a trace on a travelling flat bed chart, as shown in Figure 8.2. The acid and sulphide were kept separate in the reaction vessel until the commencement of the experiment. The reaction vessel was immersed in a thermostatically controlled water bath to a level above that of the reactants. Constant agitation was maintained. Results are set out in 8.3.

## 8.3 Results

Results are given in figures 8.4 and 8.5

## 8.4 Discussion

If $V_{\infty}$ is the amount of $H_2S$ produced when the reaction goes to completion and $V_t$ volume at time t, a plot of $V_{\infty} - V_t$ against time will produce a straight line if plotted on logarithmic graph paper, with a slope of $-k_R/2.303$ from which a rate constant can be calculated. Other plots can be tried. If a straight line is not obtained, however, the reaction may not obey an integer order.

In fact the plot does give a straight line of slope $-E/2.303R$ as shown in Fig 8.6.

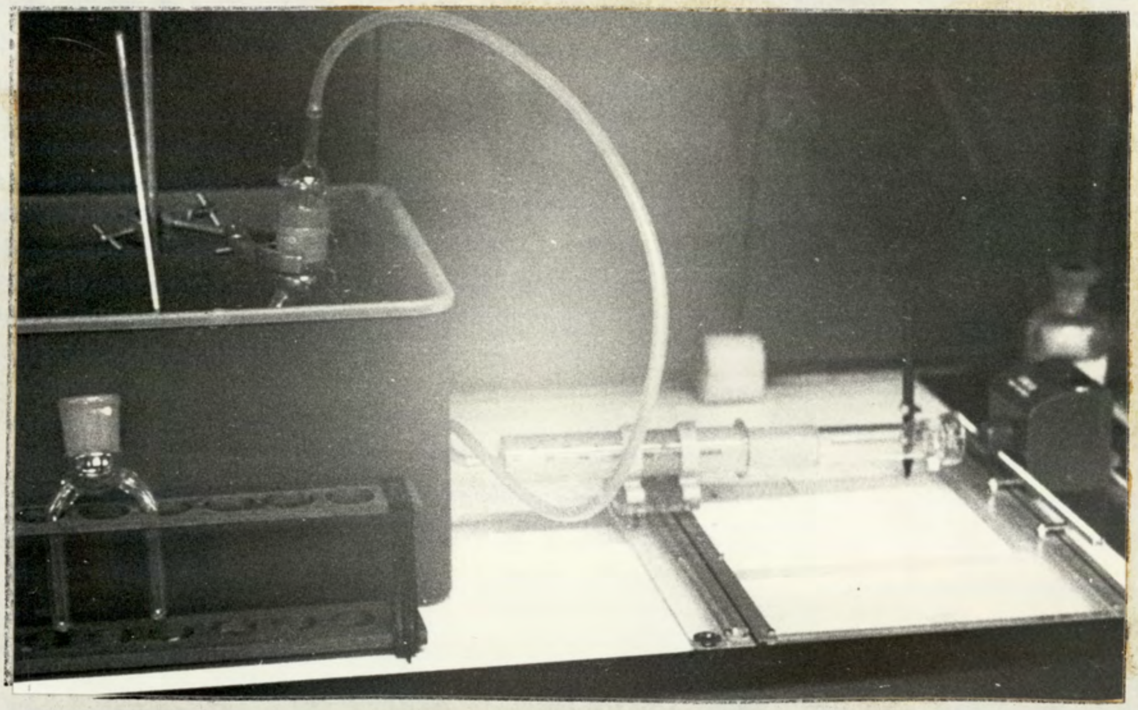


FIGURE 8.2 General view of experimental apparatus showing the divided leg vessel, gas syringe with vibrator and chart drive arrangement.

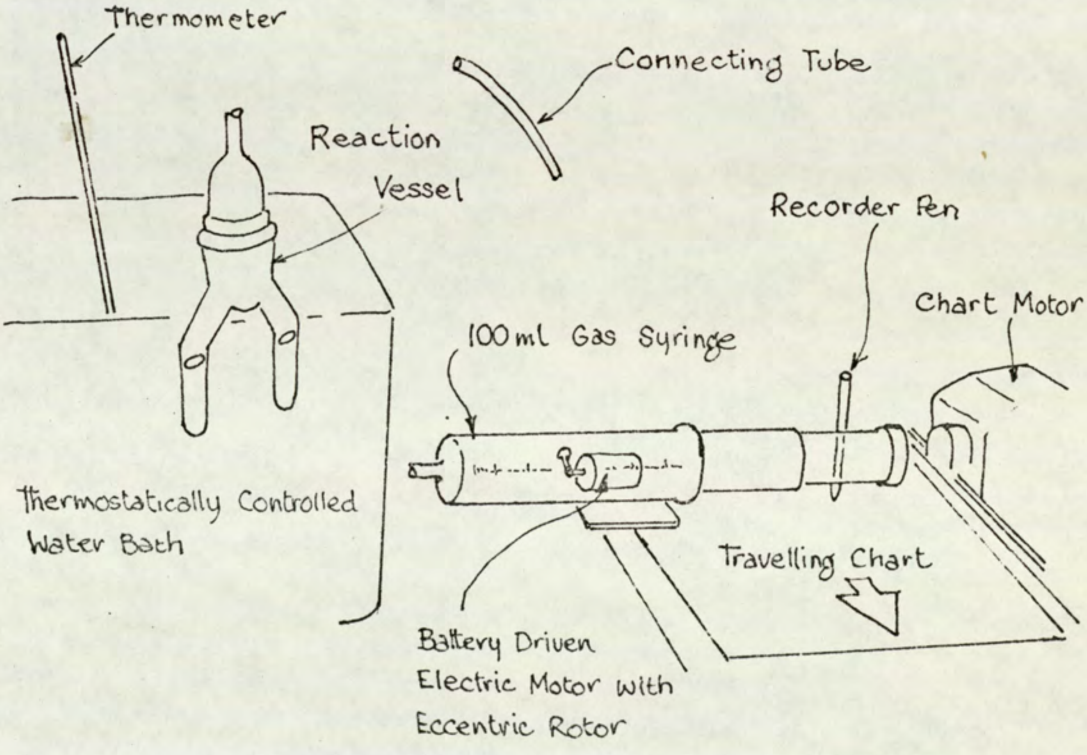


FIGURE 8.3 Annotated line diagram to correspond with photograph in figure 8.2

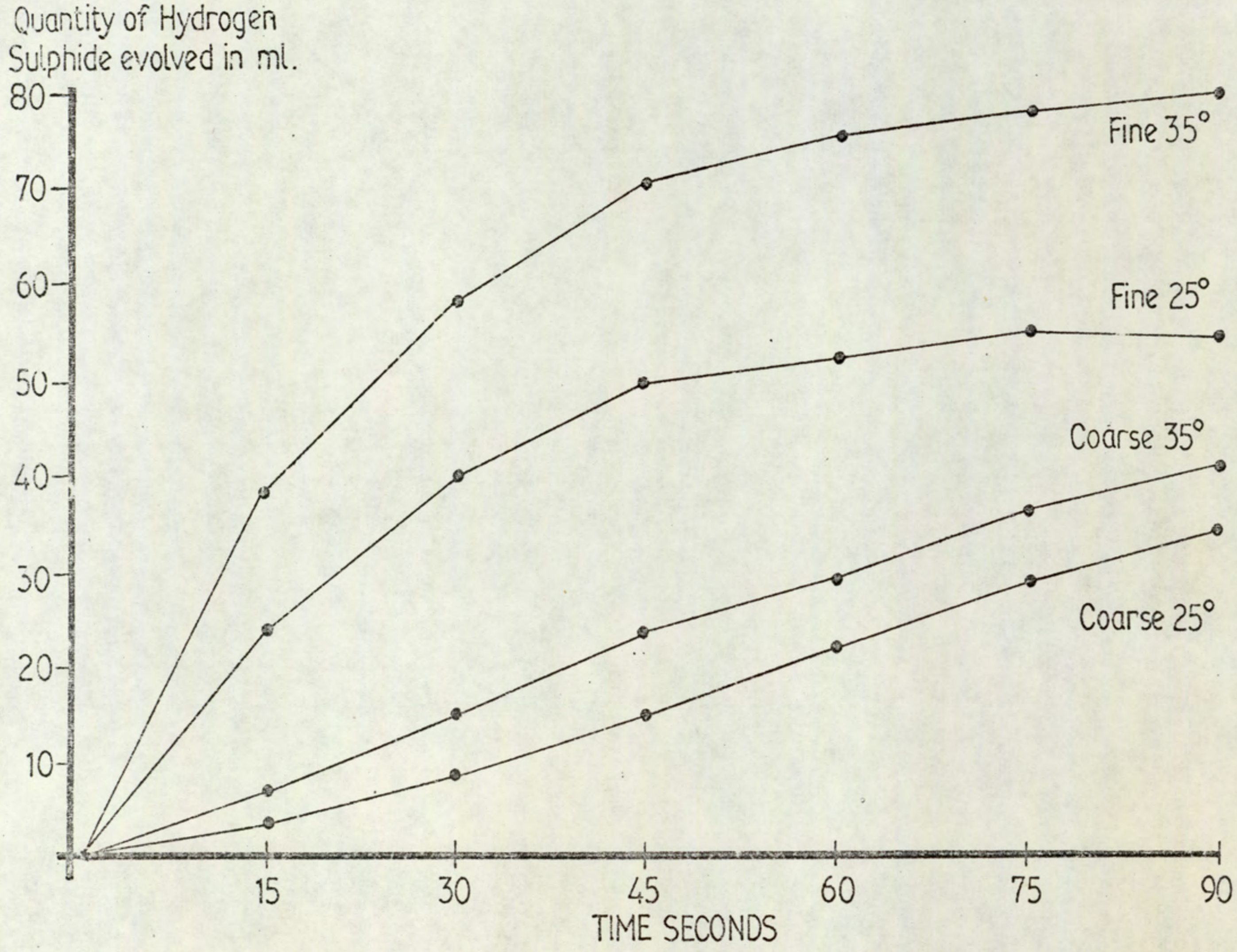


FIGURE 8.4

Results of the meeting of 5 ml of 5m hydrochloric acid and 1gm of ground ferrous sulphide ("coarse" and "fine") at 25° & 35°C.

Coarse = 1200–2400 um

Fine = 150–300 um

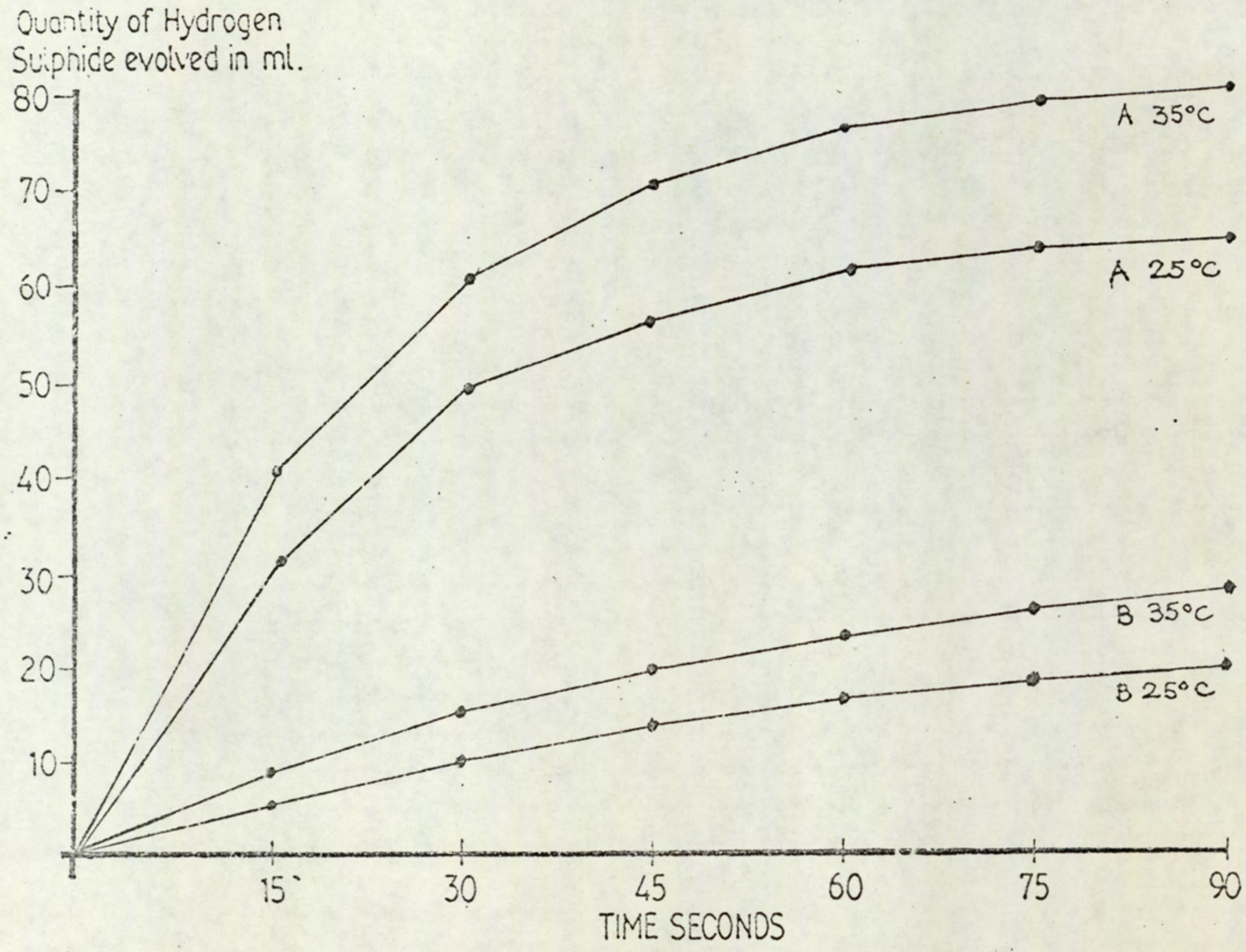


FIGURE 8.5
Results of the mixing of 5m hydrochloric acid and saturated sodium sulphide solution

A 5ml HCl + 5ml $Na_2S$

B 5ml HCl + 1ml $Na_2S$

at 25°C and 35°C in each case

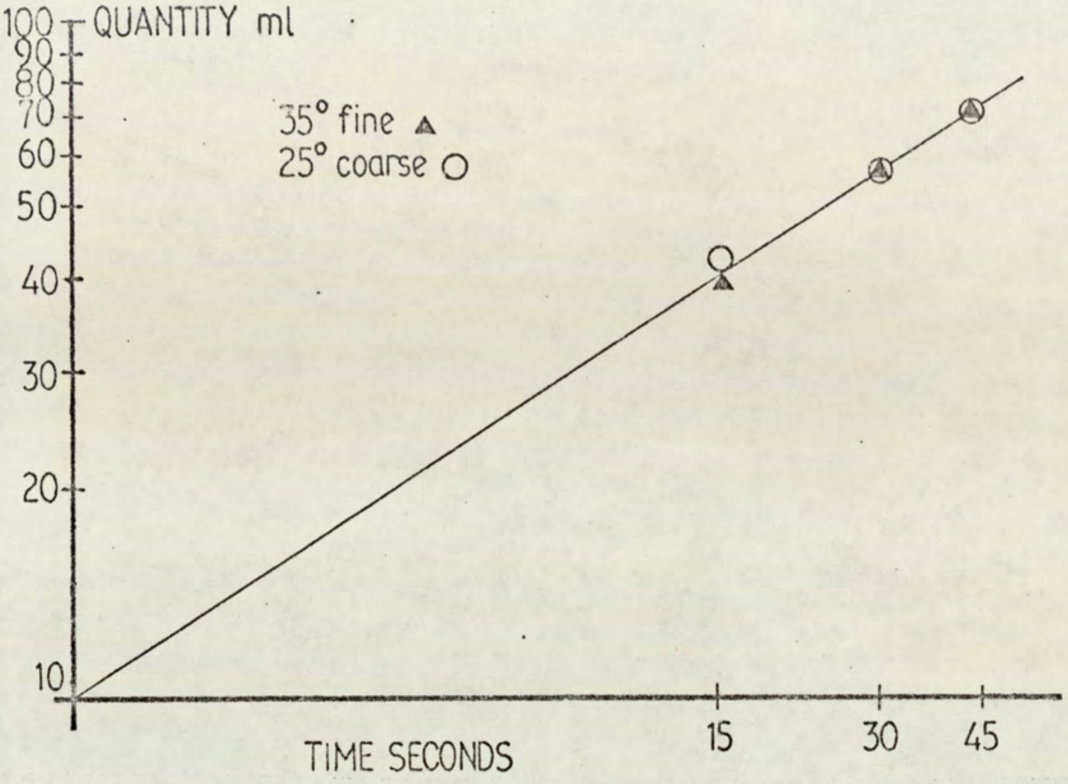


FIGURE 8.6 Comparison of the amount of gas generated as a function of time in the case of 1gm fine $Fe_2S$ (at 35°C) and the incremental increase of coarse (at 25°C) when meeting 5ml of 5M HCl in both cases.

The experiments confirm that the combination of hydochloric acid and certain sulphides results in a very vigorous reaction. Peak levels approaching 0.5 ml of $H_2S$ per second per ml HCl for liquid/liquid or liquid/solid reactions were recorded with reactants at concentrations which can be encountered in waste disposal routines. The reactions did not sustain these peak levels for longer than 20 seconds. Nevertheless because of the extremely swift physiological action of $H_2S$ (28) this is sufficient to give rise to a serious risk to operators when this rate is extrapolated to full scale with tonnage quantities of reactants. Whilst the validity of such simple extrapolation will not stand close scrutiny because of uncertainties over efficiency of mixing, heterogenous composition of waste etc., case studies Nos. 1,2,3,4 and 6 do reveal that a very serious potential for harm is presented in real life situations. This can be further demonstrated by a detailed analysis.

## THEORETICAL ANALYSIS

Laboratory experiments indicate a likely generation rate of .42 ml $H_2S$/sec/ml of 5m HCl when mixed with a 50% solution of sodium sulphide at 25°C.

As a typical tanker might deliver 5 x $10^6$ ml of HCl; hence the maximum generation rate from the mixing of such a load with an equal quantity of sulphide bearing waste would exceed 2 $m^3$/sec. As the density of $H_2S$ is 1.54 gm $litre^{-1}$ this represents approximately 3 kgm/sec. It would be anticipated that mixing would be much less than perfect and discharge may take anything up to five times as long as the laboratory experiment. If an optimistic assumption ie. division by 50 for the imperfect mixing is coupled with ÷ 5 for the extended time element, then the generation rate would be reduced by a factor of 250. This results in a peak generation rate of 12 gm $sec^{-1}$ which might well persist for 100 seconds.

When this value is fed into the dispersion predicting equation 5, the results set out in Table 8.1 are obtained.

TABLE 8.1

Variations with windspeed of critical distance (ie distance within which the TLV/STEL is exceeded) for emission of hydrogen sulphide at 12 gm/sec (based on TLV/STEL 17 mg/$m^3$)

| Wind Speed m/s | Critical distance m |
|---|---|
| 2.5 | 200 |
| 1.0 | 350 |
| 0.5 | 450 |
| 0.25 | 490 |

Should further experiments reveal that similar generation rates are achievable for other substances which might meet in the somewhat unstructured conditions which obtain on some disposal sites, then in a likewise manner similarly unacceptable airborne concentrations will result for distances of hundreds of metres from the mixing area in a downwind direction.

The results also demonstrate that the temperature effect is not large. In fact the Arrhenius equation relates the dependence of rate to temperature

$$k_R = A \exp^{-(E/RT)}$$

or
$$\log k_R = \log A - \frac{E}{2.303\ RT}$$

E being the activation energy.

SUMMARY

The experimental work produced information which emphasized the potential for harm possessed by the uncovenanted mixing of chemically incompatible substances.

# CHAPTER 9

# WIND TUNNEL EXERCISE

## 9.1 Wind Tunnel Exercise Introduction

Discussions and a literature search confirmed that the modelling of conditions in a low speed wind tunnel was sound (164, 172, 173) and provided some guidance as to the type of tunnel and models required (174, 175).

It was established that a Building Research Establishment pattern wind tunnel would be an acceptable type, and scale models of road tankers could be used at around 1/10th of full size.

## THEORY

Wind Tunnel modelling requires reproduction of (a) geometric, (b) kinematic and (c) dynamic similarity between the model with respect to airflow and the full scale object with respect to wind speed (164). For visualisation tests of sharp edged objects at low wind speeds simulation factors are much less critical than for high speed aerodynamic simulation, thus simplifying the modelling criteria.

### (a) Geometric similitude

This was achieved by using scale models in which the single scale ratio chosen (1/10th and 1/15th in this case) was enforced in respect of the corresponding dimensions of each of the principal features. (See Figure 9.3for details) Effects of minor protrusions such as rear view mirrors, were assumed to be small enough to be ignored.

### (b) Dynamic similitude

This was reproduced by scaling up the airflow by the same factor used in scaling down the model. Hence viscous and inertial forces of both systems were identical. Therefore, with an actual tunnel airflow of 1.5 metres/sec the flows being modelled were 0.15 metres/second in the case of the 1/10th scale and 0.1 metres/second for the 1/15th scale. The actual airflow being modelled in both instances corresponded to 'very light airs' on the Beaufort Scale which were just the type of conditions likely to maximise problems of gas generation.

(c) Kinematic similitude

As this requirement only applies to the relative velocity of any moving parts, its effects were ignored because the stationary mode of discharge of the tankers and also the fact that the gas flow rate from the vehicles exhaust was so relatively minor as to be incapable of being accurately modelled.

An exponent of 0.16 was chosen as representing the 'open level country' characteristic of most waste disposal site locations and the velocity profile was developed utilizing the power law principles.

## 9.2 Wind Tunnel Experimentation

EQUIPMENT

1. Wind Tunnel

The tunnel is illustrated in figures 9.1 and 9.2 and comprised an open circuit type constructed to the Building Research Establishment specification 69/68 (176) with facilities for variable velocity production within the 0.5 to 6 metres/second range. Its working section was ducted to give sufficient capacity to accommodate models subject to non infringement of the maximum blockage factor of 7.5%.

The tunnel complex was located in a large room and consisted of a bellmouth entry with a honeycomb and smoothing gauze in its throat leading into a settling length of 0.75 m to smooth out air turbulence. At the end of the settling length was a working section within an enclosed observation chamber. This comprised a working table 1.05 m wide and 2.25 m long, by 0.75 m high. The transformer section downstream converted the working cross-section of the tunnel to a shape and size suitable for the fan mounting without generating turbulence. The fan was driven by a 750 watt (one h.p.) electric motor controlled by a variable speed unit.

The observation chamber was large enough for two persons to operate using anemometers to measure air velocities, to operate the smoke generator, to take gas samples etc. All interior surfaces and models were painted matt black to facilitate visualization exercises.

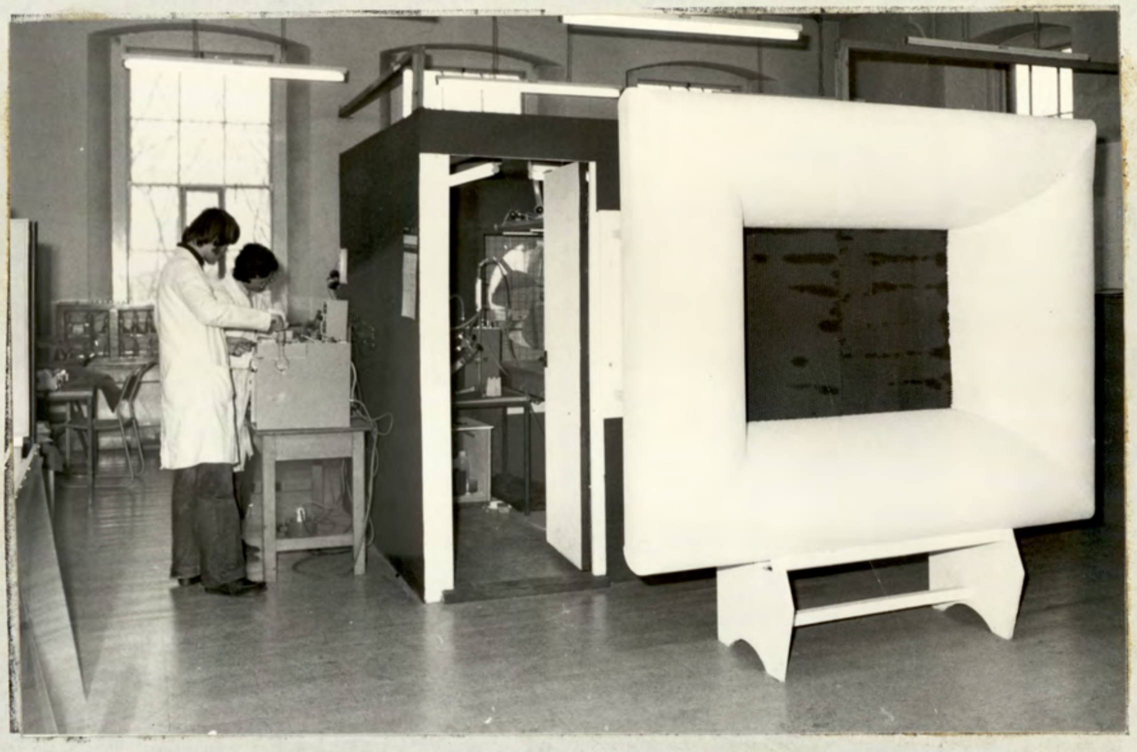


FIGURE 9.1 General view of the wind tunnel showing the open circuit nature, the bellmouth entry and gas chromatograph location

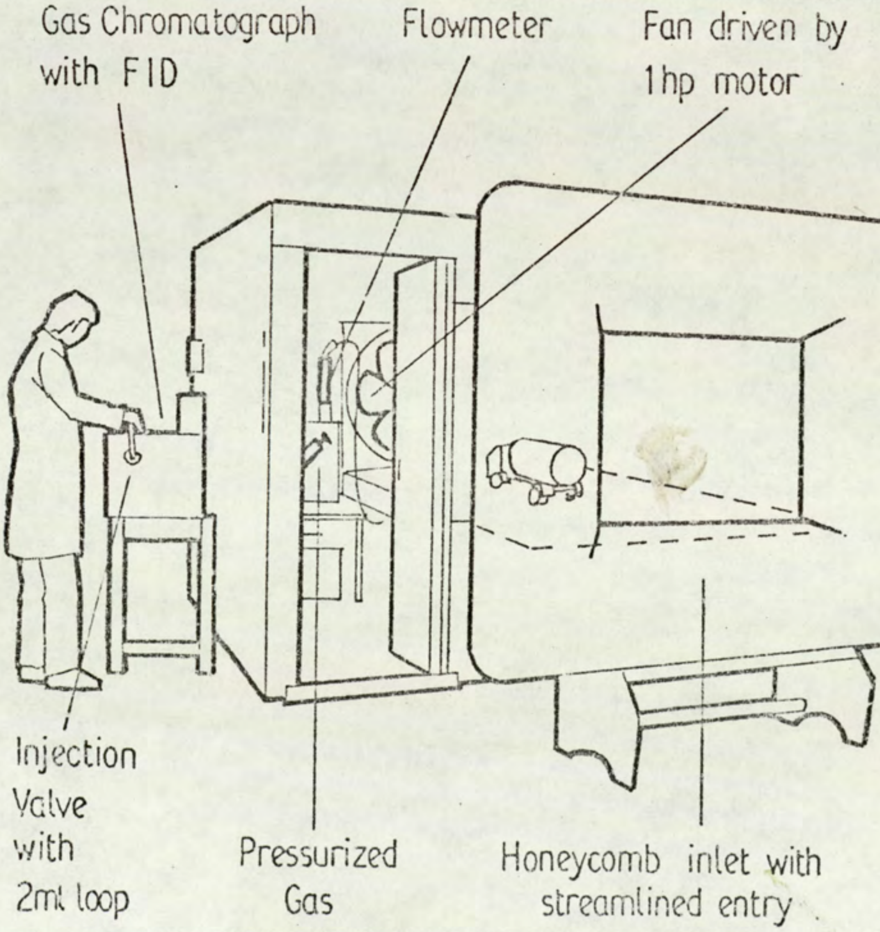


FIGURE 9.2 Annotated line diagram to correspond with photograph in Fig. 9.1

Directional lighting, overhead viewing facilities and stroboscopic illumination techniques facilitated the observation of airflow patterns and dispersion fields when smoke generation or helium filled bubbles were generated. A not wire anemometer was used to monitor air flow velocities (up to 2.1 metres/second) with pitot static tubes for higher velocities. The tunnel was calibrated to within a small (5%) variation of its mean velocity throughout its working range. The use of the graded slats horizontal to the tunnel floor at right angles to the flow allowed the development of the appropriate velocity profile within the tunnel.

## PROCEDURE

Initially an 'idealized design' tanker was constructed to 1/10th scale and a smoke generator was used for flow visualization. Investigation of the concentration of dispersants within the cab of the vehicle necessitated constructing a smaller model as the provision of an opening door on the 1/10th scale model breached the rule that the effective cross sectional area of the tanker should not exceed 7.5% of the tunnel area. Calculations based on tanker dimensions allowing for the size of an open door showed that a scale of 1/15th would be necessary. At this stage an accurate scale model of a vehicle with the most common tanker barrel dimensions was produced using manufacturer's drawings.

