Environmental Evaluation of Alternative Options for the Disposal of Oily Waste Following a Marine Oil Spill off the South African Coast and Development of a Decision Strategy.

by

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ABSTRACT

Environmental evaluation of alternative options for the disposal of oily waste following a marine oil spill off the South African Coast and development of a decision strategy.

Oil spill contingency planning for the South African Coast undertaken by the Sea Fisheries Research Institute of the Department of Environment Affairs, has revealed that alternative disposal methods for oily waste need to be investigated in order to cope effectively and timeously with a major oil spill.

Current techniques dealing with oily waste disposal are reviewed. These include recovery for re-use, stabilisation of oily waste, biodegradative techniques such as landfarming, co-disposal with municipal waste, stimulated biodegradation in ponds and direct burial, as well as burning and incineration. The suitability of these techniques, taking into account legal constraints, availability of facilities, financial considerations and environmental implications are appraised for South African conditions.

Recovery for re-use is the optimum disposal option, but the location of refineries in South Africa, the limited facilities available for oil recycling and the inability of the industries to cope with large quantities or contaminated oily waste limit the recovery application.

Stabilisation of oily waste for disposal as landfill or for use in civil engineering works requires further investigation with the South African construction industry.

Landfarming techniques are suitable for the disposal of large quantities of oily sand or sandy sludge, but careful site selection is required to limit environmental contamination.

Co-disposal of oily waste with municipal refuse is only suitable for limited quantities of oily waste and will reduce the life of the landfill site.

Direct burial or burning of oily waste are shown to be environmentally unsuitable options, but under certain conditions they may provide the only practical solutions. Facilities for incineration of oily waste are limited in South Africa.

The study shows that there is no easy solution to the disposal of large quantities of oily sludge. A combination of disposal methods will need to be used. Treatment of the oily sludge, for example emulsion breaking or separation will reduce the volumes, but costs could be prohibitive.

A strategy is developed to provide the decision maker with a framework within which the decision process towards finding the correct solution for the disposal of oily waste following an oil spill off the South African Coast can be undertaken.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE TOPIC

South Africa is situated on one of the world's major shipping routes and in 1988 approximately 178 million tons (30%) of the Middle East oil exports passed the Cape of Good Hope, bound for Europe and the Americas (Moldan & Dehrmann 1989). The average size of the tankers conveying this cargo has increased over the years and most are now of the order of 250 000 DWT (dead weight tonnage), (Schumann 1984). The increased cargo capacity has meant that fewer tankers are now required to ship the oil, reducing the probability of a casualty occurring. Nevertheless, the potential volume of oil released from a casualty involving one of these large tankers is significantly increased. Although there is currently a move towards constructing new tankers in such a way to limit oil spillage should a casualty occur (ie. by the use of double bottoms), the whole tanker fleet, in general, is ageing.

The environmental damage resulting from large, catastrophic spills is well recognised. The damage caused by the smaller, chronic operational spills from vessels other than oil tankers is less evident. It is estimated that more than 4000 vessels (tankers and others) are passing around the Cape of Good Hope annually (S.A. Navy pers. comm.). In 1988 a total of 128 oil spills, thought to originate from these vessels were sighted in South African coastal waters (Moldan and Dehrmann 1989). Only one of these spills was estimated to be greater than 10000 litres, and 80% of them were estimated to be less than 1000 litres in volume. (Reports from K6 patrol aircraft: Pollution Section, Sea Fisheries Research Institute, Cape Town.)

Most clean-up operations following an oil spill will result in the collection of varying volumes of oil, oily wastes and debris. Although a lot of small spills are sighted off the coast, they seldom reach the shore and it is the less frequent larger spills which are likely to cause disposal problems. However, a spill of some 1650 tonnes of heavy fuel oil from the *Petingo*, which ran aground six nautical miles off the coast of Richards Bay, South Africa in 1990, resulted in the collection of over 5000 tonnes of oily sand (Moldan and Jackson, 1990).

Appropriate planning, particularly pre-selection of disposal methods and sites can obviate problems following an oil spill. It is necessary therefore to review the methods available for disposal of the products of an oil spill and to identify problems as part of oil spill contingency planning.

1.2 OIL SPILL CONTINGENCY PLANNING IN SOUTH AFRICA

South Africa has kept abreast with the advances made in oil pollution control. These measures include acceding to most of the international pollution conventions, incorporating them into local statutes, establishing stockpiles of oil spill response equipment and, developing comprehensive oil spill contingency plans.