Figure 9.3 sets out the tanker dimensions utilized.

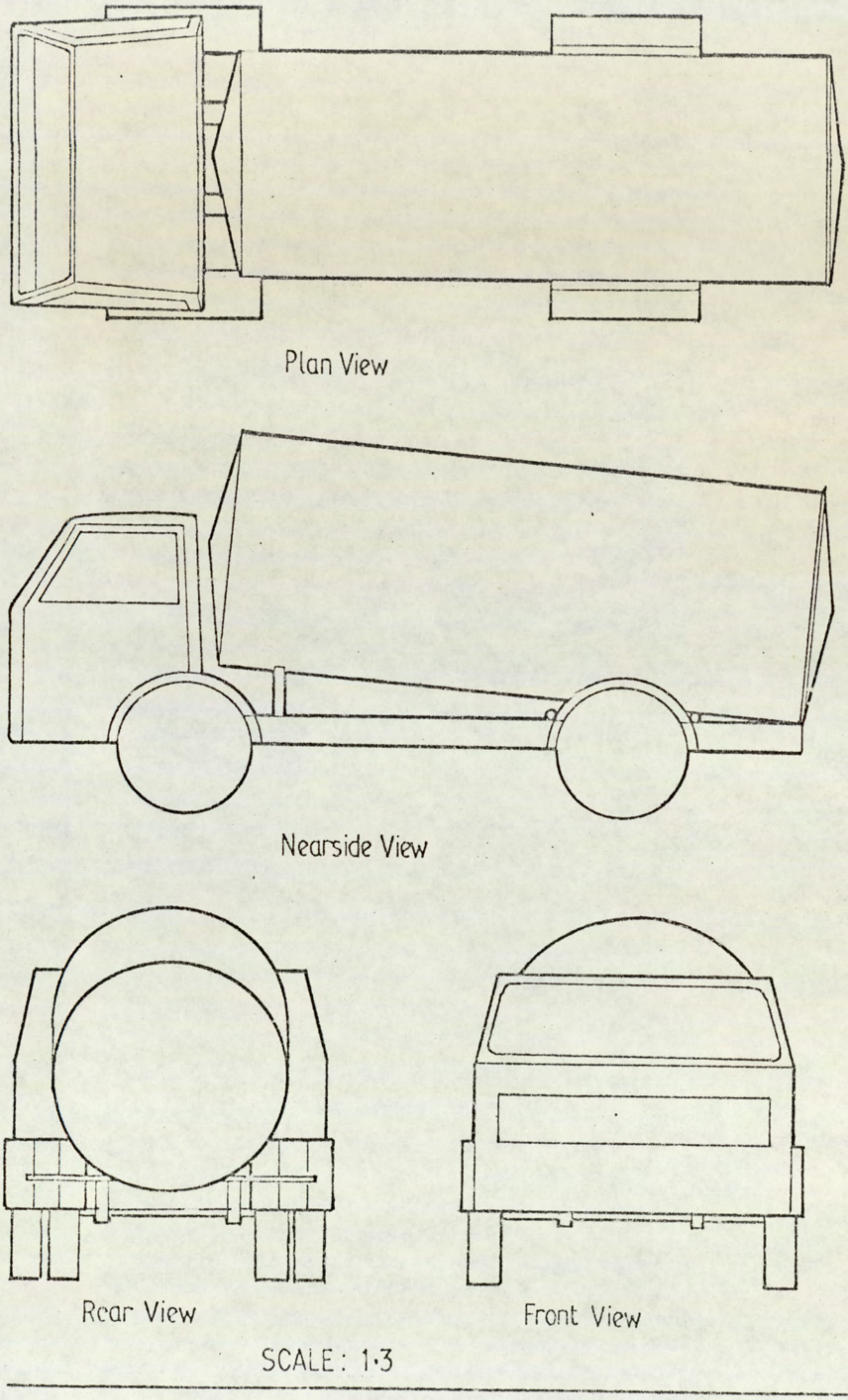


FIGURE 9.3 Dimensions of 1/15th scale tanker corresponding to Class 11 HGV 6 wheel chassis, 24 tonne maximum GVW carrying 3,000 gallon (1,3620 litre) tank.

To coincide with the change in scale helium-filled soap bubbles were used, instead of smoke, to trace the dispersion pattern. The bubbles were of similar density to air and hence the experiment was free of any bias due to the thermal lift exhibited by the smoke. The results of the visualization experiments encouraged progression to the use of a tracer gas. Initially the gas was liberated through a 5 mm diameter pipe flush with the tunnel floor. This was modified to a diffusion ending to more realistically model the practical situation of an area, rather than point source emission of contaminants. Several techniques were then explored to facilitate accurate assessment of concentration levels downwind of the generation point. In view of the very accurate measurements to be made the instrumentation required needed to be highly sensitive. It also had to be located in, or adjacent to, the wind tunnel for an extended period of time. Eventually a Pye 104 GLC was sited on the external wall of the tunnel. It was decided that pump delivery of metered samples of air from inside the tunnel was impracticable when it was discovered that no proprietary system which was compatible with the 104 was recommended and it would be necessary to fabricate a system which would have involved a great deal of development work. A simple method utilizing a number of airtight syringes which were then injected in turn into the GLC was therefore developed.

Vapour densities of relevant gases as set out in Table 9.1 were ascertained and suitable gases with corresponding densities and which would be identified on the flame ionization detector were chosen. Tests with carbon dioxide were abandoned due to the need to also operate a katharometer detector to quantify the samples.

The first experiments were carried out using ethylene which has a vapour density very similar to that of air (0.978). Subsequent experimentation was with a light gas, methane (0.563). and two heavy gases, butane (2.04) and "isceon 502" (5.02).

TABLE 9.1

Vapour densities (air = 1) of relevant and selected * gases

| Gas | Vapour Density |
|---|---|
| Toluene Diisocyanate | 6.0 |
| Perchloroethylene | 5.83 |
| Carbon Tetra chloride | 5.32 |
| *Isceon 502 (chloropentafluoroethane 51.2 %wt)<br>(chlorodifluoromethane 48.8 %wt) | 5.02 |
| Trichloroethylene | 4.53 |
| Phenol | 3.24 |
| Aniline | 3.22 |
| Toluene | 3.14 |
| Benzene | 2.77 |
| Arsine | 2.66 |
| Chlorine | 2.49 |
| Sulphur Dioxide | 2.2 |
| Ethyl Mercaptan | 2.14 |
| *Butane | 2.04 |
| Propane | 1.56 |
| Carbon Dioxide | 1.53 |
| Hydrogen Chloride | 1.36 |
| Carbon Tetrachloride | 1.33 |
| Hydrogen Sulphide | 1.19 |
| Phosphine | 1.18 |
| Nitrogen Dioxide | 1.15 |
| Ethane | 1.04 |
| Carbon Monoxide | 0.97 |
| *Ethylene | 0.97 |
| Hydrogen Cyanide | 0.94 |
| *Methane | 0.67 |
| Ammonia | 0.59 |

FIGURE 9.4 Detail inside the tunnel. The gas sampling technique is being demonstrated with the flow meter and helium filled bubble generator also visible.

2. Analytical Instrument

Pye 104 gas chromatograph provided with flame ionization detector head coupled to Servoscribe flat bed chart recorder.

Problems were encountered initially of very short injection septa life due to the relatively large bore of the sampling syringe needle. Eventually modified injection valves with storage loops of 0.5, 1, 2 and 5 ml capacity were utilized. This enabled the contents of a syringe to be introduced into the storage loop and then swept into the column by the carrier gas. Appendix XV displays a typical chromatogram which was obtained.

3. Tracer Gas Source and Calibration : 0.06 $m^3$ ( 2 $ft^3$ ) capacity bottles of pressurized gas (methane, ethylene, butane and isceon 502). Pressure gauges and regulating needle valve.

Gas flow meters, with 0 - 10 unit scale and conversion charts for the above gases in the 10 - 1000 cc/minute range, were used to measure flow and discharge was via a diffuser ending with a circular 700 $mm^2$ area.

4. Gas tight syringes of 5 ml capacity with 0.05 mm diameter needles were used for sampling. Syringes were flushed out with an inert gas between samples.

## 9.3 Results of Wind Tunnel Modelling Exercise

The initial visualization exercise with a heated smoke demonstrated that the 1/loth scale tanker induced a large amount of turbulence in its wake as demonstrated in Figure 9.5 and smoke concentrations around the cab were high. To explore this further a driver's door was cut into the cab of the model and the experiments repeated with the door open. Quantities of smoke were observed to enter the cab and so that this aspect could be properly investigated in subsequent studies, a 1/15th scale model was constructed as detailed in 9.2.

To obviate the thermal lift associated with heated smoke,subsequent visualization was achieved using helium filled soap bubbles with an effective density equal to that of air. Figure 9.6 shows the smaller tanker in use with the helium filled bubbles. (In this photograph the bubbles merely show as circles of light against the matt black exterior of the model.) This technique also demonstrated turbulence in the vicinity of the cab and some penetration into it, although the airstream was now shown to impinge upon the flat end of the tanker barrel and to rapidly diffuse to a much lower concentration.

An average of approximately 100 samples were taken with each of the four different density gases. Gas flows were varied within the scaled parameters indicated by the results of Section 7.4 and readings were taken at standard positions around the tanker as illustrated in Figure 9.7. For comparison, some additional measurments were taken without the tanker in position. Most of the experiments were undertaken with a fan speed which induced a wind velocity corresponding to "light airs" at the discharge point, although for comparison purposes, some tests were undertaken at higher air speeds. Results are set out in diagrammatic form in Figure 9.7. Appendix XII shows a typical chromatogram.

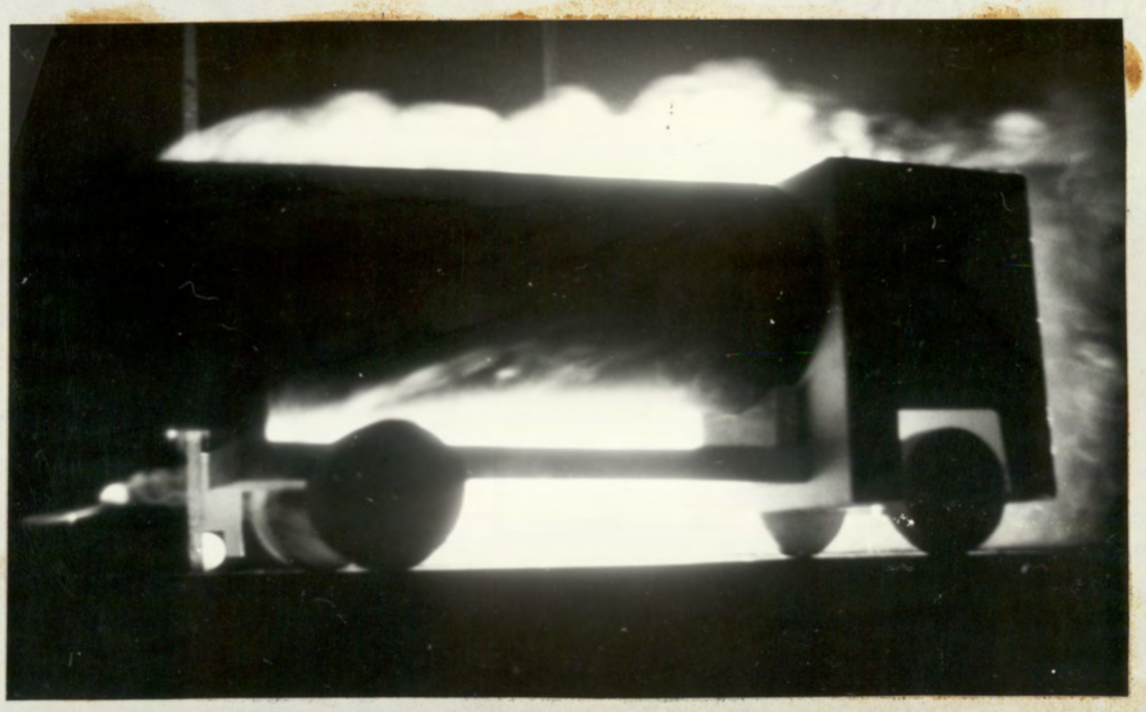


FIGURE 9.5 1/10th scale idealized design tanker in wind tunnel with smoke generator in use showing the smoke concentration build up around the driving cab and the thermal lift imparted by the heated smoke

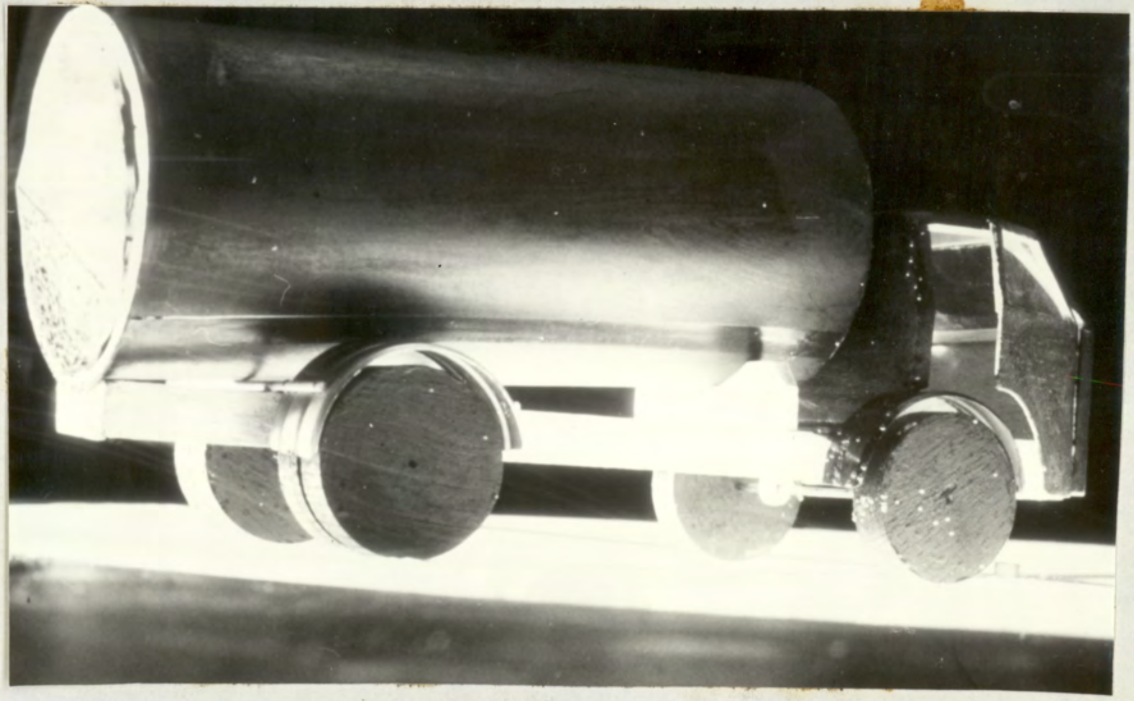


FIGURE 9.6 1/15th scale specific design tanker in wind tunnel with helium bubble generator in use demonstrating the difference in dispersion of a tracer with the same density as air

With the exception of those density differences induced by large temperature gradients, few theoretical studies or field measurements have been published on the dispersion of gases with densities markedly different from that of air, hence it is not feasible to compare these experimental results with detailed predictions available from the findings of other researchers.

However, outline comparison of the figures for dispersion of a low density gas with results of full scale experiments measuring ground level concentrations close to elevated high temperature emission sources (177), show an absence of the very extreme variations which are reported in the latter case where an individual sampling position is likely to be subject to the effect illustrated in A of Figure 9.8. In the case of a ground level emission adjacent to an obstruction as modelled in this study however, these wide fluctuations appear to be damped down. This will in part, be due to the sampling method used, which smoothed out fluctuations with periodicies less than five seconds, but may also be due to the drag of the dispersing pollutant envelope against the ground which lessens the likelihood that eddies will have the same significance at or around head height, as illustrated at B in Figure 9.8.

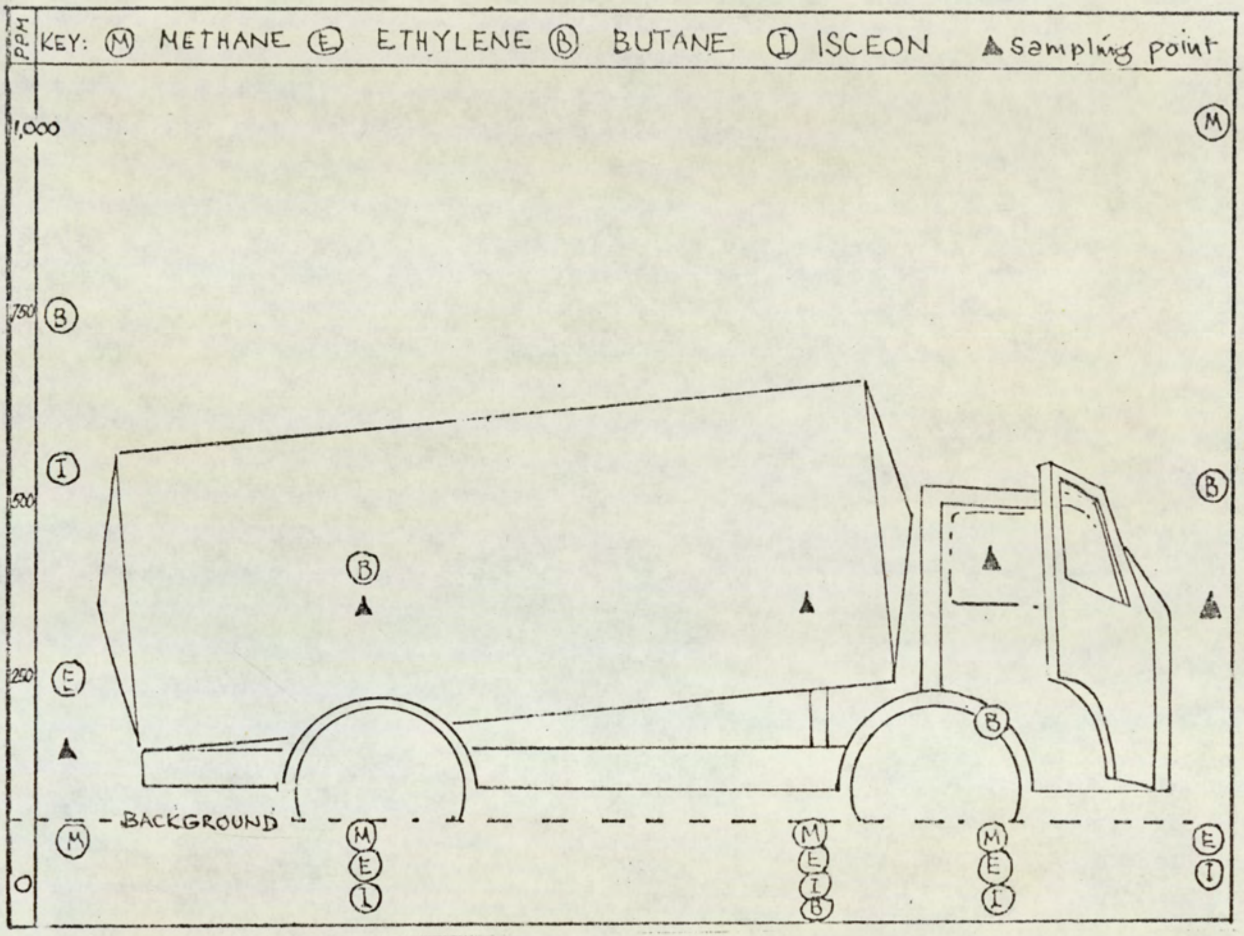


FIGURE 9.7 Results in diagrammatic form of gas sampling in vicinity of model tanker. Wind speed corresponding to "light airs" and gas flow release to 1 gm/sec.

### 9.4 Discussion of Results of Wind Tunnel Exercise

Measurements of the dispersion patterns as displayed in 9.3 suggest that in the vicinity of a relatively large obstruction the difference between the density of the dispersant and air is a highly significant factor in determining the likely concentration at any operator position immediately adjacent to the disposal point.

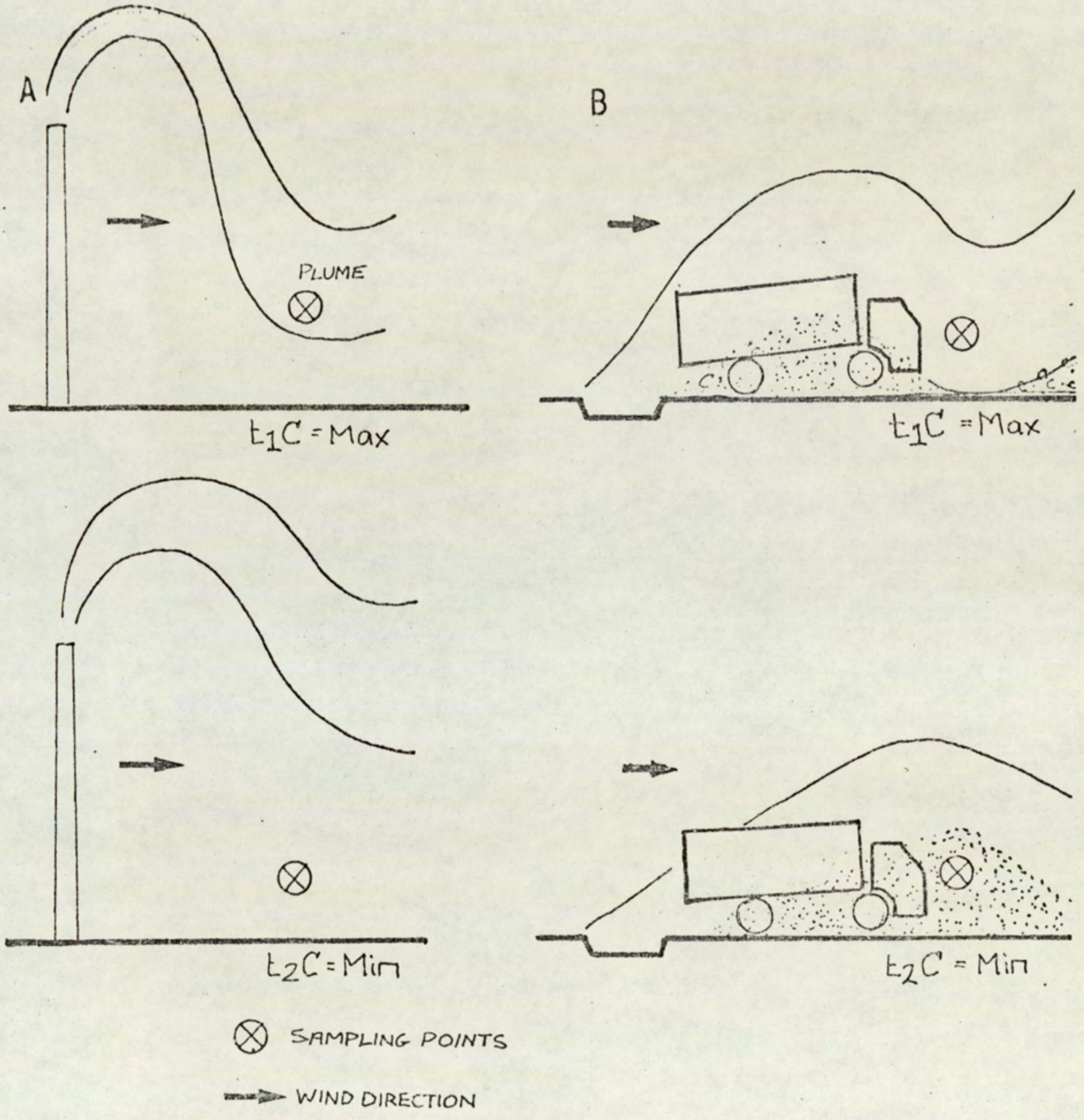


FIGURE 9.8 Representation of the passage of a single eddy for

A) Elevated source such as chimney (179)

B) Ground level source such as disposal pit adjacent to a large obstruction.

In respect of concentrations around the cab, there was a lack of correlation between the results of the smoke visualization exercise and the gas tracer study. (The readings for ethylene, which has a density similar to that of air, did not exhibit any significant increase in cab concentration contrary to expectations following the visualization exercise). However, the visualization exercise was of extremely limited scope and the tracer smoke subject to thermal lift. Moreover, neither of the discharge heads lent themselves to a correct 'area discharge' simulation nor could they be discharged at tunnel floor level. Accordingly, the entrainment and surface flow involvement which is characteristic of true ground level emissions was not correctly modelled by these techniques.

## SUMMARY

More research is required before reaching authoritative conclusions, but with regard to the validity of the approach, other workers have subsequently chosen the same gas tracer modelling technique (178, 179) for allied research topics.

The wind tunnel studies indicate that simple dispersion calculations are inappropriate to the prediction of likely airborne concentrations in the immediate vicinity of a discharging tanker. The density of the dispersing gas appears to be a major factor, for which no allowance is made in the classic dispersion equations.

Hence, attempts to accurately predict airborne contamination levels by these methods are inadvisable. Recourse to a 'worst possible' concept, in which the theoretical maximum concentration of the air pollutant at the point of generation is taken as the possible level at all points adjacent to the disposal point would seem more appropriate. This value should be increased by an adequate (perhaps x5) safety margin.

# CHAPTER 10

# CONCLUSIONS, RECOMMENDATIONS AND APPLICATIONS

## 10.1 Major Conclusions

This study demonstrated that in some circumstances operators engaged in toxic waste disposal were being unnecessarily exposed to potentially serious health hazards.

A major problem observed was the lack of positive identification of wastes and the generally uncontrolled nature of waste handling operations. The carrying out of disposal operations in the open air had led to an over reliance on the atmospheric dispersion of dangerous gases and dusts. In fact, it provided no firm assurance of safety.

Theoretical computation of the extent of the risk from airborne contaminants might be of value at distances of several hundred metres, but was insufficiently accurate close to the point of generation.

The codes of practice and training systems used by the industry during the time of the study were generally unsatisfactory.

Whilst the relatively small number of operators at risk make it questionable whether extensive additional research is justifiable in such a low cost situation, the fact that waste disposal operations often have significant environmental impact potential does emphasise the need for more research. In the interim, it might be most cost effective simply to outlaw certain practices and introduce wider safety margins into operations generally.

## 10.2 Subordinate Conclusions

1. The disposal of the three million tonnes of toxic waste produced annually in Britain was by three main methods, of which landfill was the most significant. During the last decade the impact of several official reports on waste disposal and some legislative innovations have altered the hazards to operators in toxic waste disposal. A slightly smaller total number of operators (perhaps 1,500) were found to be at risk but the potential of individual risk was higher because of the concentration of toxic wastes at a relatively small number of sites. In total less than 50 sites specialized in toxic waste disposal with several hundred also accepting small amounts of toxic waste along with other wastes. The extent of national research activity was found to be insufficient to provide all the information necessary for an objective assessment of the extent of these hazards. To this extent the direction and emphasis of the work in this thesis was justified.

2. Several factors explained the insufficiency of resources devoted by the toxic waste disposal industry to monitoring the levels of potentially troublesome contaminants or maintaining a close interest in safety performance. These included:-

(i) The difficulty of measuring accurately the levels of airborne contaminants evolved in the disposal of toxic wastes (particularly in the open). Although studies have been published of dispersion rates in other industries and fields these usually related to single contaminants either generated purposely or released at a predictable rate from a specific source.

(ii) Attempts to accurately measure the levels of airborne contaminants presupposed access to a range of sophisticated sampling and analytical equipment and an ability to predict the nature of the expected contaminants and whilst toxic waste disposal plants were carrying out chemical engineering operations many of the companies involved were only just evolving from being essentially transport undertakings and hence lacked the necessary expertise and specialist staff. Even where disposal was undertaken by the company which itself produced the waste, disposal was less rigorously policed than the production routines.

(iii)Because Factories Act legislation was inapplicable to the Solid Waste Industry (see 2.3) there was a dearth of information on the incidence of accidents due to gassing, burns from corrosive substances etc. Additionally, the scattered locations and small numbers of employees at each site has not favoured the development of strong unions who have intervened on their members behalf and demanded enquiries into accidents, full environmental monitoring etc.

3. Sites could be classified with respect to their likely safety rating by the method described in Chapter 4 which showed that landfill sites exhibited a wider range of hazard rating than incinerators and chemical treatment plants. Some improvement with time was apparent across the results in both categories.

A simple comparison of accident records from two representative sites led to the conclusion that the ratio of severe accidents to all accidents on landfill sites was 1 to 3 whereas at incinerators and chemical treatment sites the ratio was 1 to 2.

The flow chart of operator duties developed in the study (Table 4.1) provided a successful method of classifying activities. It was concluded that a very significant hazard present in the disposal routines utilized on certain sites, was the potential for exposure of operators to hazards from admixtures of chemically incompatible wastes. This tendency had been found to be exacerbated by the poor identification of wastes and the generally uncontrolled methods of waste handling, which were prevalent on some landfill sites. The Case Studies illustrated the extent of the hazards and the investigation of actual incidents and some experimentation demonstrated that the generation rate of an attack gas following the combination of incompatible substances was sufficiently high to present a potential threat to any operators in the immediate vicinity of the combining substances.

The commonest waste disposal operations resulting in the liberation of hazardous gases were summarized in Table 4.3. Investigations on sites and an analysis of case studies numbers 1, 2, 3, 4 and 6 revealed that the probability of incompatible substances actually meeting was sufficiently high to form a serious cause for concern and that even in the open air atmospheric dispersion provided no assurance of safety. This was confirmed experimentally.

4. It was shown that quantitative risk criteria are theoretically applicable to toxic waste disposal operations. An exercise (5.3) in respect of one waste disposal routine produced a tentative FAFR which permitted the significant elements of the operation to be identified.

5. The simulated full scale environmental monitoring exercise described in Chapter 6 demonstrated that the extent of the resources required for this method were beyond the scope of this thesis. The on site measurement of airborne pollutants also described at 6 provided some indication of the existence of a problem but insufficient information to properly define its extent.

6. Theoretical computation of evaporation rates from free liquid surfaces in Chapter 7 was used to predict likely generation rates where volatile wastes are disposed of by landfill, and permitted the conclusion that hazardous concentrations can exist for extensive distances down wind from solvent evaporation lagoons. Since the rate of chemical reactions cannot be theoretically computed (8.1) laboratory experiments were devised to investigate the rate at which a toxic gas was formed when two chemically incompatible substances mixed. Extrapolation to full scale operations of this generation rate in Chapter 8 permitted predictions of the amount of gas given off under the 'worst possible' circumstances. These principles may prove to be applicable to the prediction of the rate of gas released when other gases meet in similar circumstances. These small scale experiments with hydrochloric acid and various concentrations and forms of sulphides provide some indication of the likely airborne levels of $H_2S$ generation. A liquid/liquid reaction was assumed to present the greatest risk and in this case a likely maximum generation rate was found to be of the order of 0.5 ml per ml/HCl. Extrapolation of this rate to full scale quantities at ambient temperatures provides a theoretically attainable rate of .3 kgm/sec from an average tanker load assuming instantaneous discharge into a suitably large quantity of sulphide and ideal mixing conditions. The generation rate will depend upon a variety of physical variables of which the quantities of the reagents are most important and speed of discharge and degree of

mixing are highly significant. In practice, whilst the degree of mixing would be less than ideal, the result of a pumped discharge into a pit from a height of 10 metres effected in perhaps three minutes, would obviously be the induction of marked turbulence and hence relatively good local mixing. Certainly, the deaths from $H_2S$ poisoning reported as case study two and complaints of strong odours of $H_2S$ at a distance of over one kilometre from a disposal site bear out the prediction that concentrations of the order of several hundred ppm can occur in the vicinity of such discharges. Any inaccuracies in the assumptions of instantaneous discharge and perfect mixing represent safety factors but do allow for the freak worst possible circumstances which might conceivably occur.

7. Mathematical modelling techniques were shown to be of some value in calculating likely airborne concentrations adjacent to waste disposal operations, but great care is needed because of inherent limitations. As a prerequisite very accurate estimates are needed of the generation rate of the air pollutants but the low cost nature of the waste disposal industry means that very little accurate monitoring has, in practice, been attempted.
Skilled technical advice is required for the proper computation and interpretation of dispersion estimates and few waste disposal enterprises possess expertise of the necessary calibre.
The use of such estimates for predicting likely concentrations at operator stations just a few metres from the generation point can only be justified as a means of obtaining a very crude estimate of the worst possible levels likely to be encountered, and not for positioning any operator in a 'just acceptable' position. Such methods do not provide a reliable enough method of allowing for fluctuations due to the factors set out in 7.1.3 and the uncritical application of a relatively simple dispersion estimate such as Equation 5, could lead to unjustified complacency about operator safety.

8. When these facts are linked to the results of the survey into protective equipment and apparatus reported in 4.8 the conclusion can be reached that current UK toxic waste disposal practice may in some circumstances subject operators to unacceptable hazards. Moreover a successful wind tunnel modelling exercise demonstrated

that none of the mathematical models which are commonly used for for determination of dispersion of atmospheric pollutants are reliable in the first few metres of dispersion, since insufficient allowance is made either for the effects of density gradients between the dispersing material and air, or for the effects of relatively large obstructions such as waste disposal vehicles.

9. A review of the legal requirements (2.3) demonstrated that the significant changes which have occurred in the law during the present decade have required managements of toxic waste disposal sites to reappraise their attitude to the protection of operators. However the result of the survey reported in Chapter 4 demonstrated that this reappraisal had yet to have the desired effect on some of the sites visited.

10. The analysis of several toxic waste disposal codes of practice from different sources (5.1) demonstrated many failures to give proper weight to considerations of operator welfare when judged by the standards prescribed in the HASAW Act 1974. None of the safety training systems summarized in Table 5.3 appeared to provide satisfactory instruction within the full meaning of that Act. Prior to the Act very little protection was available, and most work practices were evolved without legislative oversight. As a result a discernable gulf exists between standards current in the chemical industry and those appertaining in many solid waste disposal operations.

11. The environmental implications of toxic waste disposal were outside the terms of reference to this study. However, as certain strictures designed to ameliorate the environmental impact of waste disposal, such as the introduction of site licensing had a definite bearing on operator welfare, it was suggested in 2.4 that the closest possible collaboration between site management, the Health and Safety Executive and both Environmental and Waste Disposal Authorities would be beneficial.

## 10.3 Recommendations for Further Work

Whilst the technical problems faced in toxic waste disposal are relatively straight-forward, the low cost nature of the whole exercise introduces its own rigid constraints and the absence of any broad theoretical base which has been well researched adds to the practical difficulties. Hence there is a general need for more research into the occupational and environmental health issues within the framework of existing economic constraints.

Linesfor future enquiry can be categorized as follows:

(A) Preferred Topics

(1) A comparitive study to identify the difference between health and safety standards encountered in waste disposal and in the chemical industry.

(2) Production of more detailed guidelines for site procedures to permit the production of codes of practice which prohibit certain disposal methods as unsafe.

(3) Research into the safety training needs of the work force engaged in toxic waste disposal to permit evaluation of existing training schemes and encourage the introduction of improvements.

(4) The safety of the use of evaporation as a method for disposing of certain volatile solvents should be properly investigated. The emphasis of the study should be on solvents with a TLV(STEL) lower than 250 ppm which also have a low boiling point.

(B) Minor Topics

(1) An analysis of statistics becoming available from the Waste Disposal Authorities giving details of the quantity and composition of wastes to provide an accurate assessment of the extent of the risk of incompatible substances combining in the disposal process.

(2) Prediction of the rates at which attack gases other than hydrogen sulphide are generated when chemically incompatible substances mix.

(3) A thorough assessment of dust levels to which drivers and bulldozer operators are subjected.

(4) Full scale testing of the results of the wind tunnel exercise. Alternatively the experiments could be repeated in

a larger scale tunnel.

(C) Other topics strictly outside the area of this study:

(1) Work could be usefully carried out on identifying and measuring the effects for local residents of toxic waste disposal routines, especially for uncovenanted incidents such as fires and the mixing of chemically incompatible substances.

## 10.4 Applications to Disposal Procedure

### 10.4.1 DISPOSAL SITE PLANNING AND PROCEDURE

The first requirement at a practical level must be the nomination of an individual, who should be a director in the case of a private company or a Chief Officer in the case of Local Government, who is personally responsible for the maintenance of Health and Safety by using the best practicable means available. Close collaboration between this individual, the Health and Safety Executive, the Waste Disposal Authority and the Local Environmental Health Department is advisable. Guidance in the writing of the obligatory Company Safety Statement has been provided by the Health and Safety Commission which makes reference to the need for rules to be drawn up for specific hazards. In the case of disposal sites this can best be achieved by the use of Operations Manuals. In addition to describing every operation in proper sequence these should identify all the significant hazards and the protection necessary to guard against them. As examples, in devising safe operating procedures attention must be given to the prohibition of lone working in especially hazardous situations; also too much reliance has been placed inthe past on the fact that operations largely took place in the open air and on the 'good sense' of the operators: finally, every entry into a confined space must be covered by a rigid Permit to Work system. Implications from the experimentation in this thesis for the planning of site procedures, include the inadvisability of relying upon simple guidelines such as the assumption that heavy gases hug the ground and also that dispersing gases cannot spread in an upwind direction. Expert guidance needs to be obtained. In addition,the role of the safety representatives needs careful consideration,as such individuals are entitled to demand access to particulars of all the material arriving at the site.

Any survey of the possible hazards might logically begin with those associated with the movement of material over public roads to the site.

There is a deal of speculation at present over the most satisfactory way to mark vehicles carrying toxic waste material. Specific legislation requiring positive identification of loads of virgin chemicals, with an outline of action to be taken in the case of an emergency has recently been introduced. It can be construed in any event, both as a Common Law duty and a requirement of the Health and Safety at Work Act 1974.

The best practical means concept when applied to the problems associated with the arrival of uncovenanted or 'off specification' waste may necessitate the employment of specific checks on the veracity of notifications made concerning the consignments. It is not sufficient to rely upon agreement that the waste has a particular composition. In practice provisions for such checks will vary from the absolute minimum of a simple test kit to a fully equipped and staffed laboratory on site. Hazards to workers taking samples need special consideration. Personal protection for the operators handling toxic waste must include overalls, boots and gloves, any appropriate face or eye protection, and properly chosen and maintained respiratory protection. The emphasis must be on proper maintenance as the glove with a split, or the protective mask which is incorrectly fitted or which has been left lying on the plant may present a greater hazard to the operator than the protection they afford.
Ablutions are to be provided in order to minimize the skin absorption risks associated with many toxic materials (cyanide and certain pesticides being particularly dangerous in this respect) and clothes changing facilities must be properly planned to prevent cross contamination between clean and dirty areas. Proper meals facilities in messrooms which are separated from the work area by changing rooms will prevent the hazards associated with food being consumed in working areas, or workmen eating whilst still wearing contaminated overalls.

In addition to the usual requirements of any industrial establishment for First Aid and fire fighting equipment and expertise, the nature of the undertaking will often require that deluges and eye wash facilities, antidotes and self-contained breathing apparatus are provided. This should be on the advice of a competent specialist. Proper links with the local emergency services (fire and ambulance) must have been forged to acquaint them with the type and scale of hazards. Rehearsals of emergency drills should be a feature of normal operation.

If a data bank was set up to store the results of monitoring of airborne concentrations of gases, dusts and fires during the disposal process, then the next generation of toxic waste treatment plants could be designed on more rational lines than the current 'hit and miss' principles. This need,may well be emphasized by the present tendency to locate disposal processes indoors, rather than following the tradition of open air siting. Such monitoring may, in certain cases, need to be in a continuous mode so that allowances can be made for peak concentrations when calculating likely synergistic effects. Any attack gases which are likely to be present (such as hydrogen cyanide or hydrogen sulphide) may necessitate the provision of automatic warning signals.

### 10.4.2 DISPOSAL SITE DRAFT OPERATOR PROTECTION REGULATIONS

Consideration might usefully be given to the production of specific regulations for waste disposal operations in the same manner that the Asbestos Regulations apply to the special problems in that industry. During deliberations by the Environmental Protection division of the European Economic Community over toxic waste disposal the author was invited to submit a report on his findings on operator hazards. The section of that report dealing with proposals for operator protection legislation is reproduced as Appendix IV.

### 10.4.3 Test Kit

Table 10.1 shows the recommendations for checking the veracity of notifications made under the Deposit of Poisonous Waste Act where some laboratory facilities are available.

TABLE 10.1.

Minimum necessary wastes analysis (180)

| Waste type | Minimum analysis necessary | |
|---|---|---|
| Inorganic | Reaction with water ) Identification<br>Reaction with acids ) of any gases<br>Reaction with alkalis ) evolved<br>Reaction with heat )<br>pH, total solids<br>Presence of sulphides, total cyanide, ammonium compounds<br>Concentration of metals Pb, Zn, Cd, Hg, Sn, As, Cu, Cr, N | For mixtures of inorganic and organic wastes all these analyses should be completed |
| Organic | Calorific value<br>Flash point<br>Miscibility with water (for other wastes)<br>Viscosity at various temperatures<br>Halogen, sulphur, nitrogen content<br>Ash content<br>Analysis of ash<br>Organic content by BOD, COD, PV or total carbon methods | |

The study also illustrated the need for such checks on sites where laboratory facilities were not available - notably sites which had a 'no toxic waste' policy, where the expenditure involved in providing a laboratory to ensure that every load was free of toxic constituents was unjustified. Hence in a collaborative venture (113) a survey was made of the sorts and amounts of materials being deposited or otherwise disposed of as waste plus an analysis of information on the problem of transport of industrial chemicals. A framework of the most probable hazards and ways of grouping them was developed, with particular reference to the nature of the hazard, namely immediate fire risk, strongly corrosive, etc. This influenced the order of testing. A prototype kit was first developed and tested on a number of sites and from this a production kit was developed. This is now marketed by Fospur Ltd under the name Hazkit and a patent application has been filed (181). Detailed particulars including a page from the instruction manual are set out in Appendix XVI.

# APPENDICES

APPENDIX I Factory, September 1973 pp 37, 39

# Solids waste disposal is your concern

*Industry must consider — at the earliest possible planning stage — the safest method of waste disposal and implement these decisions thoroughly*

*By Robert C Keen, Lecturer in environmental health, Bristol Polytechnic*

A new relationship is now being hammered out between industry and local authorities in the field of solids waste disposal. In the past, with a few notable exceptions, this has been far from a partnership but rather more of a situation with local authorities content to see industry making its own arrangements. The beginning of the end for this outlook was signalled by the publication of the Key Report[1] into the disposal of toxic wastes. The recent consultation document[2] makes it quite clear that central government intends to force local authorities to take notice of all solid waste arising in their district, much as they are already compelled to monitor all liquid wastes. No government can afford to ignore the doomwatch lobby and, certainly in the case of solid toxic waste disposal, much remains to be done.

The Key Committee came into being as a result of fluoracetamide poisoning and took several years to produce their rather conservative report. Despite publication early in 1970 there was still no legislation on the statute book 2 years later However the events of February/May 1972 proved decisive, because the cyanide scare certainly produced the Deposit of Poisonous Waste Act 1972 in very short order. Whether it was triggered by altruism on the part of the drivers of the phantom tippers or more logically, a trade dispute over danger money is beyond the scope of this article.

The very stiff penalties set out in Section 1 were brought into force immediately together with the framework for the notification procedure. Enabling Regulations were published later in the year defining the wastes which were exempt from the strictures of the Act. Whilst the Act has undoubtedly made some impact, it shares the common handicap, suffered also by the Litter and Civic Amenities Acts, in being difficult to enforce properly. Once again the burden of proof has been placed on the local authority to show not only the existence of an environmental hazard but also the burden of guilt of the actual culprit.

Despite its insistence on notification procedures when solid wastes are 'deposited' it does not give authorities power to refuse to accept a notification —thereby preventing the deposit — but leaves them with the task of subsequently proving an environmental hazard. To a local government administrator this is a very important difference, as the record of prosecutions under the Act bears witness — two court cases in the first 12 months of the Act's operation!

The introduction of a licensing system for every deposit may sound beaurocratic, but is more in line with needs on this overcrowded island. Blanket exemptions could cover innocuous wastes leaving the hard core of really toxic material to be tackled realistically. Is it too much to ask that industry considers the final fate of it's waste at an early planning stage and perhaps decides against a particular process because the disposal costs are too high?

With regard to poisonous waste the present disposal methods have altered very little from those set out in the Key report where it is stated that about 90% of such material is disposed of by landfill. The alternative 'disposal' methods — dumping at sea, incineration and recycling show little evidence of having yet significantly increased their share of the market.

However, the publication of reliable figures would be most useful. It is already apparent that some 'difficult' wastes are being moved hundreds of miles to suitable disposal points. This, it need hardly be pointed out, is not due to disinterest on the part of waste disposal contractors who are unwilling to offer disposal facilities in every region, but rather reflects the extreme difficulty faced by anyone trying to obtain planning permission for a toxic waste disposal complex. In fact the commercial director of one large waste disposal company is on record as suggesting that a single central body should be created to supervise toxic waste disposal control on a national scale.[3] One suspects that this was suggested, not from purely altruistic motives, but in the hope that such a body might influence local planners to look more favourably on such applications.

In the movement of poisonous and corrosive material by road many hazards are obviously presented and once again tragic accidents have served to focus public attention on the matter. It seems as a direct consequence of the M6 fatality involving a sulphuric acid tanker, orders governing the carriage of dangerous substances by road are to be laid before parliament this year.

The Home Office has divided the substance into five categories — petroleum products, flammable, corrosive, organic peroxides and gases. There are two categories of precautions prescribed. The first deals with the reporting of accidents involving injury or death and the labelling of the cargo. The second sets out additional labelling requirements, requires first-aid and fire extinguishing equipment and necessitates informing the driver of the nature of his load and the emergency drill.

Certain cargoes — petroleum — are already fully subject to the regulations but by the end of the year all dangerous cargoes should be covered by at least the first stage of the regulations thereby enabling the emergency services to more readily identify the substances involved. The Home Office have also published a list of the corrosive substances conveyed by road together with an outline of appropriate emergency action; the Chemical Industries Association have produced a recommended Code of Practice.

## Disposal methods

The main disposal methods include landfill, incineration, recycling and disposal at sea. Landfill, the most widely used method of disposal, can clearly only be tolerated in situations where there is no environmental hazard, arising either from the deposit itself or any resulting percolate from the landfill site.

Apart from such obvious dangers as those presented by highly flammable or even explosive material the problem of the security of the site must receive proper attention. Surely a double strand wire fence is insufficient protection for an acid lagoon in an area where children are known to congregate? There is now case law to show that in such circumstances a duty of care is owed even to a trespasser.

The increasing importance rightly attached to the possibility of water pollution from such sites seems to preclude the use of any but the demonstrably 'super safe' sites — those with a 100% impervious lining whether natural or artificial — such as a deep mine or sites where any escaping pollutants cannot present a hazard; a site overlying an impervious stratum on a dip slope which runs out under the sea.

The only viable alternative is where the dilution factor is so great that the hazard becomes insignificant when measured against the total intake into the site. A large local authority or contractors tip accepting conventional refuse might deal with a small proportion of toxic material by this means.

The actual deposition of material on a landfill site presents problems in view of the demonstrably high proportion of liquid to solid matter generated by the poisonous waste producing industries. In theory the trench method can be utilized in which mechanical excavators are used to make cuts 2-3 metres deep into previously deposited solid waste in a herringbone fashion. The liquid waste is then run into the trenches from a small reception pit. It is self evident that there is a critical ratio between the solid and liquid arrivals at the site and if this is exceeded, lagoons will form. In fact American practice favours the lagoon system, but of course, a continental climate will result in a high evaporation potential, whereas in this country for much of the year, precipitation exceeds evaporation so that the contents of a lagoon may even increase in volume! If the site possesses an impervious seal then the ratio becomes all important if the whole of the deposited material is not to eventually take on the consistency of porridge. Clearly, the present situation in which poisonous wastes are being concentrated on a relatively few sites is providing some very real headaches for all parties concerned.

## Incineration

The cyclone type of furnace seems to present the best solution to the technical problems associated with burning a solid or liquid material which is possibly heavily contaminated and has an extremely variable calorific value. At least one waste disposal company is installing several multi-function incinerators that will even deal with material whilst it is inside drums.

The use of gas scrubbing allows, by the appropriate dosing of spray water, effective control of the composition of the emitted gases and the possibility of heat recovery can be considered.

## Recycling

A comprehensive waste disposal complex will obviously make maximum use of recycling techniques. Clearly if company A's acid waste can be combined with company B's alkaline waste to produce a neutral material than it becomes financially advantageous for the contractor to provide the necessary tanks, retorts, paddles etc. Especially is this so when the resulting material can be sold to company C!

Naturally every large company looks very carefully at its own arisings and effluent and employs the necessary specialists and builds the required plant to effect its own recycling. Smaller companies often cannot obtain large enough economies of scale to make this operation worthwhile. Whether the government should introduce legislation to require the maximum amount of recycling is also a question beyond the scope of this article.

## Disposal at sea

Accepted by the Key Committee, but frowned upon by the Royal Commission, disposal at sea seems to be a method which arouses a strong reaction from the public, who have yet to be educated to appreciate the difference between indiscriminate dumping in a shallow, enclosed sea such as the Mediterannean and deep disposal of properly protected waste well away from the continental shelf. It is worth noting that there is a floating incinerator (M/T Vulcanus) operating out of Rotterdam burning mostly chlorinated hydrocarbons which have been given clearance by the Dutch Authorities.

## Employee health and safety

Not only industry, but also the contractors and local authorities would be very well advised to take a very critical look at their procedures under this heading. Whilst the Key Committee said very little on this score we have subsequently seen the publication of the Robens Report and the allied consultative document. Expertise is readily available in this field not only from conventional sources (eg HM Factory Inspectorate and RoSPA) but also academic institutions such as the Safety and Hygiene Group at the University of Aston in Birmingham.

## Financial aspect

A point has now been reached where the disposal costs of spent material can outweigh its purchase price. This unpalatable fact does not seem to have produced a realistic approach to the pricing of the product — managers are still often expected to dispose of material by 'kicking it about until they lose it.'

Whatever the short term constraints on the industrialist may be, the stage has now been reached in industrial development where there are enough resources to be able to afford the cost of cleaning up the mess made, and are making, during the industrial revolution. In fact a government of any political persuasion would find it very difficult to reverse the commitments already made to the provision of a safe and healthy environment at whatever cost to the economy — witness the appointment of a Royal Commission on Environmental Pollution. Here it is worth pointing out that as this movement is discernable in all of this country's international competitors, its adverse effect on the balance of trade should not be overstated.

## Legal position

The concept of notifications for every movement or deposit of poisonous wastes as contained in the Act are novel. However, Section 1 of the Act which deals with the offence of depositing such waste as to create an environmental hazard is only novel in the sense that a specific statutory offence has been created for something which previously was only capable of being dealt with as an offence against common law, or, alternatively or additionally, as a statutory nuisance under Section 92 of the Public Health Act, 1936. From the viewpoint of the community the Deposit of Poisonous Waste Act has rendered irrelevant the small print on waste contractors agreements. Despite what any such agreement may say, the local authority are empowered to prosecute any, or all, of the parties involved in any disposal arrangements which produce an environmental hazard.

Reference has already been made to the Consultation Document published in March, 1973 by the Department of the Environment entitled 'Waste Disposal — Proposals for a new framework'. This foreshadows the production of waste disposal plans for each of the disposal authorities with a strengthening of the local authorities' powers, extending as far as the licensing of disposal plants and the possible provision of toxic waste disposal plants.

The local government operational research unit has said that it has now become clear that the amount of poisonous waste to be dealt with requires an all out effort on a massive scale.

*Next month Mr Keen will provide some notes on the Act and indicate the notifications required to ensure compliance.*

## References

1 *'Disposal of Solid Toxic Wastes', the Report of the Technical Committee. HMSO 1970.*
2 *Waste Disposal. Proposals for a New Framework Consultation Document. Department of the Environment. February 1973.*
3 *The Disposal of Obnoxious Solid and Liquid Industrial Wastes Symposium Report. Institute of Public Cleansing and Institution of Public Health Engineers. September 1972.*

APPENDIX II Factory, November 1973 p 47

# Waste disposal — notes on the Act

*By Robert C Keen, lecturer in environmental health, Bristol Polytechnic*

*Section* 1 Prohibits the deposit of waste on land if it is 'poisonous, noxious or polluting and its presence is liable to give rise to an environmental hazard'.

*Depositing* consists of leaving any substance 'in such circumstances as for such a period that (it) may reasonable be assumed to have (been) abandoned . . . where it is deposited or to have (been) brought . . . to the place where it is deposited for the purpose of . . . being disposed of . . . as waste' Section 1 (2) Note that incineration and dumping at sea are included[1].

*Environmental hazard* is the creation of a 'material risk of death, injury or impairment of health' or 'to threaten the pollution or contamination (whether on the surface or underground) of any water supply' and a proviso excludes any protection which might have been sought by arguing that the waste was deposited in containers.

The following classification of the possible environmental hazards is meant as a starting point only, because the circumstances of each case must vitally affect the extent of the hazard involved.

*Physical danger at point of discharge* Safety & Health risks to operatives arising from: Handling of toxic, carcinogenic, radio-active and corrosive material: Fires, explosions and inhaling poisonous fumes.

Note related dangers to possible trespassers (human and animal).

*Pollution dangers* Air pollution — Dust, effluvia, smoke and fume. Land pollution — Gross amenity damage; Stability of site undermined; Sterilization of surrounding land due to heavy metals, pH changes etc. Waste pollution — Deposited material or percolate escaping either through surface run off or by underground movement threatening streams, rivers, acquifers, even the sea itself, either by actual poisoning or even eutrophication.

It is significant that the 'best practicable means' defence is not available and the penalties are quite severe — on summary conviction £400 or 6 months and on indictment before a jury — an unlimited fine and 5 years.

*Section* 2 Strengthens the case of any common law plaintiff in an action for damages by spelling out that an offender against Section 1 is fully responsible for all damage caused by that deposit unless the claimant was in some way also to blame.

*Section* 3 Provides that prior notice must be given to the local authority and river authority before any waste,

☐ Is removed from premises for deposit elsewhere

☐ Is deposited on any land.

The section applies to any waste, but the Deposit of Poisonous Waste (Notification of Removal or Deposit) Regulations 1972 (SI 1017) have provided statutory exemption for many innocuous waste materials such as domestic refuse, builders rubble etc, providing they do not themselves contain hazardous concentrations of poisonous substances.

The notice must indicate:

☐ The premises from which the waste is to be removed.

☐ The land on which it is to be deposited.

☐ Its nature and chemical composition (ie principal constituents which may be of environmental significance and the concentration of the specified constituents[1]).

☐ The quantity and if in containers their number, size and description.

☐ In the case of a removal, the name of the person who is to undertake the removal.

Such a notice must be given at least three clear days before the movement, to the local authority and the river authority both for the area in which the premises is situated and the area where the deposit will take place, if these are different. Extra copies must be given both to any independent contractor who undertakes the removal and the operator of the tip site.

*Section* 4 Prohibits the operator of a refuse tip from allowing the deposit of poisonous waste unless three days notice has been received. Having permitted a deposit the operator must within three days notify all the local authorities and river authorities involved.

*Section* 5 Defines local authorities, applies powers of entry and requires local authorities who themselves operate a refuse tip to go through the notification procedure and inform the river authority of every deposit.

Local authorities — not river authorities — are required to keep records of all deposits in their areas.

*Sections 6 to 8* are administrative provisions.

*'Season Ticket' Procedure* Not mentioned in the Act but outlined in the circular[1] which accompanied it as follows:

'Where similar consignments of . . . waste are being disposed of regularly . . . it would be permissible . . . to avoid the provision of separate notices for each consignment. The statute would be complied with if the required notice was given saying for example that a specified quantity of waste of constant chemical composition was being deposited on the same refuse tip every week for the next twelve weeks . . . A limit, say three months should be set to the period of such a season ticket'.

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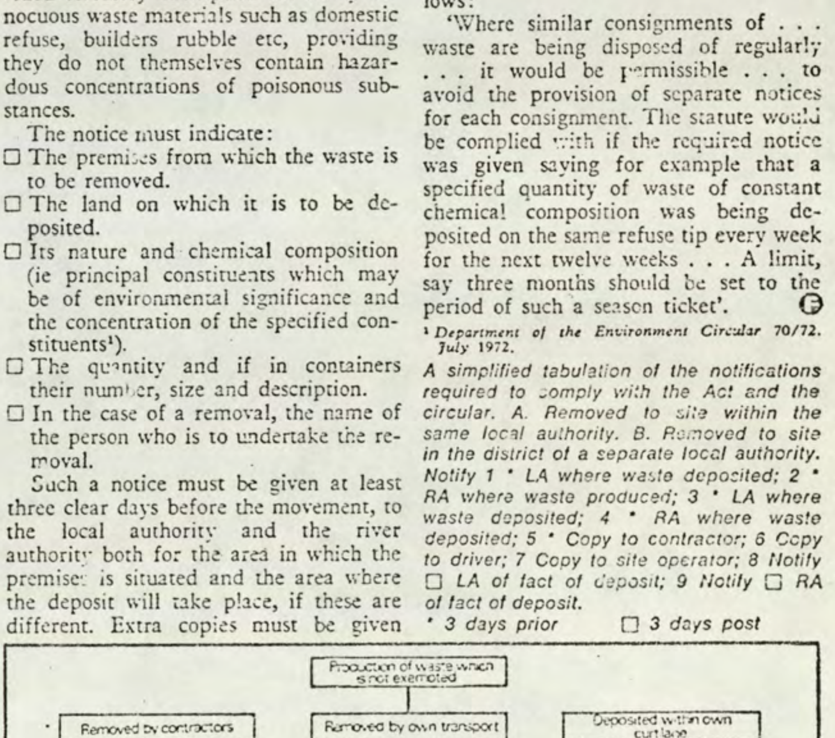
[1] *Department of the Environment Circular 70/72. July 1972.*

*A simplified tabulation of the notifications required to comply with the Act and the circular. A. Removed to site within the same local authority. B. Removed to site in the district of a separate local authority. Notify 1 * LA where waste deposited; 2 * RA where waste produced; 3 * LA where waste deposited; 4 * RA where waste deposited; 5 * Copy to contractor; 6 Copy to driver; 7 Copy to site operator; 8 Notify ☐ LA of fact of deposit; 9 Notify ☐ RA of fact of deposit.*

** 3 days prior ☐ 3 days post*



APPENDIX III

Keen R C and Mumford C J

A preliminary study of hazards to toxic waste disposal operators on ten landfill sites in Britain. The Annals of Occupational Hygiene Vol 18 No 3 pp 213-228 1975

# A PRELIMINARY STUDY OF HAZARDS TO TOXIC WASTE DISPOSAL OPERATORS ON TEN LANDFILL SITES IN BRITAIN

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Abstract—An introduction to solid toxic waste disposal on landfill sites is provided and the hazards faced by operators on such sites defined. The location of the operation in the open air offers the obvious protection of dilution of gaseous/particulate pollutants but creates difficulties when attempts are made to quantify the precise extent of the hazard.