These contingency plans form the core of the oil spill response strategy in South Africa. The ultimate goal of contingency planning is to minimise the potential for environmental damage resulting from an oil spill by predetermining the appropriate courses of action. In order to minimise loss of time when an oil spill occurs, as many decisions as possible concerning the response action need to be taken prior to the incident (Moldan 1989).
Oil spill contingency plans have been compiled for the entire South African coastline by the South African Sea Fisheries Research Institute. The entire coastline including Walvis Bay, has been divided into 26 separate zones, with a detailed plan being developed for each zone. These plans form the basis of the oil spill response protocol. They include the following information:

- legal aspects pertaining to oil spills
- liabilities, costs and claims concerning oil pollution damage
- reporting procedures
- activation of response - alert, mobilisation, implementation, review, termination
- organisational structure established for the duration of an incident
- facilities and communication networks
- specific protection and clean-up measures for each area
- maps indicating local authorities' areas of jurisdiction, access to the shoreline, etc.
- disposal sites for oil and oily debris
- equipment and manpower lists
- telephone numbers
- training of local authorities.

These plans have been put to use in a number of minor spill situations and have been found to work well in practice (Moldan 1989).

During the compilation of these plans, it was realised that in South Africa, the availability and capacity of disposal sites are limited and, should a major incident take place, problems are likely to occur with the disposal of large volumes of collected oil and oily debris. It became apparent that alternative disposal methods and disposal sites needed to be investigated in order to cope effectively and timeously with a major oil spill.

1.3 THE NEED TO PLAN FOR OIL SPILL DISPOSAL

As oil containment, recovery and clean-up technologies are improved, the necessity for disposing of greater amounts and broader varieties of spill debris becomes apparent. The result is an increased need for proper disposal methods, with special emphasis directed toward minimising adverse environmental impacts.

According to Breuel (1981), the crucial step of final disposal of the recovered material has been given low priority in oil spill contingency planning. Spill debris is often collected and stockpiled, often improperly, before disposal alternatives are identified. He states that while more sophisticated clean-up methods are being employed, little attention has been devoted to the ultimate disposal of spill debris.

Often, disposal sites and techniques are selected in the rush of the moment. This means there is generally insufficient time to evaluate the suitability of alternative options and to choose the one which offers the best conditions for environmental protection. For example, when the *Cristos Bitas* (an oil tanker, with a cargo of Iranian crude), ran aground off the British Coast in 1978, about 100 tonnes of high level beached oily waste required disposal (Fleet et al 1984). This *water-in-oil emulsion or mousse*, composed of 76% seawater and 24% weathered crude oil, was stored for two years in a disused quarry, excavated in shattered siltstones and sandstones, near Angle Bay, Pembrokeshire. Early in 1981 boreholes were drilled into the underlying strata and it was found that water in the lower horizons of one of these boreholes contained oil at a concentration of 195 mg/l (Fleet et al 1984). The disposal site was proved to be unsuitable.

The Prevention and combating of pollution of the sea by oil Act (No 6 of 1981) gives the South African Minister of Transport Affairs wide-ranging powers regarding the prevention and combating of oil pollution. However, in terms of Notice No. 1646 in Government Gazette No. 10377 of 8 August 1986, any power, duty or function regarding the combating of pollution of the sea by oil, (ie once the oil has been released into the marine environment) has been assigned to the Minister of Environment Affairs. This gives the Minister of Environment Affairs specific responsibility for environmental protection and clean-up aspects of oil spills. The responsibility for initiating and co-ordinating the necessary actions to effect protection and clean-up operations lies with the Departmental Officers. It is hoped that this rewiew of oil spill disposal techniques and applications in the South African context will be a decision-making aid for the officials concerned with combating oil spills off the South African coast.

1.4 AIMS AND OBJECTIVES

The aim of this report is to facilitate the decision making process, ensuring that the most environmentally acceptable and economically efficient means of disposing of oil, oily wastes and debris, during clean-up operations following an oil spill, are achieved.

In order to achieve this aim, the objectives of this study are:

- to explore the types and quantities of oily waste likely to require disposal following a major oil spill off the South African Coast
- to describe current methods of disposal and the environmental implications of each
- to assess these techniques in terms of their suitability to South African conditions, taking legal constraints, availability of facilities, environmental implications and economic considerations into account.