Measurements, observations, photographs and the results of interviews carried out to investigate conditions on ten landfill sites, which serve three major industrial areas, are summarized. Unsatisfactory conditions existed on many sites, and there was a lack of routine checks on the composition of deposited material.

A general absence of emergency arrangements is associated with the low cost nature of the operation. Although the hazards stem from the inherent difficulties in handling dangerous materials, they appeared to be compounded by lack of supervision and the operator's lack of information.

## INTRODUCTION

A STUDY of the administration of the *Deposit of Poisonous Waste Act* 1972 (KEEN, 1973) highlighted a lack of information as to the nature and extent of hazards to operators and others engaged in disposal operations on landfill sites. Although the World Health Organization had expressed concern over the health of solid waste workers in general (W.H.O. 1971) no systematic body of literature existed on the topic of operator hazards.

The lack of operator protection legislation was confirmed by H.M. Factory Inspectorate and the International Labour Office. Furthermore, the Commission of the European Communities revealed that the draft Solid Waste Control Programme for the E.E.C. Countries contained no specific operator protection provisions.

A brief investigation of the problem was therefore undertaken (KEEN, 1974). The literature search has been published elsewhere (KEEN, 1975a); this paper summarizes the results of site investigations.

The report of the Key Committee (MINISTRY OF HOUSING AND LOCAL GOVERNMENT, 1970) was the first official attempt to define the extent of hazards from the disposal of toxic waste but did not consider hazards to operators. It revealed, however, that nearly 90% of all toxic waste was disposed of to land. A recent survey by the INDUSTRIAL WASTE SURVEY UNIT (1974) indicated that the total figure could be of the order of 3 million tonnes annually, significantly more than suggested by the Key Committee.

Extrapolation of the Harwell figures to cover 100% of the population is indicative of 500 landfill sites taking toxic waste in England alone. However, it appears that over half of these sites could be taking under 10 tonnes of toxic waste per week with only approximately 1% of sites taking much in excess of 2000 tonnes in a week. Thus only a very small number of sites specialize in the reception of large quantities of toxic waste and a much greater number take an amount which on an individual site basis, is very small. The physical size of the site is of little consequence; some extensive local authority sites do not accept toxic waste whilst the intake to a contractor's site less than 100 ha in extent may be predominantly toxic waste with other waste being accepted to provide covering material. The authors' investigations identified several distinct types of site, each with differing problems by virtue of their ownership; viz.

1. *Sites operated by the waste producer*

This category, which includes those of the major chemical companies, accounts for the biggest proportion (approx. 70%) of all toxic waste. Moreover, these sites handle some of the most hazardous material which is landfilled. In view of the close control over the intake to the sites and the potential availability of technical assistance they would however be expected to pose less of a problem that the other groups.

2. *Sites operated by local authorities*

Since they deal with only a small amount of toxic waste (5% of the total), and are generally not operated with such a close attention to cost reduction this group may be expected to pose few problems. In addition they tend to be very selective as to which wastes they accept. However, in the absence of spot checks to ascertain the true nature of deposited waste, operatives might be subjected to hazards from unexpected toxic deposits.

3. *Sites operated by waste disposal contractors*

These sites provide for the remainder of the waste, about 25% of the total, and can be sub-divided into:

(a) Sites where the only input is that carried by the waste disposal company itself.

(b) Sites where the contractor accepts additional wastes from producers direct or from other contractors.

Clearly, operators of the latter category of site are least likely to be fully aware of the true nature of the material which is being deposited.

In the absence of any official information only an approximate estimate is possible of the number of operatives at risk from toxic waste handling. Since a typical site may take toxic waste in the proportion of 1:5 with non-toxic material, an allowance of 1 machine (e.g. a bulldozer) per 100000 tonnes of waste per annum suggests that if the global figure of 3 million tonnes is correct, 150 machine operators may be in contact with toxic waste to a significant extent. Multiplying this by 20, a ratio for delivery drivers to machine operators, yields a figure of 3000 drivers. Of the latter perhaps a third, e.g. 1000 drivers may be permanently engaged on toxic waste duties.

Some indication of the wide range of material offered for landfill is provided by Table 1. Whilst the effect of the *Deposit of Poisonous Waste Act* 1972 has in theory been to permit Local Authorities to control the intake to landfill sites, operator hazards are not commonly considered as a basis for the 'rejection' of proposed deposits. There is indeed a lack of guidance on the interpretation of the Act which refers to waste which is "poisonous, noxious or polluting and whose presence is liable to give rise to an environmental hazard". It should be noted that the Act does not actually give rejection powers to local authorities but merely makes notification a legal requirement and then empowers Local Authorities to take punitive measures if they can prove the resulting existence of an environmental hazard.

TABLE 1. ABRIDGED LIST OF MATERIALS FOR WHICH NOTIFICATIONS OF INTENDED DEPOSIT WERE MADE AT ONE LANDFILL SITE IN THE FIRST 12 MONTHS OF OPERATION OF THE ACT. (Objections raised against some materials prevented their deposit on the site in question)

Acetate
Acetone
Acid tars
Adhesives
Alkaline wash fluid
Alkali sludge
Aliphatic amines
Aluminium fluoride
Aluminium hydroxide
Ammonia
Ammonium hydroxide
Asbestos dust
Barium chloride
Behenic acid
Benzene
Benzole sludge
Bisulphite of lime
Butyl acetate
Cadmium
Calcium chlorate
Calcium fluoride
Calcium sulphate sludge
Carbon black
Caustic cleaning sol.
Cetyl stearyl acid
Chrome
Chromic acid
Chromium hydroxide
Chromic trioxide
Cider
Copper
Copper hydroxide
Cyanide
Detergent
Diatomaceous earth
Dibutyl phthallate
Dyestuffs
Enamel
Esters
Ethylene glycol
Ethanol
Ethyl benzoate
Ethylene oxide
Fats
Fatty acid and solids
Filter cake
Fluoroboric acid
Formaldehyde
Formic acid
Foundry slag
Glue
Hexavalent chromium salts
Hydrocarbons
Hydrochloric acid
Hydrofluoric acid
Ink, ink sludge
Insecticide
Iron hydroxide
Iron oxide
Isocycanates
Isopropyl acetate resins
Kerosenes
Ketones
Lacquers
Latex
Lead
Magnesium oxide
Magnesium salt
Mallic acid
Mercury
Methanol
Methyl ethyl ketone
Methylene chloride
Methylated spirits
Naphthalene
Nickel chromium
Nickel hydroxide
Nickel
Nitric acid
Nitrocellulose
Oil and grease various
Paint stripper and solvent
Paint thinner and waste
Paraffin
Petroleum ether and waste
Phenol
Phenol formaldehyde
Phenol methanol
Polyacrylic acid size
Polyamide
Polyester
Polystyrene
Polyurethane
Polyvinylacetate
Phosphoric acid
Potassium chloride
Prepolymer
Propylene oxide
Propyl alcohol
P.V.C.
Resin
Red oxide paint
Rubber
Sewage sludge
Silica alumina
Silicone catalyst
Soap
Soda ash
Sodium
Sodium chloride
Sodium hypochlorite
Sodium hydroxide
Sodium nitrate
Sodium oxalate
Solvents
Soot
Starch
Stearic acid
Steroids
Styrene
Sulphuric acid
Tar emulsion
Tallow and wax
Tin salts
Titanium oxide
Toluene
Trichloroethylene
Vanadium oxide
Vanadium
Zinc dialkyl
Zinc hydroxide
Zinc oxide
Zinc phosphate
Zinc sulphite
Xylene

The rate at which deposited liquid material disappears depends upon a multitude of factors upon which there is little published data. These include the nature of the material itself, the substance into which it is deposited, any reactions which occur with other deposited material, the configuration of the pit or trench (e.g. a simple pit quickly becomes impermeable due to 'plating out' of oils etc. on its interior), and the evaporation/precipitation ratio. In fact some soakage pits have actually increased in volume due to rainfall exceeding losses.

## FACILITIES

Facilities on a typical landfill site accepting toxic wastes tend to be very rudimentary. It may even lack basic amenities such as water supply, sewer connection, telephone and electricity supply. Whilst some sites are completely unmanned and unfenced, the typical site has a gateman and one or two machine operators who are normally bulldozer drivers.

The use of two-way radios does permit direct contact between the operator at the tip face and the actual operational centre, which may be anything from 1 to 20 km away. However their cost coupled with the present high operating noise level within landfill machinery cabs, discourages their routine use in bulldozers. Even the most comprehensively equipped sites belonging to contractors, for example, those provided with a fire tender and ambulance, may lack the tradition of a long commitment to operator safety found in the best managed factories. Thus there can be no guarantee that safety procedures will be either devised or followed.

### *Inherent difficulties*

Many contractors have evolved from Road Transport Operators since 80% of the total disposal cost may arise from the transport operations (W.H.O., 1971). Priorities naturally tend therefore to be given to the transport part of the undertaking which is in any event the major cost item, and the technical aspects of waste material handling has so far received scant attention. Conversely some waste producers disposing of their own toxic waste apply close supervision and provide full emergency equipment backed up with properly programmed training schemes for the operatives. In fact, even amongst the waste producers there is a wide variation in the scope of Education and Training Schemes, ranging from none at all to comprehensive instructions with practical sessions demonstrating the dangers of the waste material; It is, however, generally easier for a company moving its own waste to provide comprehensive instructions with regard to its properties. Contractors handling many and varied wastes are at a disadvantage in this sense. Those multi-waste landfill sites which largely take materials produced by different companies but conveyed by a third party are at the biggest disadvantage in terms of understanding the risks to which their own operators may be subjected.

The absence of a mains water supply and telephone mitigates against the provision of proper emergency facilities.

## POTENTIAL OPERATOR HAZARDS

### *Chemical*

The main risk was presumed to be an inhalation hazard under any of the following circumstances:

1. Release by highly active substances of fume or gas. This could occur if large

## INTAKE

The composition and physical state, i.e. whether solid, liquid or sludge, of toxic waste arriving at a contractor's site is represented in Fig. 1 (REDLAND PURLE, 1973).

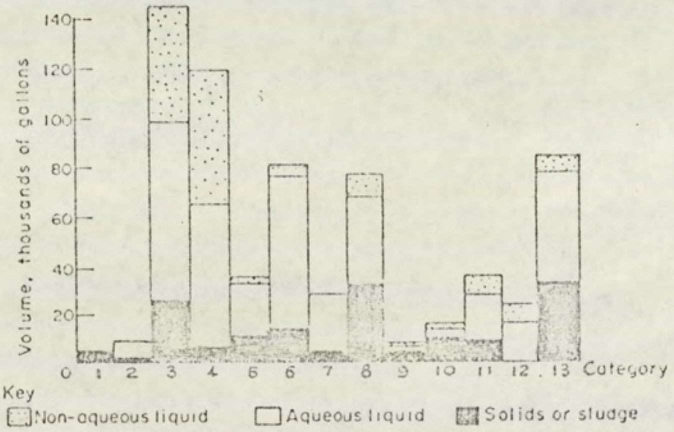

FIG. 1. Intake of toxic waste to a landfill site. Histogram showing how the week's total volume of sampled wastes were made up at one site.

*Waste categorization:*

1. Non-notifiable materials.
2. Notifiable materials. Unlikely to be hazardous or more polluting than domestic refuse, e.g. food sludges, inert sludges.
3. Oily wastes, such as interceptor wastes, oil mixtures etc.
4. Tars, phenolic wastes, bitumens, gas liquors etc.
5. Paints, varnishes, polymers and plastic wastes and any associated solvents.
6. Complex organic mixtures and any other miscellaneous toxic, but non-persistent organics that could not fit into groups 3, 4 or 5.
7. Water and persistent organics such as halogenated hydrocarbons.
8. Corrosive materials and highly toxic metals, e.g. electroplating wastes.
9. Liquids or sludges containing cyanide; with or without toxic metals.
10. Caustic liquids or sludges; containing no toxic metals.
11. Acid solutions; containing no toxic metals.
12. Unclassified materials likely to be hazardous or cause of nuisance.
13. Unclassified materials where more information is needed.

Note: Quantities of flammable and highly flammable waste not shown.

Disposal methods on landfill sites vary widely. They range from crude dumping, with the possibility of eventual cover, to relatively sophisticated operations involving reception pits, pumps and pipelines to soakage trenches. However, since the common factor in all the operations is the deposit of waste on land, all involve the entry of a vehicle or barge onto a site and the discharge of its load to the ground. In most cases there is no rehandling on the site: where it is practised either pipelines or site tankers, which are better for crossing rough terrain, are used. Ideally the solid deposit is covered as expeditiously as possible and the liquid deposit swiftly soaks away.

The officially recommended method (DEPARTMENT OF THE ENVIRONMENT, 1971) proposes that waste should be deposited in layers not more than 2·4 m deep, and covered with inert, innocuous material at the end of each working day. The cover may either be excavated on site or imported specifically. Unfortunately landfill sites, whether taking toxic waste or not, where the daily covering of deposited material with a proper seal is practised regularly, are rather rare.

quantities of such materials were tipped or otherwise disturbed, or incompatible materials such as cyanide and acids met in the disposal process (Fig. 2). For example, the health monitoring programme of one large chemical manufacturer revealed minor kidney damage to bulldozer drivers engaged in disposing of waste sludge containing halogenated hydrocarbons.

2. During entry into a confined space for cleaning or inspection. The commonest example is the interior of a road tanker barrel (Fig. 3), but also included are soakage trenches and excavations.
3. If the general site atmosphere was heavily laden with dangerous dusts or fibres such as silica or asbestos (Fig. 4).
4. Fire-fighting operations which bring the operator into contact with the products of combustion. In addition to carbon monoxide these may contain hydrogen chloride or cyanide.

Absorption via the skin or mucous membranes is a potential hazard with many materials likely to be offered for landfill. These include alkaloids, aniline, certain solvents, e.g. tetrachloroethane, phenols, methyl bromide, salts of heavy metals, and organic lead, mercury and phosphorous compounds. Such a problem would be worsened by poor washing facilities and either inadequate provision or lack of supervision over the use of protective clothing. Furthermore, the possibility of toxic effects via the digestive system needs consideration under regimes involving low levels of supervision, poor site amenity provision and absence of catering arrangements Materials likely to be troublesome include heavy metals, classic poisons (e.g. arsenic, cyanide and strychnine), synthetic poisons (acaricides, fungicides, insecticides, rodenticides) and dangerous drugs.

In addition to the accepted toxiological hazards there are also the possible effects arising from accidental exposure to corrosive materials (Figs. 2 and 5) or prolonged/intermittent exposure to dermatitic agents. The hazard to the unprotected eye from corrosive acids is obvious as is the potential for skin burns, but dermatitis problems are less easily appreciated. For example a large proportion of the materials in Table 1 can act as dermatitic agents (MALKINSON, 1960).

*Physical*

Noise can present an occupational hazard to the landfill machine operator, the bulldozer is primarily responsible (LA BENZ *et al.*, 1967) although scrapers and cranes can also offend. Vibration problems can be encountered with some designs. Although extremes of temperature should not be a major hazard, the fitting of "all weather" equipment such as cabs and heaters may increase the risk from noise and chemical agents. A poorly designed and isolated cab may resonate and increase noise levels at the operator's ear and the recirculation type heater may increase volatilization of toxic material inadvertently introduced into the cab by the operator, as well as continuously redistributing dusts and fibres.

Fire is a common hazard on landfill sites (FLINTOFF and MILLARD, 1969). However, since operations take place in the open air, the danger to operators is significantly reduced. Nevertheless, if landfill machinery is used to control the burning material by smothering or isolation, the risk to the operator may be quite high, e.g. bulldozers have been burnt out and operators have had to evacuate hurriedly. A fire brigade tender has been lost on a landfill site, trapped and burnt out by a sudden change in the wind direction.

Radiation hazards were excluded from consideration because of the strict statutory control over radioactive waste contained in the *Radioactive Substances Act* 1960.

However, in West Germany the highly radioactive waste which was discovered on a municipal landfill site at Obrigheim was traced back to a nuclear reactor (ANON, 1974).

*Mechanical*

Physical trauma is a distinct possibility on a landfill site from a variety of causes.

Vehicle accidents are common wherever heavy plant is used. Several studies have been published relating to earth moving equipment (LEFEVRE, 1964; DESMICHELLES and DESMICHELLES, 1964). It has been shown that almost all accidents involving machines overturning were fatal and bulldozers present a significant overturning risk (ANON, 1968).

Primary entanglement with machinery is a hazard of operations such as removing material fouling the driving sprockets on bulldozers or freeing any refuse skip jammed during emptying.

Machinery maintenance is sometimes carried out on site under spartan conditions with old drums, tea chests etc., taking the place of proper supports for heavy items. The high cost of ferrying tracked vehicles to a properly-equipped maintenance depot can mean that major overhauls involving several weeks work are undertaken in this way possibly without the benefit of proper cleaning facilities to decontaminate the machinery.

In addition to the straightforward, though often serious, slips and falls encountered when alighting from or entering machinery, hazards can be presented by the extremely untidy state of many sites. Hence the classic 'nail in the plank of wood' may well be disguised amongst the rubbish on which a driver alights.

*Infective*

The potential role of infective agents, particularly with reference to the above, must not be ignored. Whilst the importance of tetanus is obvious, anthrax could be the most serious danger, though there are no published data on its specific occurrence on landfill sites. Because it is spore-forming and capable of aerial dissemination, any leather, wool, or bonemeal wastes might be suspect. Slaughterhouse waste, sewage sludge, and hospital waste may contain pathogenic organisms capable of causing harm by skin contact alone, whether in the form of an infective state of an internal parasite, an ectoparasite or a micro-organism (e.g. hook worm, plague and leptospirosis, respectively).

Thus a study in India of stool specimens from refuse workers indicated that 94% were infected with selected parasites against less than 5% in the control group (W.H.O., 1971). However HANKS (1967) found with regard to the relationship between solid waste and disease that there is a problem in identifying direct health effects.

Poor personal hygiene would of course facilitate gastro-intestinal infection (e.g. salmonellosis and hydatid cysts). Rodent and insect infestations of the site are manifestly important. For example a million rats were killed in the process of clearing one open dump in America (ROBERTSON, 1959).

## PERSONAL PROTECTION AND EDUCATION

It is desirable to educate operators against inhalation, or other contamination by corrosive or otherwise dangerous substances. With corrosive chemicals, emergency showers and treament facilities are needed immediately to hand. Operators can be made aware of such hazards, plus any arising from routine contact and others, such as entanglement, noise and vibration, by proper training and education programmes. Adequate supervision is needed to ensure that protective equipment is worn and proper procedures adhered to. This is difficult to achieve in practice because landfill

TABLE 2. SUMMARY OF SITE CONDITIONS

| | | |
|---|---|---|
| Number of sites inspected | | 10 |
| Those receiving deposits of toxic waste within the meaning of the Act | | 9 |
| *Location* | Urban | 4 |
| | Rural | 2 |
| | Industrial | 4 |
| *Ownership* | Company who produced the waste | 2 |
| | Local Authority | 2 |
| | Contractor | 6 |
| *Annual intake of waste* | Average | 100 000 tonnes |
| | Range | 3000–420 000 tonnes |
| | Proportion which was toxic. Average | 33% |
| | Range | virtually nil to 50% |
| *Area of site* | Average | 60 ha |
| | One very large | 500 ha |
| | Remainder. Range | 15–150 ha |
| *Protection and provision of amenities* | Number of sites provided with: | |
| | Adequate fencing and gates | 2 |
| | Telephone or two-way radio | 6 |
| | Mains water supply | 5 |
| | Sanitary accommodation | 4 |
| | Effective decontamination facilities | 0 |
| | Comprehensive first aid post (oxygen, antidotes etc.) | 1 |
| | First aid kit | 5 |
| | Links with local emergency services | 1 |
| | Showers | 1 |
| | Wash hand basins | 4 |
| | Messroom | 3 |
| | Canteen with meals provided | 0 |
| *Personnel* | Overall average on site | 7 men |
| | If the largest and the smallest are ignored the average becomes | 3 men |
| *Landfill machinery* | Using a similar approach, the average number of machines | 2 |
| *Maintenance* | Sites with comprehensive workshop adjacent | 3 |
| *Infestation* | Sites infested with rodents | 2 |
| | Sites infested with insects | 0 |

is a low-cost operation with inherent difficulties of supervision. The very nature of the landfill operation and its exposure to the elements invites comparison with the activities of the construction industry. No statistics are available since notification of accidents on tips is not a legal requirement, but the two activities could share an equally unenviable accident record. Presently, toxic waste disposal by landfill is a unique service achieved with the minimum of expenditure in a competitive market.

## SITE INSPECTIONS

The following data are based on conditions discovered during the summer of 1974 on 10 landfill sites. Visits were made to 13 sites; 11 were fully inspected but as two of these were in the same ownership, situated close together, dealing with wet and dry refuse respectively, they have been included as one site.

The two sites in Local Authority ownership did not accept toxic waste as a matter of policy and were included as controls. In fact, the largest of the two accepted industrial waste amongst which materials were discovered that came within the definitions contained in the *Deposit of Poisonous Waste Act*.

Table 2 summarizes the results of the inspections.

## MEASUREMENTS

In view of the limited facilities available only a few rudimentary tests were possible to quantify some of the hazards to which operators may be subjected. The detection of early health impairment (e.g. by presence of metabolites in urine) was not attempted. The equipment employed is described in Table 3.

TABLE 3. EQUIPMENT USED IN INVESTIGATIONS

| Conditions investigated | Equipment | Type and make | Remarks |
|---|---|---|---|
| Noise levels inside cabs of tip machines | Sound level meter (BS.3489) reading dB(A) | Industrial grade with battery-operated calibration (Acos Cosmocord) | 'Slow' readings used. Hand-held, next to operator's ear |
| Concentration of specific gases in the the atmosphere | Hand pump and colour change tubes | Bellows type (Draeger) | Major difficulty was knowing which gas to to test for |
| Concentration of combustibles in the the atmosphere | Explosimeter | Catalytic filament and wheatstone bridge (Sieger) | Although calibrated for toluene, acceptable results given with any combustible gas |
| Concentration of breathable dusts in the atmosphere | Personal sampler pump and filter | Portable pump (Casella) with 8 μm pore size membrane filter | Used on bulldozer driver and with static holder in the open air |
| pH of solutions | Indicator paper | full range (1–14) (BDH) | |

*Noise*

The easiest stress to measure was the noise to which the machine operators, notably the bulldozer drivers, were exposed. Table 4 shows that every machine upon which measurements were made had the capacity to exceed the maximum recommended level of exposure of 90 dB if utilized for an 8 hr day, five days a week. In practice whilst most machine operators work longer hours than this the machines are not constantly operative hence either a detailed analysis would be necessary to discover how many minutes of each day are spent at the various aspects of the task, or an integrating dosimeter used.

With the exception of one elderly operator who used cotton wool, no operators wore any form of hearing protection. On one site ear muffs had been provided but were not used by the operators because they were claimed to be uncomfortable and to interfere with aural feedback from the machine.

Table 4. Noise exposure of site equipment operators
A: Noise level at operator's ear (dB(A))
B: Operator's estimate of time spent daily on duties (hr)

| | Bulldozer number | | | | | | | | | | | | Bucket shovel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | | |
| | A | B | A | B | A | B | A | B | A | B | A | B | A | B |
| Duties: | | | | | | | | | | | | | | |
| Pushing under load | 102 | 3 | 100 | 2 | 95 | 3 | 99 | 3 | 99 | 4 | 96 | 5 | 101 | 2 |
| Reversing | 103 | 3 | 100 | 2 | 99 | 2 | 99 | 2 | 99 | 4 | 96 | 2 | 101 | 2 |
| Traversing the tip with no load | 102 | 2 | 99 | 5 | 77 | 1 | 105 | 1 | 85 | 1 | 86 | 2 | 99 | 1 |

The figures under load and whilst reversing were reasonably consistent. The variation whilst traversing with no load may be due to differences in the design and age of the machine, state of adjustment, gear ratios etc.

*Gases and vapours*

*Measurements within confined spaces. Tanker barrel interiors*: Operators enter road tanker barrels principally for cleaning them out. Some loads with a heavy detritus content need cleaning after every trip (Fig. 3). A major problem in assessment of the potential hazard was the virtual ignorance of operators as to the precise nature of the load being cleaned out, or whether the residues contained traces from any of the previous loads, possibly of a very different composition. This difficulty was compounded by the use of dirty wash water from other tankers or pools on site, to flush out the tanks.

Gas detection tube measurements within tanker barrels which were being cleaned out by operators gave the results summarized in Table 5.

*Excavations*: Trenches are commonly excavated in previously-deposited waste to facilitate the soakage of liquid waste. In fact no trenches were being excavated on the sites during the survey visits, but an explosimeter measurement taken in a shallow excavation dug by a bucket shovel for test purposes gave a positive result on a site which principally accepted pulverized domestic refuse.

TABLE 5. LEVEL OF CONTAMINANTS WITHIN ROAD TANKER BARRELS

| | Drager hand pump | Previous load | Remarks |
|---|---|---|---|
| Tanker 1 | 420+ ppm benzene | Food waste (vanillin) | Benzene* possibly from solvent extraction process |
| Tanker 2 | 420+ ppm benzene | Chromic acid | Benzene* from interceptor trap contents of earlier load. |
| Tanker 3 | 10 ppm phenol | Flue dust | Phenol from the wash water drawn from a pool on the site. |

*Interference at this concentration from substances breaking through the precleansing layer must be considered. However 420 ppm is significantly above the ceiling value of the important potential interfering agents.

As the pulverizer used a water spray to lower the resistance of paper and cardboard to abrasion, it was suspected that the explosimeter reading of 5% of the lower explosive limit on an instrument calibrated for toluene was due to methane evolved in the decomposition process. No other positive readings for inflammable gases were obtained.

Two hand pump tests, in existing shallow trenches were negative for the presence of $H_2S$ although the characteristic odour was discernible on both occasions (one site accepted tannery waste, the other pulverized domestic refuse).

*General atmosphere*

Attempts to measure the general atmospheric concentration of specific gases with Draeger tubes did not produce unequivocal results. For example hydrogen sulphide was detected by its odour on at least three sites but no confirmatory readings were obtained using gas detection tubes. Phenols, the odours of which were discernible over the whole of two sites, could only be demonstrated close to the source of the contamination on one site.

Because of the low odour thresholds of these gases (0·025 and 5 ppm respectively) it might be concluded that they were present in insignificant amounts. However, further analysis using more sensitive and reliable (BOHS, 1973) techniques is suggested, because changing wind directions etc. render sampling difficult on open sites.

*Dust*

The dust samples all came from one site and were obtained during wet weather over short sampling periods. The amounts collected were small, and, indeed, were less than the statistical variation in filter weight. Although visual observation of the filter revealed considerable staining, no quantitative data were obtained. Further work is desirable, especially in dry weather under low wind conditions.