The study was undertaken as a partial dissertation and provides the level of detail commensurate with specific acedemic requirements.

1.5 APPROACH

The type and quantity of oily waste collected will often prescribe the method of disposal. For example, if the oil is liquid and not too contaminated with chlorides, water or debris, it could be sent to a refinery for reprocessing, provided facilities are available to cope with the quantities involved. For this reason, Chapter 2 describes the types and quantities of oily waste likely to result from oil spills. This is followed in Chapter 3, by an examination of appropriate, alternative disposal techniques. The suitability of these techniques to South African conditions is discussed in Chapter 4, taking legal constraints, availability of facilities, financial consideration and environmentnal implications into account. Based on the preceding information, a decision strategy is developed in Chapter 5 for the selection of appropriate disposal methods at the time of a spill. In Chapter 5, the criteria used in the selection process are defined, and the formulation of the selection procedure and its application are also described. Conclusions are drawn in Chapter 6.

CHAPTER 2

DESCRIPTION OF OILY WASTE

The primary objective of this chapter is to establish the types and range of quantities of oily waste likely to result from different spill scenarios. Oil discharged during a spill incident usually has potential for adverse environmental impacts and therefore requires appropriate disposal. Although it is difficult to predict the type or quantity of oil likely to require disposal, there are certain factors affecting the volume and type of oily waste which will be collected during a clean-up operation.

2.1 FACTORS AFFECTING THE TYPE AND VOLUME OF OILY WASTE

The volume and type of oily waste collected, depends on factors such as amount of oil spilt, type of oil, sea conditions, weather conditions and distance of the incident from the coast. These factors influence the behaviour of the spilled oil and change its characteristics. After spilling into the marine environment, the oil may undergo significant alteration due to such processes as spreading, evaporation, natural dispersion, emulsification, oxidation, biodegradation and sedimentation (CONCAWE 1981). An analysis of these processes assists in designing workable predictive models for spilled oil movement and allows for the estimation of the amount of accessible oil, serving as a basis for developing more effective data on collection techniques, improved cleanup operations and ultimately disposal options. These processes are described in more detail below.

Spreading results in greater interaction between the oil and the water and the atmosphere, which in turn influences other processes. According to Jordan and Payne (1980), spreading is probably the most significant process for the first six to ten hours following a spill.

Evaporation reduces the volume of oil, its flammability and its toxicity, but increases the viscosity and density of the residue. Evaporation removes most of the volatile, lower molecular weight compounds and in general, pentadecane (n-C15) is the lowest normal alkane commonly found in weathered oils. The more volatile components make up 20-50% of most crude oils, 75% or more of refined petroleum products and <10% of residual fuel oils, such as *Bunker C* (Jordan and Payne 1980). It is estimated that 40 % of the oil spilt from the *Amoco Cadiz* evaporated within three days (CONCAWE 1981). As a result of evaporation, the specific gravity of the residue may approach that of sea water, and if suspended matter such as sediments or oxides are adsorbed, it may sink.

Dispersion, or the formation of oil-in-water emulsion, results from the incorporation of small globules of oil, ranging in size from less than 0,5 micrometres to several millimetres, into the water column (Jordan and Payne, 1980). In general, such oil-in-water emulsions are not stable, but they can be maintained by continuous agitation or turbulence. Milne (1950) reported that one millilitre of oil can form up to 16 x 10^{12} droplets with a total surface area of about 13 m^2. Usually, oil begins to disperse immediately after it is discharged. By one hundred hours, dispersion has usually overtaken spreading as the primary mechanism for distributing the spilled oil about its centre of mass (Jordan and Payne, 1980). The rate of dispersion is a function of sea conditions and the nature of the oil and, will affect the amount of oil that is recovered. Sea conditions are influenced by such parameters as wind, currents, tides, water depth and waves.

Solution of oil in water is minimal and is confined to the lighter fractions of the oil. The rate and extent of solution is dependent on oil composition, extent of spreading, water temperature, turbulence and the amount of dispersion. Harrison et al (1975) examined the rates of disappearance for aliphatic and aromatic components from small slicks on seawater. They found the dissolution rate to be less than half of the evaporation rate. A mathematical model used in the study indicated that rates of dissolution may be as low as 1% of evaporation rates. Freegarde (1971) noted that hydrocarbon solubilities for both aliphatic and aromatic components decreased with increasing salinity, with a decrease of approximately 30% for n-paraffins.

Emulsification represents a change of state from an oil-on-water slick or an oil-in-water dispersion to a water-in-oil emulsion, with the eventual possible formation of a thick, sticky mixture (*chocolate mousse*) which may contain up to 80% water. Berridge et al (1968) found that chemical parameters such as percent residue boiling over 700^{o}F, asphaltene content and vanadium content showed definite, positive correlation to ease of formation and stability for water-in-oil emulsions. For this reason, crude petroleums with a high asphaltene content (e.g. Venezuelan and Kuwait crudes) will tend to form mousse emulsions with greater ease and stability than highly paraffinic oils such as crudes from Libya and Nigeria (Dodd 1971).

Emulsions can be extremely viscous and persistent, impeding the rate of degradation and weathering by reducing the surface area of oil exposed to water and air. Emulsification greatly increases the volume to be dealt with and for this reason can cause problems at any stage of a clean-up operation. Every effort should therefore be made to break them at the earliest possible stage in order to reduce the volume to be handled, and to reduce viscosity so as to facilitate pumping. Weathering of these emulsions often results in the formation of persistent mousse lumps or *tar balls.*

Oxidation of hydrocarbons can occur, in the presence of light, when they are in contact with water. The mechanism of this photo-involved process is described by Burwood and Speers (1974) as an autocatalytic free-radical chain reaction, which results in the formation of hydroxy compounds, aldehydes, ketones and ultimately, low molecular weight carboxylic acids. The exact impact of this process is not known, as the precise mechanisms are not fully understood (CONCAWE 1981).

Biodegradation may have a significant effect on the removal of oil from the sea. The biodegradative processes operating on an oil spill in a marine or estuarine environment, will encompass degradation via microbial metabolism, ingestion by zoo-plankton, uptake and possible retention by marine invertebrates and vertebrates, as well as bioturbative effects (Jordan and Payne 1980). All serve to partition petroleum hydrocarbons into the water column, the biomass and the sediment regimes of the ecosystem. Its rate is dependent on the composition of the oil, the surface area exposed to water and bacteria, the availability of nutrients and water temperature. These factors can cause bacterial action to be rapid (hours to days) or almost non-existent (hundreds of years) (Concawe 1981).

Sedimentation occurs when oils sink, due to weathering or absorption of heavy mineral particles (for example, sand or silt), or after the lighter fractions have been burnt off. The capacity for certain oils to sink after weathering is a function of the parent oil's hydrocarbon composition. Conomos (1975) states that *Bunker C* or *Number 6* fuel oil, which has a density greater than most other products can sometimes sink without extensive degradation. Jordan and Payne (1980) refer to the 1971 case in which two tankers collided in the entrance to San Francisco Bay, resulting in a major spill of "Bunker C" fuel. Some of the oil globules were neutrally buoyant and were rapidly incorporated into the near-bottom water of the Bay. The oil-laden bottom waters, moving independently of the surface floating slicks, resulted in the deposition of oil on beaches 16 kilometres east (upriver) of the eastern-most limit of beaches stained by the floating oil.

The spilled component may also **adsorb** onto solid materials such as wood or aquatic plants or artificial sorbents used in clean-up operations, resulting in complex spill debris mixtures.

Various calculations of an overall oil budget or mass balance have been attempted using real spill situations, controlled ecosystem or laboratory experiments, as well as computer models simulating oil spills (Jordan and Payne 1980). These assessments give an indication of the effect of the processes described above. For example, Jordan and Payne (1980) quote the French Press as giving the following estimation for the fate of the 230 000 tons of oil spilt during the *Amoco Cadiz* incident in 1978 off the coast of France:

80 000 tons went ashore

74 000 tons evaporated

20 000 to 25 000 tons were recovered

76 000 tons remained at sea: either chemically dispersed, deposited on the seabed or "disappeared".

Butler et al (1976) cite that approximately 25% of crude oil, spilled on the open ocean would evaporate within ten days. Dissolution could remove an additional 5% within the same time. They also state that photochemical reactions occur over longer periods of time (10 to 100 days) and can remove approximately 5% of the spilled oil. Microbial degradation on a time scale of 50 to 500 days was estimated to remove an additional 30% of the material, and dispersion and sinking on a 100 to 1000 day time scale removed a final 15%. The residual materials, which constituted approximately 30% of the total, were then estimated to remain on the surface as tar balls for over 100 days.