*Sampling of waste material*

When an agreement is first drawn up concerning the disposal of waste most contractors insist upon a sample of the material being submitted for analysis, if it is likely to be notifiable under the Act. However very few attempts appear to be made to check whether it is representative of the material delivered to the site (KEEN, 1975b), or whether any of the non-notified material is hazardous. Sometimes the producer

TABLE 6. PARTICULARS OF MATERIALS SAMPLED

| Material | Quantity | Reason sampled | Notified under *Deposit of Poisonous Waste Act* 1972 | Remarks |
|---|---|---|---|---|
| 1. White solid, fuming when tipped | 10 tonnes daily | pH = 1 | No | Calcium sulphate contaminated with sulphuric acid. As this site had a 'no toxic waste' policy it should not have been accepted |
| 2. Fine powdered aluminium in glass jar | 450 g | Pyrophoric and potentially explosive | Yes | Dangerous. Should not have been accepted for landfill |
| 3. Wrapping paper from wire insulation | 50m$^3$ | Inflammable | No | Easily ignited by match. Burnt with evolution of noxious fumes. Should not have been accepted |
| 4. 'Bakelite' waste from a lead works | 8 tonnes | Lead present | Yes | Positive for presence of lead and antimony. Wrongly notified. |
| 5. Sulphanilimide BPC | 20 g | Poisonous | Yes* | Sufficient to form lethal dose for at least 20 adults. Should not have been deposited in these circumstances |
| 6. Asbestos and asbestos cement | Approx. 100 tonnes present on site surface | Serious health hazard | Yes | Should have been covered immediately and certainly not used on road surface |
| 7. Varnish | 5 gal | Inflammable | No | Easily ignited by match. Should not have been deposited |
| 8. Tyre paint | 30 gal | Inflammable | Yes* | Easily ignited by match; noxious fume evolved. Should not have been deposited |
| 9. Tanker sludge following load ethyl vanillin | 20 000 gal per week. 5000 gal on this load | Digging out in process | Yes | Tanker barrel measurement: $>420$ ppm benzene. Too dangerous for entry |
| 10. Tanker sludge following loads of interceptor trap contents + chromic acid | 3000 gal this load | Digging out in process | Yes | Tanker barrel measurement: $>420$ ppm benzene. Too dangerous for entry |
| 11. Soda ash | 25 tonnes daily | pH = 11 | Yes | Should not have placed so as to require bulldozing. |

*Notified as 'factory waste'.

is even allowed to submit his own sample. During this study some samples were taken of materials which appeared to be hazardous either in view of their corrosive or highly inflammable nature. Table 6 sets out details of eleven of the samples taken and the results of further enquiries or analysis.

*Interviews*

The Factories Act does not apply to tipping operations and no official figures are therefore available to determine accident frequency on landfill sites accepting toxic waste in the U.K. Consequently, interviews were used to obtain data ; Table 7 summarizes the results of guided interviews. Many other unstructuted interviews were conducted to support personal observations and the following incidents are recorded as observed or reported first hand:

TABLE 7. SUMMARY OF INTERVIEWS

| | |
|---|---|
| Number of interviews (all males) | 25 |
| comprising: Tanker drivers | 8 |
| Skip drivers | 2 |
| General site transport | 3 |
| Bulldozer drivers | 7 |
| Others (excavator driver, foremen etc.) | 5 |
| Average age of person interviewed (range 25-61) | 38 years |
| Average length of experience working with toxic waste | 6 years |
| Number of persons who had attended an appropriate training course | 1 |
| Those given rudimentary instructions in handling toxics | 36% |
| Those offered health protection measures (anti-tetanus, blood tests etc.) | 24% |
| Those who had lost time due to incidents at work | 8% |
| Those who had suffered ill effects from incidents at work | 68% |
| *Protection provided:* | |
| Overalls | 84% |
| Apron | Nil |
| Goggles or face mask | 12% |
| Boots | 80% |
| Gloves | 84% |
| Head protection | 12% |

1. Tanker drivers without any assistance regularly entered road tanker barrels to clean out the contents. One particular driver was questioned about the presence of a strong smell of solvent; his complaints to a supervisor had apparently been ignored. The supervisor was presumably unaware of the hazards although at least two deaths have occurred on landfill sites from this cause alone.
2. A driver jammed the operating lever of a skip advance mechanism to facilitate his manual guiding of the fulcrum hooks. Had his fingers become trapped during this process very serious injuries would probably have resulted as the skip continued to advance to the discharge position.
3. One driver without any protective clothing used an unchocked wheeled gang-plank to gain access to the top of a site tanker whilst transferring concentrated mineral acid.
4. One driver utilized an emergency stop to jolt an empty skip into the correct carrying position on his vehicle.
5. Two operators, overcome by fumes (thought to be hydrogen sulphide) whilst working in the open air, resumed work without even being given a medical check.

6. A driver who had been hospitalized following acid burns to his legs still did not wear appropriate protective clothing. The same driver returned to a tanker carrying concentrated nitric acid which had developed serious leaks, protected only by a dust mask.
7. The management of a site where a bulldozer had been lost over the tipping face into a deep pool approached a mechanic who was known to be a strong swimmer, with a request to dive to the machine and attach a line. The pool had a high phenol content.
8. A tanker driver, despite the acid-induced state of disintegration of his boots, refrained from wearing appropriate protective clothing.
9. A bulldozer driver wrapped a wet towel around his face to lessen the discomfort of inhaling the fumes from the 25 tonnes a day of soda ash which he had to move.
10. A wheeled-shovel driver had attempted to extinguish a tip fire with his machine and been almost trapped in his cab when the hydraulic system caught fire, but still tackled fires with a similar machine.

## PRELIMINARY CONCLUSIONS

The potential for serious operator hazards was found to exist on many of the landfill sites visited.

Hazards stemmed from the nature of the operation and the dangerous materials handled, but were apparently compounded by lack of supervision and ignorance on the part of the operators.

As waste disposal is still generally regarded as a low priority, low cost exercise, specialized facilities for coping with emergencies on site were virtually non-existent or non-operational.

The *Deposit of Poisonous Waste Act* has resulted in most of the toxic materials being concentrated on a few sites, effectively increasing the hazard for a limited number of operatives.

Although the effect of the Act has also been to generate more information relating to deposits, very little of this information has reached the operator and little or no attempt is made to check the veracity of declarations concerning the nature of deposits.

### *Recommendations*

The survey described merely served as an introduction to a further investigation which is extending to all methods of solid toxic waste disposal (KEEN, unpublished) this involves visits to disposal processes (including incinerators, high density balers and vessels disposing at sea) and representative premises where toxic waste is produced to investigate storage, collection and disposal hazards. However, there would appear to be a need for measures to reduce potential operator hazards. These should include the provision of:

Safer operating procedures, competent supervision with appropriate professional support and training for supervisors and operatives.

Full scale personal protection and emergency facilities.

Mechanical handling of toxic wastes.

Checks on composition of deposited material.

*Production of the following items is urged:*

Code of Practice for disposal of toxic waste by landfill.

Operators manual for disposal of toxic waste by landfill.

An identification card for display on vehicles giving particulars of the waste carried.

The pooling of information relating to operator hazards would be facilitated following the nomination by the Health and Safety Commission of a National Reference Centre (such as the Harwell Hazardous Wastes Service).

Other measures which appear necessary are:

1. An enquiry to determine the true status of United Kingdom toxic waste landfill sites from an operator accident and disease viewpoint.
2. Quantification of the hazard to operators from:
   (a) Atmospheric contamination arising when hazardous materials such as asbestos and radioactive substances are landfilled. This study has now been put in hand (Kinsey, 1975).
   (b) Tackling fires on landfill sites by various methods.
3. Evaluation of the various respiratory protective devices, including full air-conditioning of machinery cabs, which are available for operators engaged in activities mentioned in 2 above.
4. Development of suitable field tests to be used for spot checks on the composition of waste arriving for disposal. Particular attention to be given to the inherent difficulties in safely obtaining a representative sample. (This work is now in hand following a grant of funds by the Environmental Health Officers Association.)
5. An investigation into the relationship between the particulars set out in notifications received and the actual quantity and composition of waste arriving for disposal (using both laboratory analysis and the tests developed in 4 above) to evaluate the effect that any deviation from the expected composition might have on the well-being of operators.

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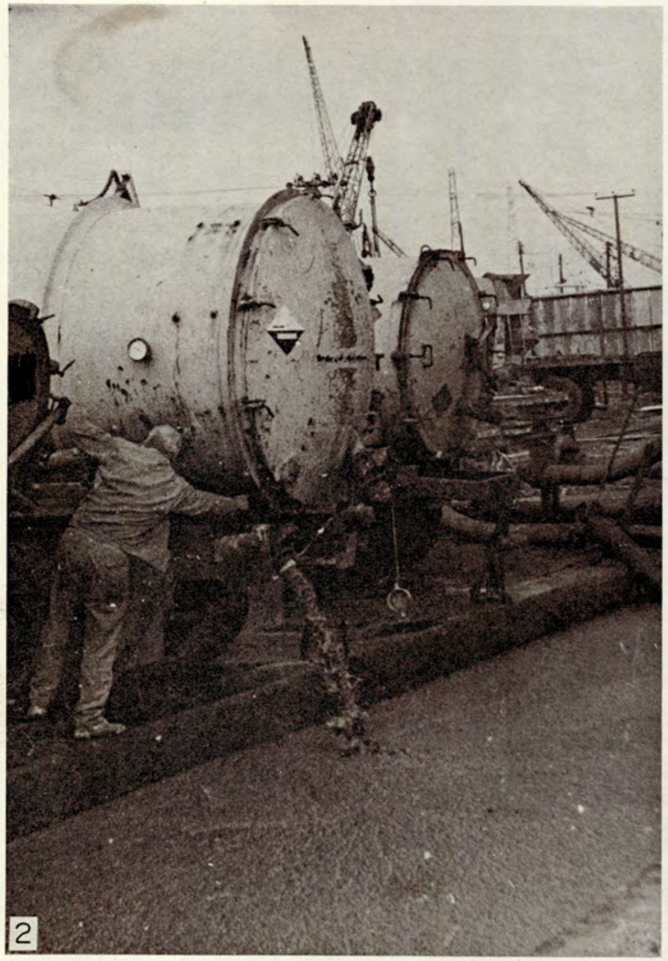

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FIG. 2. Operator controlling the discharge of waste into reception pit which is deep enough to present a drowning risk and besides containing a toxic and/or corrosive mixture might give off hazardous gases.

FIG. 3. Despite the lack of any exploratory checks this operator climbed into this tanker barrel to complete the emptying process. Detector tube measurements by the authors revealed that the atmosphere was potentially hazardous.

4

5

FIG. 4. Roadway largely surfaced with asbestos-containing waste shown carrying heavy traffic which has compounded the material and is now liberating dust.

FIG. 5. In a setting which demonstrates the poor condition of site roadways and lack of attention to tidiness, an operator is shown transferring concentrated mineral acid without any protective clothing, working on a wheeled gangplank which is unsecured. There is no assistance immediately to hand.

APPENDIX IV

## DRAFT
## of
## REGULATIONS FOR THE PROTECTION OF WORKERS
## engaged in
## TOXIC AND DANGEROUS WASTE DISPOSAL OPERATIONS

In producing this draft the following assumptions are made:-

1. The regulations will be made under a general Health and Safety at Work Act which itself will lay down in general terms, duties for employer and employee. Besides requiring every company to nominate an individual director who is personally responsible for maintenance of Health and Safety by the best practical means, it will include provisions regarding cleanliness, safety committees, accident registers etc. Consequently only those problems unique to waste disposal have been specifically covered.

2. The existence of several separate regulations (such as those dealing with labelling) have been assumed, as has a separate code of practice providing detailed guidance on items such as the classification of the extent of the hazard, the discharge of loads, health education etc.

Draft Regulations for the protection of workers engaged in Toxic and Dangerous Waste Disposal Operations.

Contents:

Reg. No.

1 Definitions
2 Application
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5 Identification of Waste
6 Operating procedures
7 Plant and monitors
8 Emergency equipment
9 Personal protection
10 Sanitary Accommodation etc.
11 Meals facilities
12 Medical Supervision
13 Monitoring of hazards
14 Register

Schedule No.

1 Emergency Equipment
11 Sanitary Accommodation etc.
111 Meals and Drinks Facilities

Regulation 1 Definition

In these regulations the following expressions will have the meaning assigned:-

Toxic and Dangerous Waste:- any substances or objects which the holder disposes of or is required to dispose of, according to article 1 of the Directive on wastes adopted by the Council of the European Economic Communities on ............ but which, in particular, may present an immediate or long-term danger from man and the environment by reasons of their toxicity, their persistence, their concentration and their quantity, (and for these reasons should be subject to special care and controls).

Those regarded in particular as toxic and dangerous wastes are listed in the annex to the third draft of the Council's directive reference ENV/151/1/75.

Disposal

- the collection, classification, transportation, treatment and destruction of poisonous and dangerous wastes as well as their storage and disposal on or in the ground.
- recycling operations necessary for their re-use, (recuperation) or storage.

Hazardous

Involving the risk of impairment of health of workers. Besides wastes which are immediately dangerous to life whether by ingestion, inhalation or skin contact, includes those which present longer term risks such as dermatitis and carcinogenisis.

Appropriate Authority - as defined in article 29 of the third draft of the Council's directive reference ENV/151/1/75.

Worker

In addition to employees, also includes contractors and sub-contractors.

Regulation 2 Application

Without prejudice to any general liability contained in the principal legislation, the provisions of these regulations apply to any person or enterprise including a state owned operation (hereinafter referred to as the company) which engages in the disposal of toxic and dangerous waste; or any worker engaged in any process incidental to such operation.

In the event of a contravention of the regulations and following conviction in an appropriate court, in the case of the company, the penalty shall be an unlimited fine and in the case of any employee (whether director or worker) to whom blame is directly attributable the penalty shall be a limited fine or period of imprisonment.

Regulation 3 - General requirement

(1) It shall be the duty of every company engaged in the disposal of toxic and dangerous waste to arrange for the connection of the necessary basis services (water supply, electricity) and means of rapid communication (telephone or two-way radio), to make liaison with the local emergency services (fire, police, ambulance etc.) to provide such plant, vehicles and equipment, to set up appropriate procedures, and to provide the necessary degree of competent supervision so as to enable it to carry out its operations without hazard to the health of its workers.

In particular, and without prejudice to the generality of the foregoing, the company shall comply with the provisions set out in the following regulations.

(2) It shall be the duty of every worker to comply with the requirements of the company in respect to behaviour, use of protective equipment, adoption of emergency routines or whatever, so as to prevent any breach of these regulations.

Regulation 4 - Education

The Company shall ensure that satisfactory provision has been made for the education and training of all workers in matters relevant to the hazards associated with their duties, and that the workers understand the dangers to which they may be exposed. The appropriate authority shall be responsible for specifying the qualifiactions necessary to comply with this regulation.

Regulation 5 - Identification of waste

In order to prevent hazards arising during the disposal process when incompatible substances meet the company shall require positive identification of every consignment of toxic or dangerous waste which it accepts. Such identification to be in the form which complies with the Toxic and Dangerous Waste Labelling Regulations and to be additional to any notifications required by other legislation. Sufficient checks on the veracity of the notifications made concerning the nature of the consigned material shall be made to ensure that waste accepted for disposal does not differ too significantly from the expected composition that a hazard might result to any worker.

Regulation 6 - Operating Procedures

In devising safe operating procedures the company shall:-

(1) Draw up a scheme for the best practicable means of avoiding danger and set this out in a written statement of policy.

(2) Produce a suitable operator instruction manual for every operation.

(3) Prohibit the employment in especially hazardous situations of single handed workers.

(4) Provide, by a permit to work system, safe routines for entry, into confined spaces and working there.

(5) Make provision for emergency routines which shall be regularly rehearsed and reviewed.

Regulation 7 - Plant and Monitoring

The Company shall provide sufficient plant, vehicles and equipment competently designed and constructed of suitable materials, provided with any necessary indicating and/or recording instrumentation, so as to prevent any hazard to workers during the disposal process.

Where necessary, an indication of the presence of factors injurious to human health shall be permanently maintained in the form of continuous automatic monitors capable of providing an appropriate warning.

Regulation 8 - Emergency Equipment

The Company shall provide and maintain such equipment and trained personnel for dealing with emergencies as is appropriate for the hazards and scale of operations. Without prejudice to the generality of the foregoing, the following items shall be maintained in a readily accessible position in accordance with the standard set out in Schedule 1.

(1) First Aid Equipment
(2) Antidotes
(3) Deluges
(4) Eye Wash Facilities
(5) Fire Fighting Facilities
(6) Respiratory Protection

Regulation 9 - Personal Protection

Without prejudice to the requirement concerning the safe operation of plant, the Company shall provide and maintain suitable and sufficient personal protection to minimize hazards to the workers. Without prejudice to the generality of the foregoing the following items shall be provided to a standard agreed with the appropriate authority and certified as acceptable:-

(1) Overalls
(2) Boots
(3) Face or eye protection
(4) Gloves
(5) Head protection
(6) Respiratory protection

Regulation 10 - Sanitary accommodation etc.

In order to minimize skin absorbtion of toxic material the company shall provide sanitary accommodation, ablutions and facilities for the changing and storage of clothes in accordance with the provisions of Schedule II. The Company shall ensure that there is no cross-examination between the "clean" and"dirty" clothes storage facilities.

Regulation 11 - Meals facilities

In order to prevent the ingestion of toxic material the company shall provide suitable and sufficient facilities for the taking of drinks and eating of meals in accordance with the provisions of Schedule III. The company shall ensure that no worker enters the facilities so provided whilst wearing any item of personal protection provided in pursuance of R.9.

Regulation 12 - Medical Supervision

In order to compliment the aforementioned provisions, but in no circumstances as an alternative to them, the company shall provide such level of medical supervision and health monitoring as are deemed appropriate by the appropriate authority.

Regulation 13 - Monitoring of hazards

After consultation with the appropriate authority the company shall monitor the presence or otherwise of every hazardous substance which is likely to contribute a risk to workers health. The results of any such monitoring shall be entered in the register required under R.14.

Regulation 14 - Register

Records shall be maintained by the company in the form of a register of the following matters:-

(1) Daily record of the quantities and composition of toxic and dangerous waste received or consigned.

(2) Results of any occupational health monitoring programme required by Reg. 12.

(3) Results of any environmental monitoring programme required by Reg. 13.

Any such records to be maintained for a period of five years, be communicated to the appropriate authority at specified intervals and be freely available to the safety committee.

APPENDIX V

## BLANKSHIRE COUNTY COUNCIL - WASTE DISPOSAL SURVEY

Date of Interview ... 1st January 1978 Conducted by A.N. Inspector

1. NAME OF COMPANY ... MECHELEC Ltd

1a DISTRICT COUNCIL ... North Blankshire DC

1b REGIONAL WATER AUTHORITY ... Nessex

2. ADDRESS ... Trading Estate, North Blankshire NIA.316

3. TELEPHONE NUMBER ... B. 1234

4a NATURE OF BUSINESS ... SIC IX MLH 361

4b WHAT IS PRODUCED Mechanical Electrical Engineering Equipment

4c WHAT RAW MATERIALS ARE USED .. Wide variety - Steel, copper plastic etc - unable to obtain precise details

5. NUMBER OF EMPLOYEES (At above address)

(a) Office ... 2,000 ... (b) Factory ... 3,000

6. NAME OF PERSON INTERVIEWED Ext.

(a) Mr A Smith ... 100

(b) Mr Z Jones ... 101

7. POSITION IN FIRM

(a) Manager - Central Services

(b) Salvage controller

8. WASTE PRODUCTION

How much waste is disposed of from the above address each year/month/week/day/- Use tons, cwts., cubic yards, gallons etc. Not quantities such as 'drums', 'tankers', skips', 'bins'.

(a) Solid Waste .. 6,600 tonnes p.a. - 1,200 t general factory rubbish, 5,400 t sand, 2t selenium contaminated waste

(b) Semi-Solid and Sludge Waste .. 4,500 gallons p.a. neutralized acid sludge containing nickel & cyanide

(c) Liquid Waste (Excluding effluent to stream or sewer): 24,000 g. p.a. waste oil. 1,200 g. p.a. waste solvents. 2000 g. p.a. iso propyl alcohol contaminated with 3% Hydrogen fluoride. 2000 g. p.a. scrap paint & varnish

(If more than one waste in any of the above classes, please list them separately. Include all wastes from the above address, including radioactive wastes.)

(d) Trends (Does firm have plans which may alter this information).

... Not at present ...

9. WASTE TYPE (Describe as fully as possible the nature of the waste disposed of. Where relevant give chemical names, concentrations, etc. Make special note of any toxic or otherwise hazardous components. Itemise separate waste streams as in your answer to Question 8. Indicate those wastes notified under the Deposit of Poisonous Wastes Act 1972.)

(a) Solid Wastes General Factory Rubbish including food waste from canteen. Sand from foundry. Selenium contaminated clothing.

(b) Semi-Solid and Sludge Wastes Neutralized acid sludge from the trtmt plant. Contains > cyanide & > nickel

(c) Liquid Wastes See 8C

10. Who takes the waste away? Solid waste removed by own skip vehicles. Semi solid & liquid waste removed by specialist contractors - Messers Greenland Jewel of Nessex

11. Where is it taken to? (Define location accurately e.g. address) Solid waste to West Blankshire & South Blankshire landfill sites. Semi solid to Greenland Jewel Treatment plant, Nessex Liquid waste to Nessex Sewage Works South Blankshire

12. What happens to it there? Is it -

(i) Tipped on land Solid waste tipped. Sludges further neutralized

(ii) Incinerated No

(iii) Reclaimed, recovered or otherwise (specify) used in any process No

(iv) Disposed of at sea No

(v) Chemically treated prior to any of the above (specify if possible) Yes Sludge is neutralized

(vi) Something-else - specify No

13. Who operates the tip/~~incinerator/etc. site~~ (at which the waste is disposed of?) Operated by Blankshire County Council For other details see Deposit of Poisonous Waste Act forms

14. How is the waste stored before its removal?

(i) in skips - give capacity 8 m³ for solid

(ii) in tanks - give capacity 3 × 5,000 lit. waste oil
1 × 2,500 lit neutralized acid sludge
1 × 500 lit — " —
1 × 15000 lit for IPA + 3% hydrogen fluoride

(iii) in drums - give capacity Some 200 litre drums for solvents
Some 25 litre drums for scrap paint & varnish

(iv) other - describe Large plastic bags for selenium contaminated protective clothing

(v) Is container closed or open? Open

15. How often is waste required to be removed from the premises?

(If more than one type of waste, answer for each)

Solid - Daily : Oil - monthly -: Neutalized

Acid sludge - three times p a . IPA - Annually

Scrap paint & varnish - on demand

16. Is there an incinerator on the premises capable of burning waste? (if 'Yes' indicate type and capacity). No

17. Is any waste not included above burned on this incinerator? (if 'Yes' give quantities and nature of materials so burnt) —

18. (a) Does the firm reclaim or re-cycle within its own operation any of its own waste materials? (If'Yes' give details)

Yes - Selenium recovered from aluminium by Mechelec

(b) Is waste capable of reclamation? Yes in part

19. Does the firm have an effluent treatment plant? (If 'Yes' outline process and give capacity.) Yes - Treatment plant complying with Nessex Trade Waste Consent - Licence Number 004

20. Does the firm have any other waste treatment equipment that is used in processing the waste before disposal? (e.g. balers, shredders) - specify No

21. Are the waste treatment facilities indicatedby answers to Questions 14, 16, 19 and 20 fully utilised by the firm's own wastes? No - the Selenium recovery plant is operated at 20% capacity

22. If not would the firm be prepared to consider their use by other companies? Yes

23. Does the firm have any waste disposal problems now or in the foreseeable future? Reclamation of solvents & IPA is presently under consideration

# APPENDIX VI
# CLASSIFICATION OF DIFFICULT WASTES

| Type of waste | Groups and *Sub-groups* | Group code | Sub-group code |
|---|---|---|---|
| Inorganic acids | Hydrochloric acid | A10 | |
| | Sulphuric acid | A20 | |
| | Nitric acid | A30 | |
| | Chromic acid | A40 | |
| | Phosphoric acid | A50 | |
| | Hydrofluoric acid | A60 | |
| | Others | A90 | |
| Organic acids and related compounds | All | B10 | |
| | *Aliphatic acids eg formic, acetic and oxalic acids* | | *B11* |
| | *Aromatic acids eg benzoic, phthalic acids* | | *B12* |
| | *Acid anhydrides eg acetic, phthalic anhydrides* | | *B13* |
| | *Acid chlorides eg acetyl, benzoyl chlorides* | | *B14* |
| | *Sulphonic acids* | | *B15* |
| | *Others* | | *B19* |
| Alkalis | Alkali metal oxides and hydroxides, calcium oxide, proprietary alkaline cleaners | C10 | |
| | *Sodium and/or potassium hydroxides or oxides* | | *C11* |
| | *Calcium oxide* | | *C12* |
| | *Proprietary alkaline cleaners* | | *C13* |
| | Ammonia | C20 | |
| | Others | C90 | |
| | *Calcium hydroxide* | | *C91* |
| | *Sodium and/or potassium carbonates* | | *C92* |
| Toxic metal compounds | Cadmium | D10 | |
| | Mercury | D20 | |
| | Lead | D30 | |
| | Arsenic | D40 | |
| | Others | D90 | |
| | *Copper* | | *D91* |
| | *Zinc* | | *D92* |
| | *Barium (water soluble forms)* | | *D93* |
| | *Thallium* | | *D94* |
| | *Nickel* | | *D95* |
| | *Vanadium* | | *D96* |
| | *Silver* | | *D97* |
| | *Others* | | *D99* |
| Non-toxic metal compounds | Iron | E10 | |
| | Others | E90 | |
| | *Ammonium salts* | | *E91* |
| | *Titanium* | | *E92* |
| | *Others* | | *E99* |
| Metals (Elemental) | Alkali, alkaline earth and other hazardous metals | F10 | |
| | *Sodium and potassium* | | *F11* |
| | *Calcium* | | *F12* |
| | *Mercury* | | *F13* |
| | *Aluminium* | | *F14* |
| | *Magnesium* | | *F15* |
| | Other metals | F90 | |
| Metal oxides | Hazardous oxides | G10 | |

| Type of waste | Groups and *Sub-groups* | Group code | Sub-group code |
|---|---|---|---|
| Metal oxides (*contd.*) | *Cadmium oxide* | | *G11* |
| | *Beryllium oxide* | | *G12* |
| | *Others* | | *G19* |
| | Other oxides | G90 | |
| Inorganic compounds | Cyanides | H10 | |
| | *Sodium and potassium cyanides* | | *H11* |
| | *Soluble complex cyanides* | | *H12* |
| | *Ferro and ferri cyanides* | | *H13* |
| | *Other cyanides* | | *H19* |
| | Others which liberate toxic gases on acidification | H20 | |
| | *Sulphides, selenides, tellurides and arsenides* | | *H21* |
| | Oxidizing compounds | H30 | |
| | *Hypochlorites and chlorites* | | *H31* |
| | *Chlorates, perchlorates, bromates, iodates, periodates, persulphates and permanganates* | | *H32* |
| | *Peroxides* | | *H33* |
| | Toxic compounds | H40 | |
| | *Chromates* | | *H41* |
| | *Fluorides, silicofluorides, borofluorides* | | *H42* |
| | *Arsenates and arsenites* | | *H43* |
| | Others | H90 | |
| | *Carbides and acetylides* | | *H91* |
| | *Borates* | | *H92* |
| | *Nitrites* | | *H93* |
| | *Nitrates* | | *H94* |
| Other inorganic materials | Asbestos | J10 | |
| | Slag including boiler and flue cleanings | J20 | |
| Other inorganic materials (*contd.*) | Mineral processing wastes | J30 | |
| | Silt and dredgings | J40 | |
| | Water (contaminated) | J50 | |
| | Metal scrap | J60 | |
| | *Ferrous metal scrap* | | *J61* |
| | *Non-ferrous metal scrap* | | *J62* |
| | Others | J90 | |
| Organic compounds | Hydrocarbons (not included in M) | K10 | |
| | *Aliphatic hydrocarbons* | | *K11* |
| | *Aromatic hydrocarbons* | | *K12* |
| | Phenols, analogues and derivatives | K20 | |
| | *Chlorinated phenols and analogues* | | *K21* |
| | Peroxides | K30 | |
| | Halogenated cleaning compounds | K40 | |
| | *Trichloroethylene* | | *K41* |
| | *Perchloroethylene* | | *K42* |
| | *Trichlorethane* | | *K43* |
| | *Trichlorotrifluorcethane* | | *K44* |
| | *Others* | | *K49* |
| | Halogenated compounds excluding cleaning compounds | K50 | |
| | *PCBs and analogues* | | *K51* |
| | *Other halogenated hydrocarbons* | | *K52* |
| | *Other halogenated organics eg chlorinated dioxins* | | *K53* |
| | Organo metallics | K60 | |
| | *Tetra ethyl lead* | | *K61* |
| | *Tetra methyl lead* | | *K62* |

| Type of waste | Groups and *Sub-groups* | Group code | Sub-group code |
|---|---|---|---|
| Organic compounds (*contd.*) | *Others* | | *K69* |
| | Nitrogen, sulphur or phosphorus-containing compounds | K70 | |
| | *Amines and amides* | | *K71* |
| | *Nitro compounds* | | *K72* |
| | *Nitriles* | | *K73* |
| | *Isocyanates* | | *K74* |
| | *Other organo nitrogen compounds* | | *K75* |
| | *Organophosphorus compounds* | | *K76* |
| | *Organosulphur compounds* | | *K77* |
| | Oxygen containing compounds | K80 | |
| | *Esters* | | *K81* |
| | *Ethers* | | *K82* |
| | *Aldehydes and Ketones* | | *K83* |
| | *Alcohols* | | *K84* |
| | Others | K90 | |
| | *Chelating compounds* | | *K91* |
| | *Phthalates* | | *K92* |
| Polymeric materials and precursors | Precursors, monomers and products of incomplete polymerization | L10 | |
| | *Epoxy resins (not finished products)* | | *L11* |
| | *Polyester resins (not finished products)* | | *L12* |
| | *Phenol-formaldehyde resins (not finished products)* | | *L13* |
| | Finished products and manufacturing scrap | L20 | |
| | *Polyurethane* | | *L22* |
| | *Other resins and polymeric materials* | | *L29* |
| | Scrap rubber (including tyres) | L30 | |
| | Latex, latex and rubber solutions and suspensions | L40 | |

| Type of waste | Groups and *Sub-groups* | Group code | Sub-group code |
|---|---|---|---|
| Polymeric materials and precursors (*contd.*) | Synthetic adhesive wastes | L50 | |
| | Ion-exchange resin wastes | L60 | |
| Fuel, oils and greases | Mineral oils | M10 | |
| | Kerosene and derv | M20 | |
| | Fuel oil | M30 | |
| | Vegetable and other oils | M40 | |
| | Oil/water mixtures | M50 | |
| | Fats, waxes and greases | M60 | |
| Fine chemicals and biocides | Pharmaceutical and cosmetic products | N10 | |
| | *Pharmaceutical products in retail containers* | | *N11* |
| | *Pharmaceutical products in bulk and production containers* | | *N13* |
| | Biocides | N20 | |
| | *Pesticides* | | *N21* |
| | *Herbicides* | | *N22* |
| | *Fungicides* | | *N23* |
| | *Other biocides* | | *N29* |
| Miscellaneous chemical waste | Mixed organic compounds | P10 | |
| | Mixed inorganic compounds | P20 | |
| | Unidentified chemical waste | P30 | |
| | *Organics identified by trade names* only* | | *P31* |
| | *Inorganics identified by trade names* only* | | *P32* |
| Filter materials, treatment sludge and contaminated rubbish | Used filter materials eg kieselguhr, carbon, filter cloths | Q10 | |
| | Contaminated rubbish (including bags and sacks) | Q20 | |
| | Empty used containers | Q30 | |
| | Industrial effluent treatment sludge | Q40 | |

*Where trade names are used the source of the material should be specified.

| Type of waste | Groups and *Sub-groups* | Group code | Sub-group code |
|---|---|---|---|
| Interceptor wastes, tars, paint, dyes and pigments | Tank cleaning sludge (note K60 for lead content) | R10 | |
| | Interceptor pit wastes (note M10–M30 for oil content) | R20 | |
| | Printing industry wastes (ink manufacture and use) | R30 | |
| | Dyestuffs waste | R40 | |
| | Distillation residues | R50 | |
| | Acid tars | R60 | |
| | Tar pitch, bitumen and asphalts | R70 | |
| | Paint waste (manufacture and use) | R80 | |
| Miscellaneous wastes | Tannery and fellmongers waste | S10 | |
| | *Tannery waste* | | *S11* |
| | *Fellmongers waste* | | *S12* |
| | Cellulose wastes (natural and synthetic) | S20 | |
| | Waste treated timber | S30 | |
| | Soap and detergents | S50 | |
| | *Soap* | | *S51* |
| | *Detergents* | | *S52* |
| | Other industrial wastes | S90 | |
| Animal and food wastes | Animal processing wastes | T10 | |
| | *Carcasses and flesh* | | *T11* |
| | *Blood, fat grease etc* | | *T12* |
| | *Excrement* | | *T13* |
| | Food processing wastes (including starch) | T20 | |
| | Glue wastes | T30 | |

APPENDIX VII

Keen R C and Mumford C J
Health and Safety at Work
October 1978 pp 70-73

# Waste disposal...

## Reducing the risks involved

Accidents such as the death of a driver at a tip two years ago and recent public sensitivity to incineration of waste insecticide from the USA by a UK contractor are the direct and indirect consequences of bad disposal practice in the past. Concern over hazards to operators, however, is more recent than the question of environmental impact of waste materials – which has attracted interest for several years. This article summarises present practice, reviews the occupational health and safety hazards associated with toxic and dangerous wastes, and outlines measures to reduce or mitigate them.

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Of the 160 million tonnes of solid waste generated annually in the UK about 5 million tonnes (3.1 per cent) may possess properties that result in its being classified as "toxic" (harmful through ingestion, inhalation or skin contact) or "dangerous" (associated with a fire or explosion hazard).

Disposal of these materials encompasses landfill or incineration as well as any recycling, detoxifying, liquefying or encapsulation process which is part of the routine. Since few waste disposal routines are fully mechanised there are numerous ancilliary operations in collection, delivery, loading/unloading and debagging/dedrumming which, though relatively simple, tend to bring the operators into close contact with the wastes.

In 1970 solid waste disposal comprised about 95 per cent landfill (mostly tipping into disused mineral workings), 4 per cent incineration and 1 per cent dumping at sea. Landfill was also the predominant method for toxic waste disposal and the picture remains substantially the same today.

In addition, some wastes are disposed of into mine shafts, while several chemical waste treatment plants and incinerators are now in operation but only cater for a relatively small amount of total arisings[1].

Disposal sites differ according to their ownership. Those operated by the waste producer usually dispose of a smaller range of wastes of known origin compared with the mixed wastes handled by waste disposal contractors. The most significant differences are between landfill sites and waste treatment centres.

The site shown in fig 1 may not be typical but it does illustrate the essential simplicity of toxic waste deposition on land, and the isolated nature of the location still inherent in many operations. Waste should be deposited in layers of restricted depth and covered with inert, innocuous material at the end of each working day[2].

A plentiful supply of adequate cover is not always available and complaints about the environmental impact associated with some tipping operations are most often due to this fundamental requirement being overlooked.

Disposal methods on landfill sites vary from crude dumping to relatively sophisticated operations involving reception pits, pumps and pipelines to soakage trenches. In some cases the waste is transferred to site tankers, which are better suited than delivery vehicles for crossing the rough terrain of the tip. Ideally the solid deposits are covered as swiftly as possible and the liquid waste rapidly soaks away. The recent introduction of site licensing requirements, such as the provision of security fencing, is beginning to reduce the possibility of trespassers gaining unauthorised access to landfill sites, but the presence of totters, who make a living by sorting through wastes such as those containing lead, needs to be taken into account.

Tighter security and better controls tend to be characteristic of treatment sites where wastes are incinerated, treated chemically, or in some cases dedrummed and repacked for sea disposal. The fact that wastes are to be processed rather than dumped means that much greater attention must be given to waste composition and storage. Therefore analytical facilities are normally provided at such premises.

Within the last decade legislation has increased the controls exercisable over waste disposal routines. Thus the new County Waste Disposal Authorities have been granted site licensing powers under the Control of Pollution Act 1974 and the notification procedure introduced by the Deposit of Poisonous Waste Act 1972 remains in force. But from the waste producer's viewpoint disposal is a low cost, low priority exercise and problems may arise from this.

Whatever the method of disposal, wastes need to be segregated, collected, transported and possibly even processed first. A provisional code of practice published in 1972 proposed that the waste producer should classify the various wastes, certify their contents and disclose any known hazards[3]. Identification may first be made in terms of physical properties – liquids, slurries, sludges, thixotropic solids or solids, and then as to hazard using the scheme shown in table 1.

Wastes in different classes, or of different content, should be segregated wherever reasonably possible to allow for separate collection, transportation and disposal. The producer is recommended to ensure that his employees and those of any carrier conform to the code of practice. The latter's responsibilities include the provision of equipment, containers and vehicles of suitable design and condition, the instruction and training of his own employees, and a system of work to ensure that suitable waste handling equipment and protective clothing are used when necessary. Ideally the routes of vehicles should be planned and, in the case of hazardous wastes, personel should be issued with written instructions and appropriate emergency services advised of the journey. The vehicles, or containers, should carry bold markings, relevant safety information and some form of Transport Emergency Card or Hazchem marking if appropriate.

The introduction of the Deposit of Poisonous Waste Act produced a radical change in disposal procedures though the methods remained essentially the same with operations concentrated on fewer sites.

This change, coupled with increasing complexity of wastes, and subsequently the introduction of the Health and Safety at Work Act, prompted studies of toxic waste disposal routines[4] and the environmental health[5] and occupational safety and health problems[6,7] associated with them.

Several potential toxic and physical hazards to operators have been found to arise during waste disposal. In the case of **inhalation of dust, fumes or gases** sufficient exposure may occur to exceed the STEL (short term exposure limit) during the tipping, or disturbance, of waste (for example asbestos) despite the operation taking place in the open air. As an example the picture opposite shows the extent of the dust cloud produced by a bulldozer pushing waste to the edge of a tipping face on a landfill site. Here the operator had contrived to work from upwind of the deposit, a measure not always possible.

Dedrumming or debagging of waste may also result in intermittent exposure to dust clouds or toxic gases. For example a dedrumming operation in which a pneumatic chisel was in use under wet conditions for opening spent cyanide drums is shown in fig 2 and somewhat rudimentary debagging of lead waste in fig 3. Less obvious sources of toxic emissions are the wetting of reactive waste, such as certain metal drosses, and the mixing of incompatible materials such as hypochlorites, cyanides or sulphides with acids. Admixture of wastes for neutralisation or other treatment can take place in lagoons rather than process vessels so that control is harder to ensure. Exposure may also arise in confined spaces during entry for cleaning or inspection of tanker barrels, treatment tanks, soakage trenches or excavations. Finally toxic gases such as carbon monoxide, hydrogen chloride or hydrogen cyanide might be produced during accidental or unauthorised waste combustion.

Some toxic substances sent for disposal could affect operators through absorption or injection via intact mucous membranes or skin. These substances include solvents, phosphorous compounds, aniline and alkaloids. Exposure may arise through manual operations which either inherently, or by the adoption of "short cut" methods, result in physical contact. A contaminated particulate solid can be assisted in its travel through a conveyer by the simple expedient of "treading" it. Here the significance of the typical minor injuries common to much work may be altered. The presence of toxic substances or pathogenic organisms means that contamination of any wounds may have serious consequences.

Table 1 Classification for hazardous wastes

| | |
|---|---|
| Class 1 | – Explosives |
| Class 2 | – Gases: compressed, liquefied or dissolved under pressure |
| Class 3 | – Inflammable liquids |
| Class 4(a) | – Inflammable solids |
| Class 4(b) | – Inflammable solids or substances liable to spontaneous combustion |
| Class 4(c) | – Inflammable solids or substances which in contact with water emit inflammable gases |
| Class 5(a) | – Oxidising substances |
| Class 5(b) | – Organic peroxides |
| Class 6(a) | – Poisonous (toxic) substances |
| Class 6(b) | – Infectious substances |
| Class 7 | – Radioactive substances |
| Class 8 | – Corrosives |
| Class 9 | – Miscellaneous dangerous substances, that is any other substance which experience has shown, or may show, to be of such a dangerous character that these rules should apply to it |
| Class 10 | – Dangerous chemicals in limited quantities |

Significant intake of toxic materials by ingestion through the digestive system is no longer a problem in factories generally, because better hygiene regulations have prohibited eating and drinking in specific work areas and provide minimum requirements for washing facilities. But on any waste disposal site lacking these provision, hazards might arise from classic poisons (such as cyanides, arsenic and strychnine), synthetic poisons (for example acaricides, insecticides, fungicides and rodenticides), drugs, or in the longer term heavy metals.

Eye or skin injuries can arise through handling a variety of corrosive chemicals, such as alkalis, acids, phenols or cresols. A dermatitic hazard may be associated with prolonged or intermittent exposure to a wide range of other materials.

Of the possible physical hazards fires, although unauthorised, are common on landfill sites but present minimal to operators because work is in the open air. But the use of landfill machinery to control burning material by smothering or isolation has given rise to hazardous situations and has resulted in at least one fatality. A noise hazard may arise with the operation of some landfill machinery such as bulldozers, scrapers and cranes.

Primary entanglement with machinery on some operations, such as removal of material foulding the drive on bulldozers or freeing jammed skips, is one of the major mechanical hazards. Many waste disposal sites are isolated, so that machinery maintenance may be carried out under rudimentary conditions; this may result in "under-maintenance" and, since facilities for machinery decontamination can be rudimentary, may enhance any toxic dermatitic hazards.

Where heavy plant is used there is always a possibility of vehicle accidents and a risk of overturning bulldozers or compactors on badly planned landfill sites. Normal slips and falls are as likely on waste disposal facilities as in other factories but the untidy state of some sites, which can easily degenerate into little more than crude dumps, tends to create an increased risk of simple accidents.

**Table 2 Examples of wastes from one company**

**A company employed 70 men in reconditioning steel drums. During the process 100 gals/day of semi-solid waste were drained from the drums. The notification sent by the company under the Deposit of Poisonous Waste Act indicated that the drums had contained the following materials:**

- **Resins – alkyd, acrylic, polyamide, phenolic polyurethane, polyester, polystyrene, emulsions of polyvinyl acetate and chloride, acrylonitrile, butadiene, styrene rubber;**
- **Solvents – hydrocarbon, triethylene glycol, acetone;**
- **Adhesives – petroleum-based contact type;**
- **Paints, varnishes, lacquers with and without pigments, hardeners, plasticisers and foaming agents used in the plastics industry.**

**This was not based on analyses, because it is difficult in practice to devise a system which would ensure that the numerous components of a mixed waste are accurately recorded.**

Attention has been drawn to the potential role of infective agents such as anthrax and leptosporosis in affecting operators' health; any leather, wool or bonemeal wastes may produce the former and the presence of rodents increases the likelihood of the latter. Any hospital or slaughterhouse wastes or sewage sludge may contain pathogenic organisms that can be dangerous via skin contact. Poor personal hygiene could also result in gastro-intestinal infections.

To handle a waste safely it is necessary to know, in general terms at least, its toxicity, flammability, stability, corrosiveness, dermatitic potential, reactivity and any other properties that could create a hazard to operators. Contractors who handle a variety of wastes may be at a disadvantage here, especially if collection and transportation is by a third party. Therefore it is essential that wastes are properly notified.

Under the Deposit of Poisonous Waste Act, every producer must provide information on the nature and quantity of wastes to be disposed of. A model form has been proposed on which the producer is requested to declare the waste's chemical composition; provision is made for an analytical report[10]. Any risks, the best practicable means of disposal and authorisation for such disposal are recorded on the form, a copy of which is carried by the driver of the delivering vehicle used to transport the waste to its disposal point.

Under a code of minimum acceptable standards for the collection, transportation and disposal of waste contractors should ensure that the producer declares all relevant details of the chemical and physical nature of the waste, its "quality", rate of arising and any special properties[11]. Consideration can then be given to any hazards likely to arise in loading, transportation, unloading, treatment and/or disposal before it is removed.

The unusual case of a drum reconditioning company (summarised in table 2) highlights the problem of accurate notification.

Monitoring of wastes as a check against notification documents, to avoid admixture of incompatible chemicals and to minimise environmental pollution, may be prohibitively expensive. This is exemplified by the range of properties from which a selection must be made, as summarised in table 3[10].

**Table 3 Waste analysis**

**For inorganic wastes**

| | |
|---|---|
| **Reaction with water** | *Identification of any gases evolved* |
| **Reaction with acids** | |
| **Reaction with alkalis** | |

**Effect of heat**
**pH, total solids**
**Presence of sulphides, total cyanide, ammonium compounds**
**Concentration of metals Pb, Zn, Cd, Hg, Sn, As, Cu, Cr, Ni**

**For organic wastes**

**Calorific value**
**Flash point**
**Miscibility with water (or other wastes)**
**Viscosity at various temperatures**
**Halogen sulphur nitrogen content**
**Ash content**
**Analysis of ash**
**Organic content by BOD, COD, PV, or total carbon methods**

*For mixtures of inorganic and organic wastes, all these analyses should be completed.*

A test kit is now marketed that will identify hazards (not chemicals) in categories such as poisonous, explosive, flammable and corrosive. In principle any unexpected positive result from a site test performed on a small sample of waste can be followed by more sophisticated analysis or enquiry to the waste producer.

Simple guidelines are available for safety during some operations involved in waste disposal[11]. Firstly the waste should be categorised and certified by the producer and checked by the contractor, who should advise on segregation and storage prior to collection. Admixture of wastes during transportation or disposal should be avoided unless there is technical evidence to show that no personnel or environmental hazard will be created. The correct type of container or tanker should be selected for transportation: loose waste or containers should be adequately checked and secured during transportation.

Safety measures advisable on a disposal site operation reflect those which tend to be taken for granted in chemical manufacturing or bulk chemical handling factories. Some of them are of even more significance because of the variety and admixture of wastes that may be processed.

There should be operating manuals describing every operation and recipe, the correct sequence, potential hazards and specific measures to guard against them. Lone working should be prohibited in specially hazardous situations or in confined spaces.

For work in confined spaces or on contaminated equipment there should be a permit-to-work system.

Operators should be provided with appropriate overalls, boots, gloves, eye or face protection and respiratory equipment. This clothing and equipment must be inspected or maintained on a regular basis as necessary.

Washing facilities should be provided to the standards acceptable under section 58(1) of the Factories Act[12] and changing facilities should be planned to eliminate any cross contamination between clean and dirty areas.

Provision of a messroom reached from the working areas via the changing facilities, and prohibition of its use by operators in overalls, is a useful arrangement. The usual first aid and firefighting provisions are necessary plus provision for eyewash facilities, and emergency deluge showers or equipment. Telephones should be available in strategic locations for contacting emergency and fire services when necessary. Rehearsals of emergency drills should be performed at regular intervals.

In future more attention will need to be given to mechanisation and improved engineering design both to increase operating efficiency and to remove the operator from contact with the waste. A pneumatically operated tanker discharge valve obviates the need for a driver to either lean over the pit or tank into which waste is to be discharged. Alternatively, and equally unacceptable, he would have to open the valve before reaching the pit and reverse the tanker while waste is discharging from it. If the scale of operation permits, solid waste handling can be completely mechanised as illustrated for domestic refuse in fig 4.

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Fig 1

Fig 2

Fig 3

Fig 4

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# SAFE DISPOSAL OF TOXIC WASTE

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The Key Report (1) began by stating that the word toxic was synonymous with poisonous and after pointing out the difficulty of defining a toxic concentration, suggested that the environmental implications of the material when deposited were also important. In fact the Deposit of Poisonous Waste Act, 1972, in defining 'poisonous' makes reference to any material, the presence of which gives rise to an environmental hazard (i.e. the creation of material, risk of death, injury or impairment of health). Hence explosive or highly inflammable materials, possibly of scant toxicological significance, such as paint residues, are included.

Whilst the physical state of the waste is usually a solid or semi-solid, liquids are not excluded from the definition unless they leave the premises by sewer rather than tanker.

The convention of regarding radioactive wastes as an entirely separate problem will be observed in this paper.

It is of significance that the Key Report estimated that in the UK 88% of toxic waste was disposed of to land. By categories, this included flammable waste 82%, acid or caustic 72% and indisputably toxic 96%.

The basic operation on a landfill site is merely that of tipping material on land. Fortunately it is often feasible to combine waste disposal with land reclamation, so that many landfill operations are reclaiming derelict land or mineral extraction quarries, but the term also encompasses the creation of artificial mounds of waste, such as are sometimes encountered on estuaries. Present practice in the UK favours the use of techniques to ensure the rapid covering of deposited hazardous solid or semi-solid material, or the provision of trenches to facilitate the safe absorption of liquid waste into previous deposited innocuous waste.

It may be worth noting that our standards for discharge of toxic substances to land (also to water and air for that matter) will in all probability have to yield to the pressure for harmonization being exerted by the European Economic Community.

Whilst waste disposal might seem to be a topic outside the proper area of interest for an Economic Community, a moment's reflection will reveal that a member state which was irresponsibly disposing of its wastes could thereby obtain (at least in the short term) a financial advantage over its more responsible neighbours. Hence the directives already published on Waste Disposal and Waste Oils provide for a common standard of Environmental Protection.

Such directives can have very serious implications for the waste disposal industry. For example, Article 14 of the Second Preliminary Draft of the proposals for a Council Directive on the Disposal of Toxic and Dangerous Substances included a provision which would have prevented toxic waste being combined with domestic or other waste, thereby requiring a radical re-structuring of the UK landfill disposal practice. Lest it be thought that proposals such as this are totally unrealistic, it is worth reflecting that the Dutch take land pollution so seriously that the MV 'Vulcanus' finds it profitable to operate out of Rotterdam, steaming in circles on the North Sea incinerating some of the sort of wastes that are accepted for landfill here. The importation of waste from abroad for disposal in the UK provides food for thought in connection with our standards. (One quarter of the cyanide wastes treated within the area of the Greater London Council during 1973 were from Europe and one fifth of the P C Bs incinerated in the UK in 1975 were also imported.)

The recent report of the Secretariat of the United Nations Economic Commission for Europe into high waste technology in the inorganic chemical industry concludes that unless remarkable progress is made their quantities may double every 10 to 12 years.

Waste production in the manufacture of soda ash, caustic soda, chlorine, sulphuric acid, titanium dioxide, ammonia phosphoric acid, nitric acid and sodium dichromate has been analysed and the study suggests that due to environmental protection measures, increased costs will be so steep that production in some older plants sited in areas posing difficult waste disposal problems will become uneconomic.

## Case Studies

Perhaps the clearest way to demonstrate the possibilities for harm arising from toxic waste disposal in the absence of any official statistics is by reference to selected case studies from the UK:

### Risks to Operator and Drivers

In addition to the notorious fatality at Pitsea due to hydrogen sulphide the following is a selection of incidents which have come to the notice of the author as having occurred within the last 5 years:

1. Dump truck driver died while disposing of waste near a pit containing cyanide waste.
2. At least two deaths and several narrow escapes when operator entered, (for cleaning purposes) road tanker barrel interiors which were in use for transporting waste.
3. Driver seriously injured when the rear door blew off a tanker loading waste at the producer's premises.
4. Operators driving contractor's bulldozers moving waste from a large chemical complex in the North West, suffered minor kidney damage due to the chlorinated hydrocarbons in the sludge.
5. One operator died and 7 hospitalized at Market Drayton following generation of arsine from smelter waste.
6. Seven men (including an ambulance crew) overcome by solvent fumes during disposal of waste paints on a landfill site in Luton.
7. Two labourers killed by gas whilst tunnelling on an industrial waste tip in the West Midlands.
8. A narrow escape for a tanker driver carrying an entirely uncovenanted mixture of hot sulphuric and nitric acids which, besides requiring the services of a fire brigade to check the runaway pressure rise, appreciably reduced the thickness of the 6mm steel tanker barrel.

## Risks to persons residing close to disposal sites

1. Large quantities of Nitrogen Dioxide have been emitted at ground level in at least two separate incidents at landfill sites, the first being due to the use of a totally unsuitable site tanker, the barrel of which was rapidly perforated by nitric acid and the second due to a failure to allow for the increased reactivity of nitric acid at high temperature induced by exceptional weather conditions.

2. Explosion of a very large oil storage tank in use at the height of the oil crisis for emulsion splitting and oil recycling, discharged a mixture of hot oil and acid over a wide area, also resulted in two operators being overcome by fumes.

3. Several major fires on landfill sites have posed serious hazards to local residents, not only from the products of combustion themselves, but also airborne missiles resulting from exploding drums and finally pyrolysis products (notably phenol) gaining access to public water sources.

4. "Neighbourhood Cases" of Asbestosis including deaths amongst individuals whose only known connection with asbestos has been to reside adjacent to landfill sites.

From outside the UK, the following items merit attention:

1. Within a few days of its opening, a large Dutch trade waste incinerator was put out of action by a major explosion caused by an uncovenanted load.

2. Two men were killed in Germany by an explosion due to an unexpected constituent in a waste oil which was being recycled.

3. Of the large number of incidents in the USA (now afforded their own 'Hazardous Waste Disposal Damage Reports' by the Environmental Protection Agency) the following are worth reference:

    a. Arsenic wastes which had been buried in Minnesota, USA, 30 years before, hospitalized a number of people in 1972 when their water supply became contaminated.

    b. New Jersey bulldozer driver burnt to death following explosion of drum of waste acetone.

    c. The spraying of farm roads and a horse arena in Missouri with waste oil containing dioxin gave rise to the deaths of 63 horses and numerous other stock and affected 10 humans, 2 of whom were very seriously ill.

    d. Finally, perhaps one of the least expected hazards arose during transportation of waste organic lead in San Fransisco where bridge toll collectors on a route regularly used by disposal vehicles became ill as a result of inhaling the toxic material.

## Introduction

The Deposit of Poisonous Waste Act was introduced in 1972 as a result of the attention the media were giving to the 'Cyanide Scare'. This Act was not really a determined attempt to solve the problem, but rather an exercise with rather limited objectives, firstly to provide legislative reinforcement to the common law 'tort' of nuisance arising from the dumping of waste, secondly to re-write the statutory nuisance category contained in Sec 92 1(c) of the Public Health Act 1936 as a direct offence, with the "best practicable means" defence available to industrialists deleted, and finally to generate shoals of statistics relating to the quantity and composition of toxic waste.

However, the over-reaction on the part of Local and River authorities at the time produced major changes not in the disposal methods, but rather in the availability of disposal sites. An unprecedented number of authorities effectively introduced embargos on any toxic waste disposal in their areas and the toxic waste was channelled into a much smaller number of sites that were not so restricted. For example, the liquid waste intake to Pitsea in Essex grew by a factor of more than eight in the three years following the introduction of the Act.

Hence the 3 million tonnes annual production of toxic waste is now being carried around our crowded roads to a much greater extent, 75,000 tonnes a year travel an average of 350 Kms. and some wastes travel 750 Kms. for disposal (2), (3,000 tankers a month through Basildon) and consequently besides the operators on those handful of toxic waste sites and the residents living close to them, both the vehicle drivers and the general public are also subject to increased hazards. Because these smaller number of sites still use traditional landfill methods and hence provide a cheaper service, the sophisticated treatment plants are in the main woefully underemployed.

Some comfort can be taken over the subsequent emergence of legislation which is showing signs of improving the lot of two of the groups referred to above who are most seriously affected by these changes. The Health and Safety at Work and the Control of Pollution Acts both appeared on the Statute Book in 1974 and the virtually immediate implementation of the former Act, besides purely fortuitously giving many solid waste workers their first statutory protection whilst at work, also introduced the statutory obligation for site operators to consider the effects of fumes and other emanations from their processes. This additional reinforcement of the law of nuisance has recently been complemented by the delayed introduction of Part 1 of the Control of Pollution Act, which is now introducing licensing of waste disposal sites by County Councils (and the G L C ) who are Waste Disposal Authorities in the case of England, and by District Councils in Wales. Hence people living close to such sites should now be afforded a measure of protection against the very real risks to which they have been subject. For example, the implications of a massive release of toxic gas will now have to be considered - especially in the light of the findings of the Flixborough induced enquiry (3). Several relatively simple prediction systems exist and in fact if dose rates in grams per unit time will suffice, then a modified inverse square law rule can be utilised. Likely aerial concentrations at the perimeter fence can then be compared with the short term limits now reprinted by the Health and Safety Commission from the American Conference of Governmental Industrial Hygienists' published figures. At this point, the "reasonable man" on the top of his mythical Clapham omnibus might be expected to ask whether this is enough protection in this over-legislated island.

In the author's opinion the answer must be no, and the reasons are not difficult to discover. All of these legislative innovations, laudable as they might be, are examples of the application of remedies on the wrong interface. The weight of the legislation is being directed towards ameliorating the problems inherent in safety disposing of the waste and has only an incidental effect on the increase in the volume and unpleasantness of the waste itself. The legislature would be rewarded with more success if more attention was directed to the point of generation of waste.

The Alkali Acts since their inception have concentrated on registerable processes and it has been an automatic offence not to have registered with a central inspectorate if operating any of the scheduled processes which are likely to give rise to highly offensive air pollutants. Hence a mere handful of inspectors who possess detailed knowledge of the industry concerned and the power to put firms out of business, have been able to control a large number of processes. They have worked alongside local authority inspectors who have been dealing with generally less offensive and immediately dangerous forms of pollution, mostly smoke and sulphur dioxide.

However, the present structure under the Control of Pollution Act requires every waste disposal authority (and there are more than 40 of them in England alone), to obtain the necessary expertise to oversee the disposal of very complex wastes once they have left the factory gates - a problem which will in practice be found to defy solution. For example, it is now very easy for an unscrupulous industrialist who has just been quoted £100 a tonne for disposal of an extremely toxic waste to arrange for it to be salted amongst the innocuous solid waste which is regularly leaving his premises. The odds against this anti-social behaviour coming to light are very slight. A postal survey of the Waste Disposal Authorities in 1974 revealed that few checks were carried out on the veracity of deposits actually made (4). This contrasted markedly with the extensive analyses of samples taken prior to deposit. (Many of which the industrialists were allowed to submit themselves.) Random checks undertaken by the author with a simple test kit developed for the purpose, have shown that it is not difficult to demonstrate the presence of significant quantities of hazardous material even on landfill sites with an absolute 'no toxic waste' policy.(5)

Hence the author would agree with the conclusions reached in the 5th Report of the Royal Commission on Environmental Pollution (6) which urged the creation of a unified Inspectorate to properly deal with the interactions between land, water and air pollution possible as a result of disposal of certain wastes.

Finally industry must begin to pay as much attention to its solid waste as it has become used to paying to its liquid and gaseous wastes. For example, in relation to cyanide wastes, the implications of a tanker leaving a producer's premises laden with 15 tonnes of this material instead of the expected 15% hydrochloric acid can no longer be ignored, any more than can the serious hazards that are posed for workers who have to shovel cyanide from skips when it is heavily contaminated with scrap metal, wire and glass fragments. Bearing in mind that the lethal dose of cyanide when ingested is half a gram, the likely outcome of a puncture wound from a piece of cyanide contaminated wire direct into an artery should be taken into account by the persons consigning the waste.

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## APPENDIX IX

Report to O.E.C.D. Committee 25/26th May, 1979

Waste Disposal

In this discussion of the legal controls over wastes associated with chemical substances radioactive materials will be excluded and a distinction will be made between:-

(a) Wastes arising during the production of the chemical substances in question

(b) Wastes formed either as a direct consequence of their use or during their recyding or ultimate disposal.

With the possible exception of some minor control over occupational use of chemicals, the earliest examples of legislation in the UK with respect to wastes associated with chemical substances were directed against the gross abuses in category (a) above which occurred during the mergence of the chemical industry in the 19th century. Action in respect of category (b) has followed much more slowly and in a piecemeal fashion. Indeed development of legislation to control solid wastes has lagged behind that in respect of gaseous and liquid wastes. An Official Committee pointed out as recently as 1970 that whilst there was a well developed body of legislation devoted to liquid and gaseous wastes, no such body of legislation existed for solid toxic waste control. This gap is still in the process of being filled.

The development of common law actions in respect of waste disposal problems associated with the production and use of chemical substances is traceable back for a century or more. As might be anticipated some of the oldest cases are also in respect of pollution from the emergent chemical industry, although the distinction between categories (a) and (b) is not so easy to define.

There is a noticeable lack of precise legal standards relating to acceptable levels for specific wastes. In this connection the use of the "best practical means" concept needs to be examined, as it has been a fundamental principle that the industrialist against whom a complaint has been laid has had, in most circumstances, a defence open to him by way of justifying the nuisance if it could be established that it was a necessary part of a business process and the best practicable means of preventing it had been adopted. This term is amplified, so far as the Public Health Act 1936 is concerned for example by S.110 which requires the court to have regard to cost and to local conditions and circumstances. Also in the Clean Air Act "practicable" is defined as meaning "reasonably practicable having regard, amongst other things, to local conditions and circumstances, to the financial implications and to the current state of technical knowledge" and "practicable means" includes the "provision and maintenance of plant and the proper use thereof". Similar definitions are found in S.72 of the Control of Pollution Act. The existence of this defence makes it difficult to assess just what degree of nuisance justifies formal proceedings before the Court and, against that background, how far an authority can legitimately go in requiring industrialists to carry out remedial measures. Clearly there can be no precise standard as to what is "practicable" to minimise the effect of a noisy operation or a noxious accumulation and the judgement is a subjective one. Moreover a determination in one case is unlikely to be of much assistance in dealing with another because what are called "local conditions and circumstances" will be different each time. Hence there is no clear and unambiguous case illustrating the effect of this defence. Despite the uncertainty which it introduces it is necessary qualification of the general liability for statutory nuisances, allowing for the continuance of necessary but unpleasant operations if at least reasonable efforts have been made to mitigate their effects upon others. It introduces into the statutory law the same degree of elasticity as can be detected in the law which governs private nuisances which affect convenience and comfort. For example, the private action of Walter v Selfe in 1851 produced the ruling that: 'Nuisance is an inconvenience materially interfering with the ordinary comfort, physically, or human existence, not merely according to elegant or dainty modes of living, but according to plain and sober and simple notions among the English people.' More than 100 years later, however, it was ruled in the case of Halsey v Esso Petroleum in 1961 that: 'If a man lives in a town, it is necessary that he should subject himself to the consequences of those operations of trade which may be carried out in the immediate locality, which are actually necessary for trade and commerce, and also for the enjoyment of the property and for the benefit of the inhabitants of the town and of the public at large'.

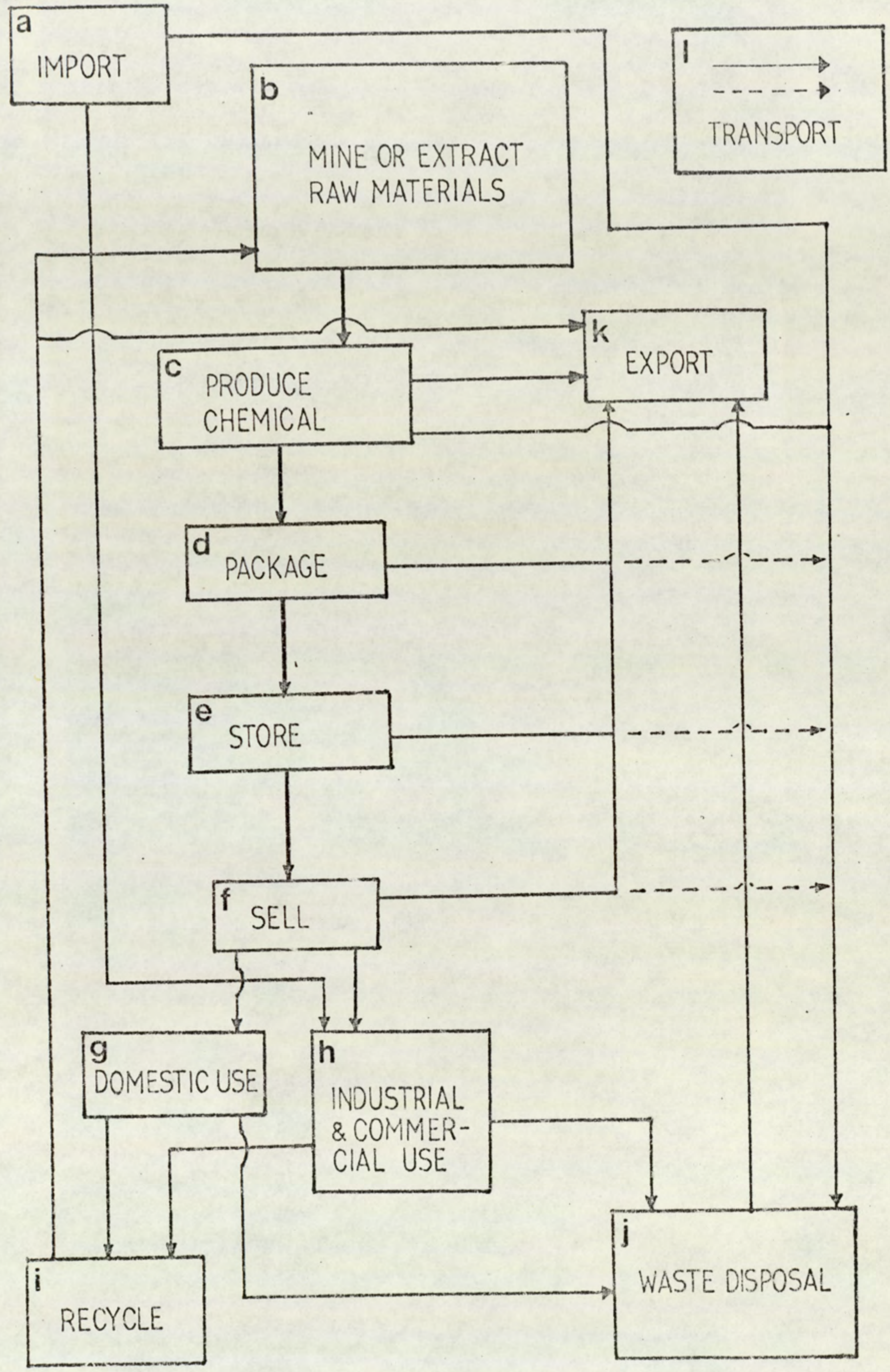
There have been several recent legislative innovations in respect of waste disposal. Health and Safety at Work and the Control of Pollution Acts both appeared on the Statute Book in 1974 and the virtually immediate implementation of the former Act, besides purely fortuitously giving many solid waste workers their first statutory protection whilst at work, also introduced the statutory obligation for site operators to consider the effects of fumes and other emanations from their processes. This additional reinforcement of the law of nuisance has recently been complemented by the delayed introduction of Part 1 of the Control of Pollution Act, which is now introducing licensing of waste disposal sites by County Waste Disposal Authorities in the case of England, and by District Councils in Wales.

Table 1 provides a synopsis of the legislation which currently exists to control waste disposal and sets out the control agencies responsible for enforcement. This multitude of enforcement agencies has been unfavourably commented upon by the Royal Commission on Environmental Pollution and it urged the creation of a unified Inspectorate to properly deal with the interactions between land, water and air pollution which are possible as a result of disposal of certain difficult wastes. In order to provide a guide to the framework within which the waste disposal legislation fits Figure 1 and tables 2a and 2b are also included. These provide in diagrammatic form a comprehensive summary of all the legislation for controlling the effects of chemicals on workpeople the public and the environment.

## TABLE 1 WASTE DISPOSAL LEGISLATION

| TYPE OF WASTE | LEGISLATION | CONTROLLING AUTHORITY | STANDARDS |
|---|---|---|---|
| AIRBORNE: | | | |
| Emissions from "Scheduled processes". | Alkali Works Regulation Act 1906 | Alkali Inspectorate (H.S.E.) | Best practical means to be used. 'Presumptive' standards published for certain substances e.g. $SO_2$, $H_2SO4$ in flue gases. |
| Emissions from non scheduled processes. | Public Health Act 1936<br>Clean Air Acts 1956 & 68<br>Control of Pollution Act 1974 | District Councils | Best practical means to be used. No legislative standards 'Statutory Nuisance' Concept. |
| Emissions from premises where people are employed. | Health & Safety at Work Act 1974 | Her Majesty's Factory Inspectorate (H.S.E.) | No legislative standard. |
| WATERBORNE: | | | |
| (a) Inland Waterways & Estuaries | | | |
| Effluents from "Trade Premises". | Public Health Act 1936<br>Public Health (Drainage of Trade Premises Act) 1937 | Water Authorities | Certain legislative standards e.g. Petroleum "Consents" used for certain other discharges e.g. Cyanide, Phenol, Lead etc. |
| Other Effluent | Rivers (Prevention of Pollution) Acts 1951 & 1961<br>Clean Rivers (Estuaries & Tidal Waters) Act 1960<br>Water Resources Act 1963<br>Salmon & Fresh Water Fisheries Acts 1923-1965<br>Control of Pollution Act 1974 | — " — | No legislative standard. Royal Commission Report produced recommendations. |
| (b) Deep Sea | | | |
| Discharge beyond low water mark. | Dumping at Sea Act 1974 | Ministry of Agriculture Fisheries & Food Licensing Division | Certain wastes banned, e.g. mercury. Others disposed of in prescribed areas at rates specified in the licence. |
| DISPOSAL TO LAND: | | | |
| Any deposit of waste likely to cause an environmental hazard. | Deposit of Poisonous Waste Act 1972<br>Control of Pollution Act 1974 | County Authorities in England<br>District Councils in Wales | No legislative standards. Items such as builders rubble excluded. Codes of practice produced specifying levels of certain wastes such as cyanide. |
| Litter | Dangerous Litter Act 1971 | District Councils | No legislative standards. |
| Accumulations which are prejudicial to health or a nuisance. | Public Health Act 1936 | District Councils | 'Best practicable means' defence available to industry. |

FIGURE 1



The 1978 Labelling Regulations apply to most operations, excluding waste disposal, beyond the point of production.

| TABLE 2a | LEGISLATION FOR CONTROLLING THE EFFECTS OF CHEMICALS ON: | | |
|---|---|---|---|
| (I) THE PUBLIC AND THE ENVIRONMENT | | (II) WORKPEOPLE | |
| ACT OR REGULATION | ENFORCED BY | ACT OR REGULATION | ENFORCED BY |
| (a) Public Health Acts<br>Clean Air Acts<br>Health & Safety at Work Act | Local Authorities<br>Health & Safety Ex. | Carcinogenic Substances Regulations.<br>Merchant Shipping Rules.<br>Air Navigation Order.<br>Health & Safety at Work | Health & Safety Ex<br>Department of Trade and Industry. |
| (b) Alkali Acts<br>Public Health Acts<br>Clean Air Acts<br>Health & Safety at Work Act | Health & Safety Ex<br>Local Authorities<br>Health & Safety Ex. | Mines & Quarries Act<br>Factories Act<br>Health & Safety at Work Act | Health & Safety Ex |
| (c) Public Health Acts<br>Clean Air Acts<br>Health & Safety at Work Act | Local Authorities<br>Health & Safety Ex. | Factories Act<br>Explosives Act<br>Health & Safety at Work Act | Health & Safety Ex |
| (d) Public Health Acts<br>Clean Air Acts<br>Health & Safety at Work Act | Local Authorities<br>Health & Safety Ex. | Factories Act<br>Explosives Act<br>Health & Safety at Work Act | Health & Safety Ex |
| (e) Public Health Acts<br>Clean Air Acts<br>Health & Safety at Work Act | Local Authorities<br>Health & Safety Ex. | Offices, Shops & Railway Premises Act<br>Health & Safety at Work Act | Health & Safety Ex<br>Local Authorities. |
| (f) Public Health Acts<br>Clean Air Acts<br>Food & Drugs Act<br>Fertilizers & Feed-stuffs Act | Local Authorities | Offices, Shops & Railway Premises Act<br>Health & Safety at Work Act | Health & Safety Ex<br>Local Authorities. |
| (g) Public Health Acts<br>Clean Air Acts | Local Authorities | NIL | NIL |

Continued .......

TABLE 2b LEGISLATION FOR CONTROLLING THE EFFECTS OF CHEMICALS ON:

| (I) THE PUBLIC AND THE ENVIRONMENT | | (II) WORKPEOPLE | |
|---|---|---|---|
| ACT OR REGULATION | ENFORCED BY | ACT OR REGULATION | ENFORCED BY |
| (h) Public Health Acts<br>Clean Air Acts<br>Health & Safety at Work Act | Local Authorities | Factories Act<br>Carcinogenic Substances Regulations<br>Health & Safety at Work Act | Health & Safety Executive |
| (i) Public Health Acts<br>Clean Air Acts | Local Authorities | Factories Act<br>Health & Safety at Work Act | Health & Safety Executive |
| (j) Public Health Acts<br>Clean Air Acts<br>Control of Pollution Act<br>Deposit of Poisonous Waste Act<br>Dumping at Sea Act<br>Water Acts | Local Authorities<br>Waste Disposal Authority<br>Ministry of Agriculture<br>Regional Water Authorities | Health & Safety at Work Act<br>Factories Act | Health & Safety Executive |
| (k) Public Health Acts<br>Clean Air Acts | Local Authorities | Health & Safety at Work Act<br>Merchant Shipping Rules<br>Air Navigation Order | Department of Trade & Industry |
| (l) Health & Safety at Work Act<br>Petroleum (Consolidation) Act<br>Labelling of Road Tankers Regulations | Health & Safety Executive<br>Home Office | Health & Safety at Work Act<br>British Rail & British Waterway Byelaws | Health & Safety Executive<br>British Rail<br>British Waterways Board |

## APPENDIX X

## Control of Pollution Act 1974

Part 1 revises the law on the collection and disposal of waste by local authorities. The waste disposal authorities (county councils in England and district councils in Wales) must ensure that satisfactory arrangements are made for disposal, either by the authority or by other operators of all controlled waste in their area. Controlled waste consists of household commercial and industrial waste but if any controlled waste is difficult or dangerous to dispose of then the Secretary of State has power to make regulations for the disposal of that "special waste". The Deposit of Poisonous Waste Act, 1972 is not repealed but sections in the new Act, together with the enabling power to make regulations are intended to eventually replace the 1972 powers.

Disposal authorities have to prepare waste disposal plans based on the kind and quantity of controlled wastes involved, the methods, sites and equipment which are required for this purpose, including schemes for waste reclamation. A duty is placed on the disposal authorities to consult with other authorities and this will involve the district councils as collection authorities.

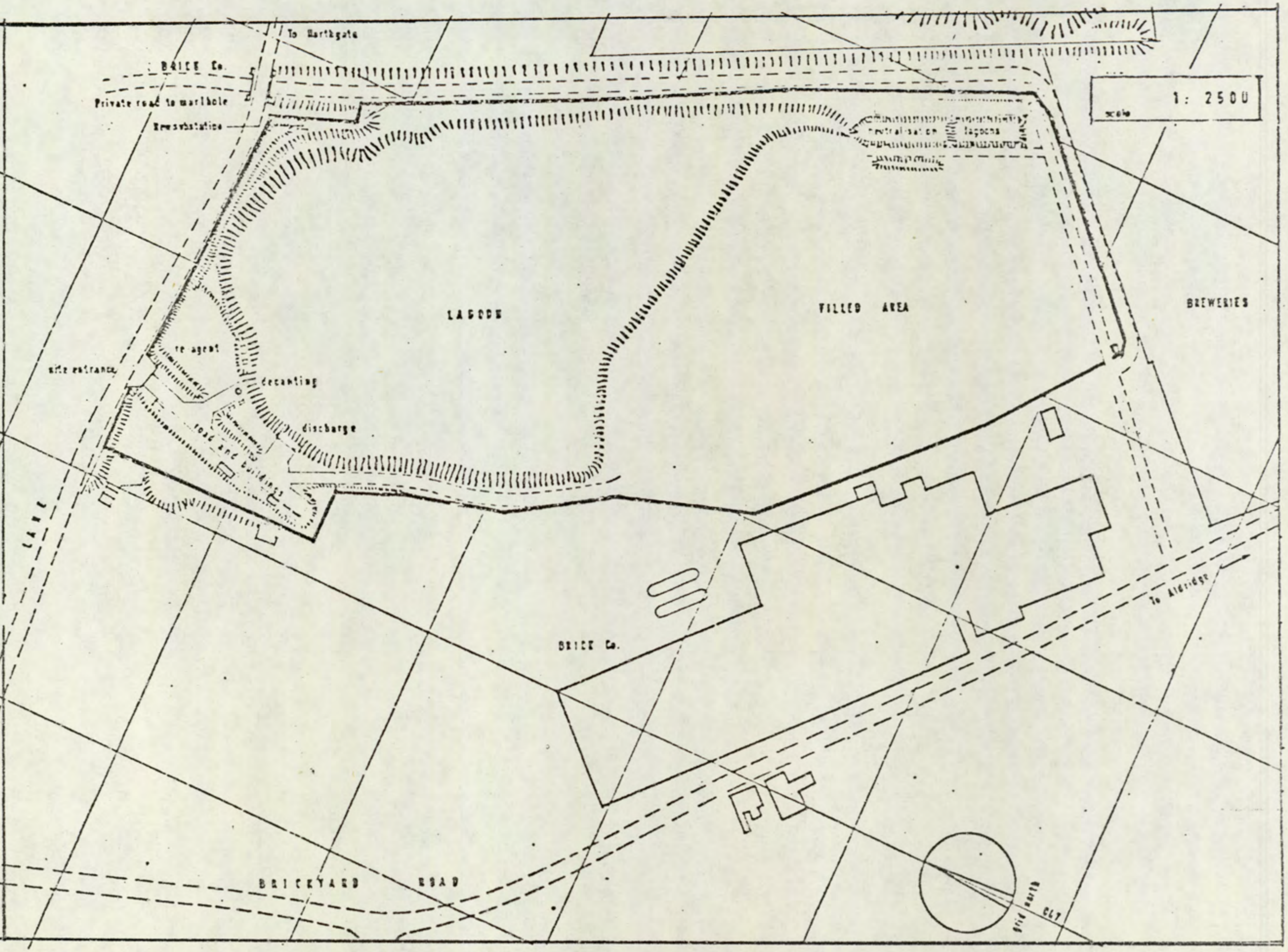
The Act introduces a licensing system by which the disposal authorities are able to regulate disposal and an offence will be committed if a person deposits waste anywhere except on a licensed site and in accordance with the conditions of the licence. A licence is also required for the use of any plant or equipment in the disposal of waste.

The Secretary of State can prescribe exemptions in certain circumstances including cases for which adequate controls are provided by another enactment. This could be applied to individual incinerators which district councils have approved under the Clean Air Acts and the Department will consider this point when proposing possible exemptions from licensing so as to avoid duplication of control or conflicting interests between counties and districts. Before issuing a disposal licence there has to be consultation with the district council and regulations will be made regarding the conditions which may be attached to licenses. These will include the kinds and quantities of waste which may be disposed of, special precautions necessary, hours of work and any works necessary for the satisfactory disposal operations.

The Disposal authority is also required to consult the Health and Safety Executive over the question of operator safety when issuing licenses. While a disposal licence is in force it is the responsibility of the disposal authority to supervise the licensed activities.

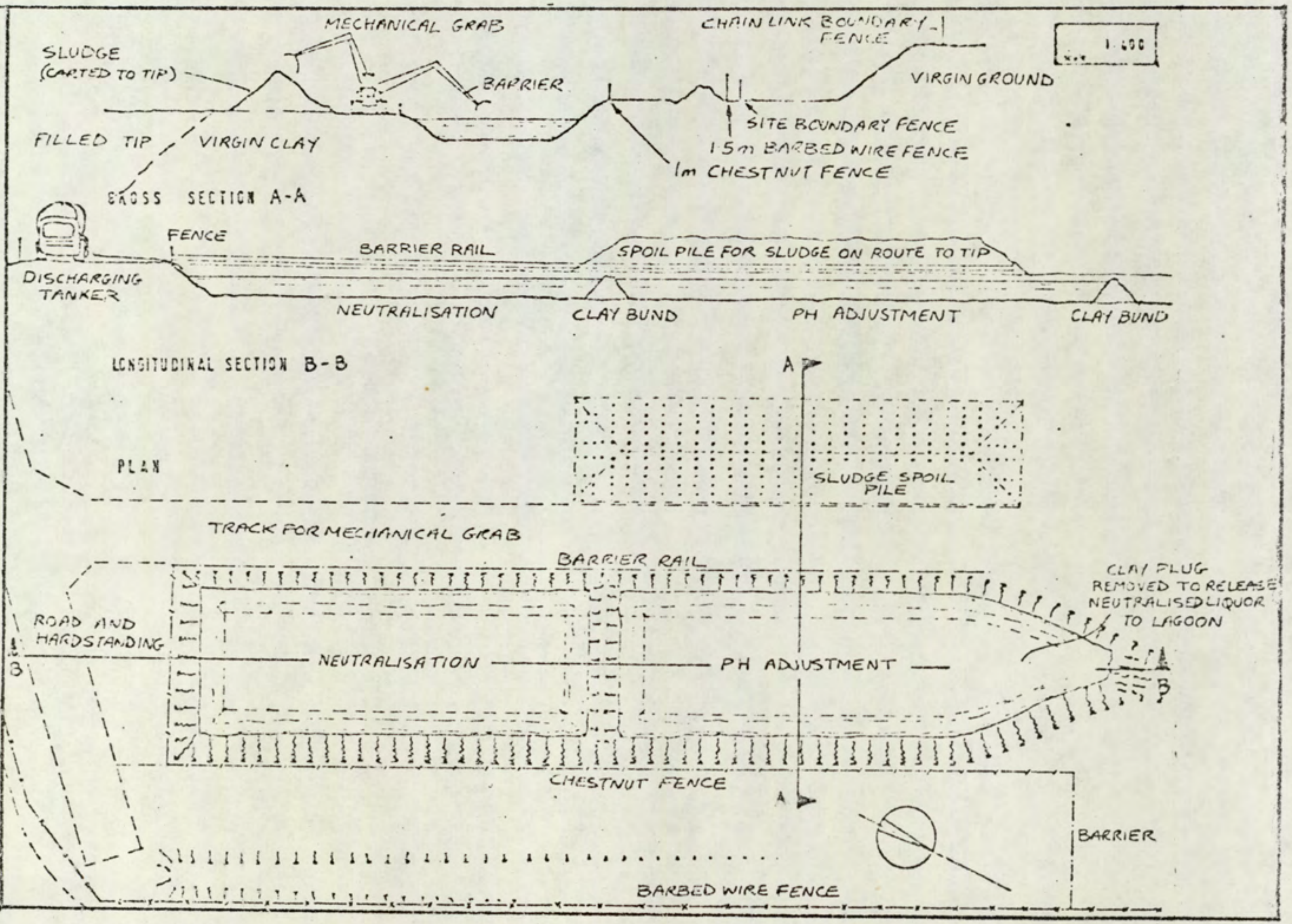
## APPENDIX XI

General arrangement of acid treatment and storage lagoons on landfill site



## APPENDIX XI

Details of neutralization and pH adjustment lagoons on landfill site.



<u>APPENDIX XII</u>

| | | |
|---|---|---|
| GUIDED INTERVIEW/INSPECTION SHEET | Date: | |
| Company: | Interviewed by: | |
| Address: | Position in Company | |
| | Telephone | |
| Nature of Business: | Number of Operators M | |
| | F | |

**SAFETY** -

Chain of Responsibility:

Company Statement Available?

| | |
|---|---|
| Advice available from: | Chemist on site? |
| Regular meetings held? | Totters prohibited? |
| Operators represented? | |
| Operation Manual available? | Permit to Work System Operational? |

**OPERATIONAL DETAILS:**

| | | |
|---|---|---|
| Protective Clothing Provided & Laundered | Specify: | |
| Changing room? | With Lockers? | |
| Sanitary Accommodation | Ablutions | |
| Eye Wash | Emergency Shower | |
| Fire Fighting Arrangements | Water Supply | |
| Links with Emergency Facilities: | Eating arrangements | |
| First Aiders | Inter site Communications | |
| Antidotes | $O_2$ | |
| Breathing Apparatus | | |
| Monitoring: Environmental | | |
| Personal (Presence of metabolites etc) | | |

**EDUCATION & TRAINING FOR SAFETY**

Specify company policy

**REPORTED INCIDENTS**

Specify

Is critical incident technique applied

*Ann. occup. Hyg.* Vol. 20, pp. 85–89. Pergamon Press 1977. Printed in Great Britain

# SHORT COMMUNICATION

## A PRELIMINARY SURVEY OF THE HAZARDS TO OPERATORS ENGAGED IN THE DISPOSAL OF ASBESTOS WASTE

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and

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An earlier study of the hazards to toxic waste disposal operators on landfill sites (Keen and Mumford, 1975) showed that unsatisfactory conditions existed on many sites and there was a lack of routine checks on the composition of deposited material. The general absence of emergency arrangements was linked with the low cost nature of the operation. Hazards which stemmed from the inherent difficulties in handling dangerous materials appeared to be compounded by the paucity of supervision and the operator's lack of information.

The aim of the present study was to establish the degree of hazard to operators in the specific case of disposal of asbestos waste, and to relate this to the hygiene standards currently enforced in British factories manufacturing asbestos products (H.M. Factory Inspectorate, 1970).

The major categories of asbestos waste are indicated in Table 1 together with an indication of the volume of such wastes arising in the U.K. About 99 % of all asbestos waste is disposed of by landfill operations. A certain amount of waste is tipped wet in the form of sludge and this is generally treated in a similar way to dry waste and covered by suitable overburden. The basic process is extremely simple and in fact there should be little problem with such method of disposal if carried out in accordance with the Code of Practice (Asbestosis Research Council, 1973), since asbestos is not very susceptibie to leaching from the soil. This latter point is still under investigation.

It is of relevance to summarise the A.R.C. recommendations for the collection and tipping of asbestos waste. Fine dust should be collected by bagging off into polythene sacks of adequate strength which can be tightly sealed. Loose fibre should be handled in a similar way but, in the case of material collected by vacuum cleaning, disposable paper bags may be used. Waste insulation material can be collected on polythene sheeting which is then folded to form a sealed container. Automatic collection into disposable receptacles is desirable for broken pieces and rejects of friable

TABLE 1. AMOUNT OF ASBESTOS WASTE ARISING IN 1974 IN THE U.K.
(Information supplied by the major manufacturers; excluding de-lagging operations)

| Category | Amount (tonnes) |
|---|---|
| Fine dusts | 9493 |
| Loose fibres, floor sweeping, etc. | 1690 |
| Off-cuts, broken pieces and rejects of materials | 764 |
| Off-cuts, broken pieces and rejects of high density materials | 32 813 |
| Sacks and bags | 243 |
| Wet scrap, slurries and sludges (20% asbestos) | 18 607 |
| Crocidolite | 18 |
| Total | 63 628 |

material. Empty sacks or bags should be bundled and sealed in an impermeable bag.

Under the *Asbestos Regulations 1969*, no asbestos waste should be despatched except in suitable closed receptacles which prevent the escape of asbestos dust; if they contain crocidolite they must be marked with a specific warning. Waste sealed in bags or receptacles needs no special transport but containers are available which can be removed direct to a disposal tip by specially fitted road vehicles. Wet waste should be transported in suitable vehicles, such as sludge tankers. Empty containers or vehicles should be cleared of loose fibre or dust by, for example, vacuum cleaning. The action necessary in the event of spillage during transport ranges from rapid recollection in the original receptacle by the driver to summoning assistance and rapid containment by covering and/or wetting, followed by controlled removal dependent upon the quantity spilled. In any event written instructions should be issued to drivers.

At the tip there should be vehicular access for the waste to be deposited at the face itself, which should not exceed 2 m in height. Vehicles should have a low discharge point and waste should be deposited at the foot of the face. Alternatively, if waste has to be deposited over the tip face, care is necessary during tipping and formation of the tip to avoid spillage from receptacles. Deposited material should be covered with at least 230 mm of consolidated earth, or other dry wastes, to form a seal. This should be done promptly and coverage should be complete at the end of the day. In the case of crocidolite waste covering should be immediate. Disposal of limited quantities of wet waste is acceptable on a dry tip but it must be covered to eliminate dust escape on subsequent drying-out.

Waste from high density material is unlikely to produce a dust hazard on tipping but may do so if subjected to pounding by lorries or bulldozers (KEEN and MUMFORD, 1975). Therefore the disposal methods should be as already described but with covering as soon as practicable rather than daily. High density waste may also be disposed of in wet pits containing sufficient water to maintain coverage.

It is difficult to estimate the number of persons liable to be at risk, but if the data are reliable (MINISTRY OF LABOUR, 1967), then the two major sites in the country are taking about half the asbestos waste produced. In these two sites only two machine operators are employed, together with about 10 full-time drivers per site. It is very difficult to extend these figures countrywide but on the assumption that there are on average about 3 asbestos receiving sites per county (DEPARTMENT OF THE ENVIRONMENT, unpublished) it might be said that there are about 150 operators in the country exposed to some degree of asbestos as a major part of their occupational exposure to toxic materials. Associated with this there are probably about 1000 drivers, based on the assumption of one driver per factory to which the *Asbestos Regulations 1969* apply.

## ASSESSMENT OF OPERATOR HAZARDS

A sampling programme at a number of landfill sites was arranged: This was a time-consuming exercise since it was necessary to visit sites that received both small and large quantities of asbestos to find if there was a range of concentrations of asbestos fibre in the air. Time was spent contacting 18 local authorities within about 150 miles of Birmingham to discover the main sites for asbestos disposal. Eight sites were finally selected in Lancashire, the West Midlands, Warwickshire and Kent all being about the same area but taking volumes of asbestos ranging from 200 to 32 500 tonnes a year. The volume of asbestos in proportion to other wastes therefore varied considerably. All the sites had at least one full-time operator. A total of 38 samples were taken and fibre counts made in accordance with standard procedure (ASBESTOSIS RESEARCH COUNCIL, 1971). The results of this sampling exercise are summarised in Table 2. Samples were taken at a number of points on the tip, usually down-wind where there was a prevailing wind. Atmospheric samples were taken on the actual operator of the machine burying the material or between 30 and 50 m down-wind from the tip face. It soon became apparent that exposures to dust were likely to be low if recommended procedures (ASBESTOSIS RESEARCH COUNCIL, 1973) were followed. In addition, of course, exposure times were short if these procedures were followed and, indeed, in the case of the largest amount of material buried at any one time, which was approximately 50 tonnes, the total time taken to completely bury the material was approximately one hour. In only one case did fibre counts approach the hygiene standard value of 2 fibres/cm$^3$ but in most cases the amount airborne was less than 0.02 fibres/cm$^3$. No crocidolite fibres were detected, probably due to the low amounts tipped at the sites studied.

In addition to the sampling programme at the sites and having regard to earlier work (KEEN, unpublished) it was decided to make a number of other observations during the visit. These were:

1. *Compliance with the Code of Practice for the Handling and Disposal of Asbestos Waste Materials*. Although fibre counts rarely exceeded the hygiene standard of 2 fibres/cm$^3$, compliance with the Code of Practice was very variable. Some firms collected fine dusts in 200 gauge polythene bags, as recommended, but others dispatched fine dust in lightweight paper bags mixed with other materials which burst on tipping, releasing clouds of dust. High density material was generally tipped loose. No vehicle was cleaned after use as recommended. Generally all material was covered promptly but dust was emitted due to manipulation of the waste by the machinery on site. Discussions with the local authorities concerned indicated that all of them had tightened up on the Code of Practice during the last few months.

2. *Supervision*. This was minimal on sites, the only representative of the contractor present being either the machine operator or the gate keeper/record keeper.

TABLE 2. RESULTS OF ASBESTOS SAMPLING

| Site | Major use | Amount deposited (tonnes/yr) | Operators exposed | Samples taken | Average time of sample (h) | Average concentration (fibres/cm$^3$) | Time worked by driver (h/week) |
|---|---|---|---|---|---|---|---|
| A | Asbestos | 12 200 | 3 | 13 | 1 | 0.02 | 12–20 |
| B | Asbestos | 32 500 | 6 | 6 | 1½ | 0.5 | 40 |
| C | Toxic waste/ asbestos | 2000 | 5 | 6 | 1 | 2.00 | 40 |
| D | Toxic waste | 1000 | 3 | 4 | 1 | 0.02 | 40 |
| E | Toxic waste | 1000 | 3 | 6 | 2 | 0.02 | 40 |
| F | Toxic waste | 150 (50% crocidolite) | 4 | 2 | 2 | 0.02 (No crocidolite) | 20 |
| G | Toxic waste | 150 | 4 | 1 | 1 | 0.04 | 40 |

3. *Protective clothing.* Overalls were usually provided for drivers and machine operators. Laundering was usually infrequent and it would be worth investigating the amount of asbestos dust carried home by employees on their overalls. At the sites visited respirators approved under the *Asbestos Regulations 1969* were provided at only two.

4. *Other facilities.* The opportunity was taken to examine briefly other facilities provided for tip operators and other visiting employees at the sites visited. It was noted that the majority of observations made earlier (KEEN, unpublished) with regard to welfare facilities (e.g. washing facilities, first-aid, fire fighting, means of access and fencing of machinery) held good for these sites. The general standard prevailing with regard to these matters was extremely poor and would seem to be a more important problem than the actual concentrations of asbestos dust. For example, a dangerously high tip face (in excess of 15 m) was discovered.

## CONCLUSIONS AND RECOMMENDATIONS

Although no serious operator hazards were discovered with respect to asbestos waste on the sites surveyed, the results must be considered within the limitations of the sampling technique and the rapidity with which conditions may change. Conditions could be further improved by a higher standard of enforcement of the Code of Practice.

Apart from any hazard from asbestos itself, the survey indicated shortcomings with regard to the more general health, safety and welfare of site employees and other visiting employees (KEEN and MUMFORD, 1975). As has been shown (KINSEY, unpublished), working conditions for waste disposal operators are generally much worse than those of other occupationally exposed groups, unless they form an integral part of a larger group, from whom they derive protection, e.g. operators who deal with radioactive waste. The general requirements contained in Sections 2–9 of the *Health and Safety at Work, etc. Act 1974* should be implemented without delay on all sites to improve conditions.

Because of the limitations of this particular study, a more detailed survey, perhaps on a larger site, should be undertaken, in order to provide a clearer picture of levels of exposure to asbestos dust. The collation of information on waste disposal operators' health and safety, and on the quantities and methods of asbestos waste disposal should be a primary aim of the enforcing authorities—Health and Safety Executive, Department of Environment and Local Authorities.

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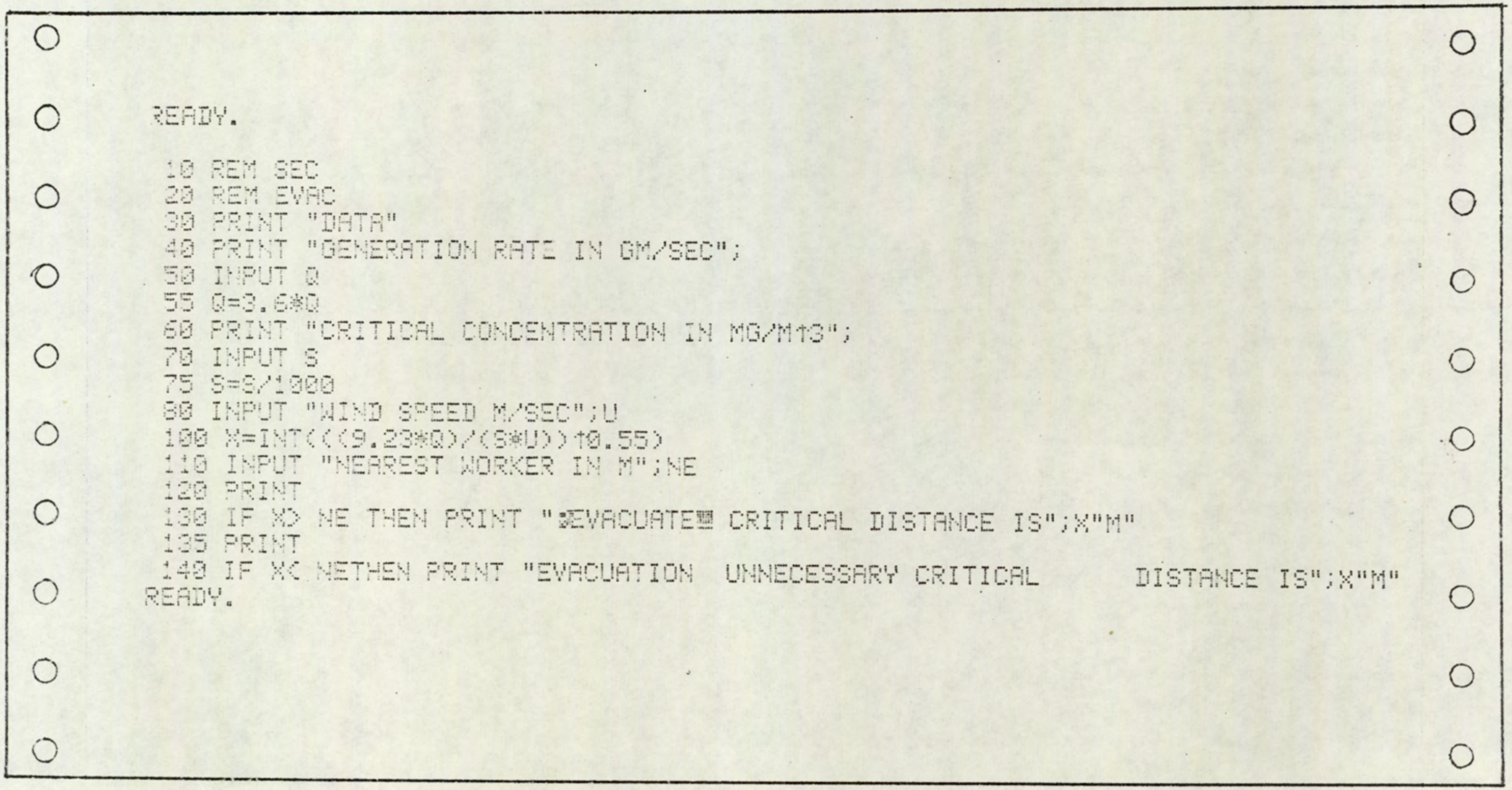
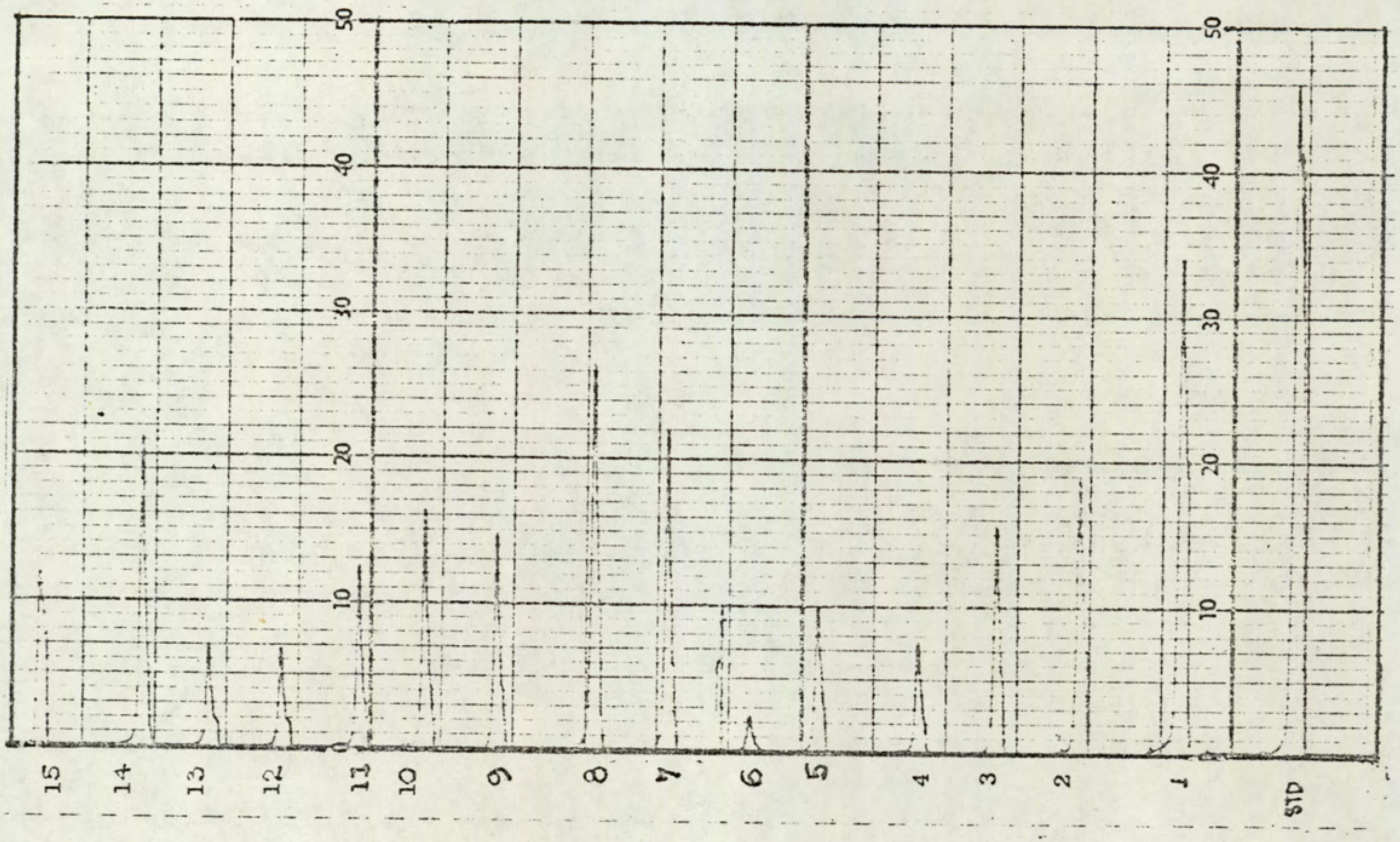
## APPENDIX XIV



```
READY.

 10 REM SEC
 20 REM EVAC
 30 PRINT "DATA"
 40 PRINT "GENERATION RATE IN GM/SEC";
 50 INPUT Q
 55 Q=3.6*Q
 60 PRINT "CRITICAL CONCENTRATION IN MG/M↑3";
 70 INPUT S
 75 S=S/1000
 80 INPUT "WIND SPEED M/SEC";U
 100 X=INT(((9.23*Q)/(S*U))↑0.55)
 110 INPUT "NEAREST WORKER IN M";NE
 120 PRINT
 130 IF X> NE THEN PRINT "▒EVACUATE▒ CRITICAL DISTANCE IS";X"M"
 135 PRINT
 140 IF X< NETHEN PRINT "EVACUATION  UNNECESSARY CRITICAL       DISTANCE IS";X"M"
READY.
```



Typical chromatogram
Pye 104 GLC with FID

2 ml injections
60°C oven temp.
APL column (apiezon L)
length 0.5m

## APPENDIX XV

## APPENDIX XVI

## 'Hazkit' for identification of hazardous materials

Certain of the principles utilized in the kit could be regarded as self-evident to the scientific mind. For example the idea of removing a portion of the unknown and testing that small portion some distance away from the main bulk. Concepts such as these are not self-evident to everyone however, and are consequently explained in the instructions.

The chemistry is mainly derived from classical wet chemical analysis, with simplification, modified so that certain interferences (such as gold in the test for mercury) have been ignored. To achieve this simplification took some two years in which a large range of formulations and test materials were tried. It must be stressed that the kit is not a semi-micro analysis outfit in a box. It seeks to identify hazards, not chemicals, in categories such as poisonous, explosive, flammable, corrosive, etc. Where a chemical term has some kind of common currency and where the extra information could be useful to those dealing with a situation, then it is used, e.g. strong corrosive - caustic poison, heavy metal, cyanide, poison fumes - arsenic, etc.

Certain physical tests are included which enable, for example, the estimation of the degree of fire hazard. There is more to this than putting a match to the sample and though the final actions seem very simple, they are based on sound principles as to the nature of fires, and do permit identification of substances which although non-flammable, will burn when they have dried out.

Throughout, the prime aim is to ensure safety. As a small detail, eye-shield and gloves are included. In the schedule of tests the first instruction is to approach cautiously, and to back off if certain signs are observed such as choking, stinging eyes, a bitter taste in the mouth. The user is told what these may indicate, and instructed not to smell or taste things, nor to enter dust or smoke clouds without breathing apparatus etc. The first test then involves touching with a moist test-paper. This warns if there is any danger of violent reaction with water, before subsequent tests involving aqueous reagents. Generally speaking, the greater the immediate danger, the sooner it is detected.

A particular problem of development has been one of detection limits, since the kit is not aimed at the subtle long term effects or trace elements. It is believed that the kit as it now stands represents a sensible compromise. Real dangers give solid unmistakeable positive tests. Very low levels give negative results. A doubtful result means -

probaly not safe to drink, but unlikely to be highly dangerous.
For example, Test Paper E is not a 'universal' pH strip but a yes/no indicator for acid, caustic and poison.

The kit may be considered to have three prime methods of use. Firstly, to enable someone with no scientific training to identify, accurately and rapidly, chemical hazards in a totally unknown solid, liquid, sludge or mixture. Examples are firemen faced with spillages, police dealing with broken drums on a motorway, tip operators checking that a supposedly 'safe' load has no uncovenanted components. Secondly to enable someone with some knowledge of the material (and possibly some general knowledge or experience) to use specific tests for hazards that are suspected of being present, e.g. checking that plating waste does not contain cyanide; checking that caustic waste really is caustic and not acid before it is mixed with sulphide; examining hydro-carbons for gross contamination with chlorocarbons. Thirdly as an on-the-spot method for someone concerned with inspection (Safety Officer, Factory Inspector, Environmental Health Officer) to decide if samples should be taken for a full laboratory analysis. Thus making more effective use of laboratory facilities.
The contents of the Hazkit are shown in Figure A and a typical page from the instruction handbook is reproduced as Figure B.

FIGURE A

Hazkit Contents

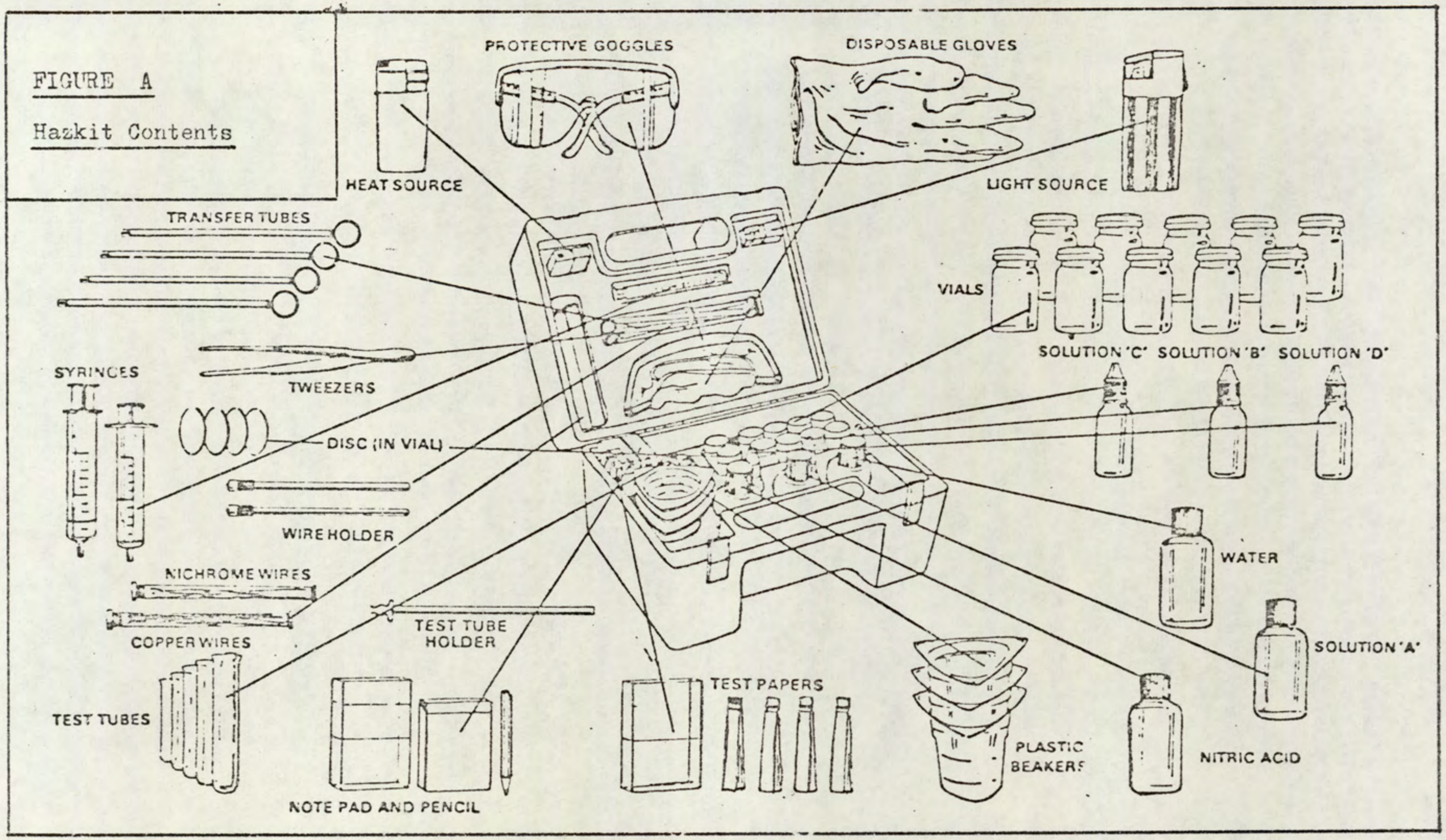
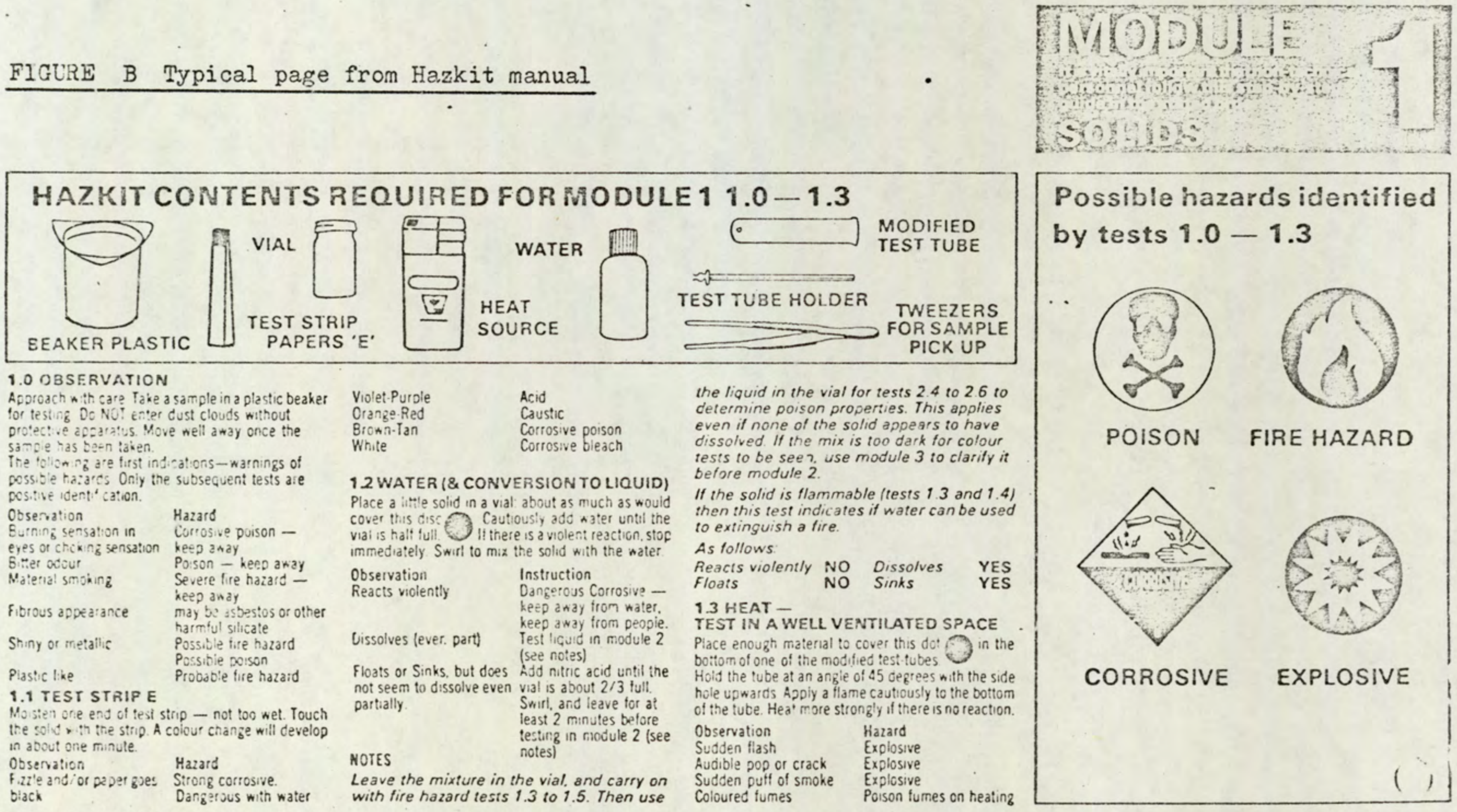


FIGURE B Typical page from Hazkit manual



MODULE 1

SOLIDS

## HAZKIT CONTENTS REQUIRED FOR MODULE 1 1.0 — 1.3

BEAKER PLASTIC
VIAL
TEST STRIP PAPERS 'E'
HEAT SOURCE
WATER
MODIFIED TEST TUBE
TEST TUBE HOLDER
TWEEZERS FOR SAMPLE PICK UP

### 1.0 OBSERVATION

Approach with care Take a sample in a plastic beaker for testing Do NOT enter dust clouds without protective apparatus. Move well away once the sample has been taken.
The following are first indications—warnings of possible hazards Only the subsequent tests are positive identification.

| Observation | Hazard |
|---|---|
| Burning sensation in eyes or choking sensation | Corrosive poison — keep away |
| Bitter odour | Poison — keep away |
| Material smoking | Severe fire hazard — keep away |
| Fibrous appearance | may be asbestos or other harmful silicate |
| Shiny or metallic | Possible fire hazard<br>Possible poison |
| Plastic like | Probable fire hazard |

### 1.1 TEST STRIP E

Moisten one end of test strip — not too wet. Touch the solid with the strip. A colour change will develop in about one minute.

| Observation | Hazard |
|---|---|
| Fizzle and/or paper goes black | Strong corrosive. Dangerous with water |
| Violet-Purple | Acid |
| Orange-Red | Caustic |
| Brown-Tan | Corrosive poison |
| White | Corrosive bleach |

### 1.2 WATER (& CONVERSION TO LIQUID)

Place a little solid in a vial: about as much as would cover this disc ● Cautiously add water until the vial is half full. If there is a violent reaction, stop immediately. Swirl to mix the solid with the water.

| Observation | Instruction |
|---|---|
| Reacts violently | Dangerous Corrosive — keep away from water, keep away from people. |
| Dissolves (even part) | Test liquid in module 2 (see notes) |
| Floats or Sinks, but does not seem to dissolve even partially. | Add nitric acid until the vial is about 2/3 full. Swirl, and leave for at least 2 minutes before testing in module 2 (see notes) |

NOTES

*Leave the mixture in the vial, and carry on with fire hazard tests 1.3 to 1.5. Then use the liquid in the vial for tests 2.4 to 2.6 to determine poison properties. This applies even if none of the solid appears to have dissolved. If the mix is too dark for colour tests to be seen, use module 3 to clarify it before module 2.*

*If the solid is flammable (tests 1.3 and 1.4) then this test indicates if water can be used to extinguish a fire.*

*As follows:*

| | | | |
|---|---|---|---|
| *Reacts violently* | NO | *Dissolves* | YES |
| *Floats* | NO | *Sinks* | YES |

### 1.3 HEAT —
### TEST IN A WELL VENTILATED SPACE

Place enough material to cover this dot ● in the bottom of one of the modified test-tubes.
Hold the tube at an angle of 45 degrees with the side hole upwards. Apply a flame cautiously to the bottom of the tube. Heat more strongly if there is no reaction.

| Observation | Hazard |
|---|---|
| Sudden flash | Explosive |
| Audible pop or crack | Explosive |
| Sudden puff of smoke | Explosive |
| Coloured fumes | Poison fumes on heating |

## Possible hazards identified by tests 1.0 — 1.3

POISON
FIRE HAZARD
CORROSIVE
EXPLOSIVE

# REFERENCES

## REFERENCES

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