2.2 TYPES OF OILY WASTE

Moldan and Dehrmann (1989) report that bulk carriers account for 46% of vessels observed discharging oil off the South African Coast, general cargo vessels account for 24% and oil tankers for 16% of the observed spills. These spills result in the release of either Middle East crude oil which is being transported around the coast, or heavy fuel oil used to fuel the vessels, and to a lesser extent, lubricating oils. But for oil spill management, these classes are generally irrelevant. The behaviour of a certain type of crude oil may be very similar to a particular refined product and very different from other crude oils, or due to weathering, the viscosity and other properties of the spilt oil may vary considerably. It is therefore, the classification of the collected mass which is relevant for oil spill disposal purposes.

Various spill scenarios under different environmental conditions result in different types of recovered spill mass. These can be classified as follows:

- **fresh liquid oil** which may contain small amounts of seawater.
- **weathered liquid oil** with higher viscosity ranging to sludge, water in oil emulsions (*chocolate mousse*) and *tar balls.*
- **oily solids** consisting of weathered oil mixed with sediments (eg sand), organic debris or artificial sorbents used in mopping up operations.

2.3 QUANTITIES OF SPILLED MASS

Spill volume is an important variable to be considered. The disposal system should be capable of handling various quantities of collected spill mass. Although most spills sighted off the South African Coast are small (see section 1.1), it is the rare, large spill that will require an effective disposal plan. The amount of oily waste likely to require disposal following a large spill can vary considerably, ranging from a few hundred tons to many tens of thousands of tons (CONCAWE 1984).

The *Amoco Cadiz* incident off the coast of France in 1978 resulted in a spill of 230 000 tons of crude oil (Bao-Kang 1987) most of which came ashore necessitating large scale disposal operations. Although exact quantities requiring disposal are not documented, Such and Le Roux (1980) report that during the period April to September 1978, a total of 165 000 tonnes of oiled beach material were treated with lime, prior to disposal.

The *Exxon Valdez* incident in Alaska in 1989, resulted in thousands of bags of oily debris, many of which were burnt using hospital incinerators (Hodgson 1990). Fifty thousand tons of additional oil soaked material were shipped to a toxic waste dump in Oregon, and recovered oil was recycled (Hodgson 1990). This is believed to be only part of the collected waste.

On the other hand, the *Castillo de Belver* incident off the western Cape, South Africa, in 1983 released approximately 170 000 tons of crude into the sea (Moldan et al 1985). Unknown quantities of oil burned at sea, but due to strong offshore winds, no oil reached the shore.

It is evident that major oil pollution incidents can result in varying volumes and types of oily waste, and that difficulties can arise in the disposal of these large amounts of oily material. Any single disposal technique may not be able to cope with large volumes and different types of oily waste, and best results could probably be achieved by using several methods in parallel. A description of these different methods of disposal is given in Chapter 3.

CHAPTER 3

DESCRIPTION OF DISPOSAL TECHNIQUES FOR OILY WASTE

This Chapter reviews and summarises the relevant literature on the disposal techniques for oily waste collected after an oil spill at sea. An extensive computer-based literature search was undertaken for this study, to ensure coverage of recent international developments in disposal techniques for oily waste. The data bases that were used covered such fields as biotechnology, chemistry, aquatic sciences, engineering, environmental reviews and pollution and oceanic sciences. The literature study revealed many publications on clean-up aspects of marine oil spills, but the disposal of the collected oily waste was rarely discussed in any detail.

It is assumed at this point that the oil, oily waste and debris have been collected into some type of identifiable volume by primary recovery efforts. This report does not therefore deal with temporary storage and transportation of the oily waste.

The prime aim of oil spillage disposal should be recovery for re-use. Where ultimate recovery is not practical or cost effective, then destructive methods may have to be used as a last resort.

A special task force on Oil Spill Clean-up Technology (OSCUT) of the Oil Companies International Study Group for Conservation of Clean Air and Water - Europe (CONCAWE) has prepared a report entitled *Disposal techniques for spilt oil* (CONCAWE 1980a). This report provides a good description of the different disposal techniques in order of preference under the following categories, :

- recovery of oil for re-use
- stabilisation of oily waste
- destruction or decomposition of oily waste.

These categories are retained for the purposes of discussion in this Chapter.

3.1 RECOVERY FOR RE-USE

Refineries, recycling contractors and fuel burning installations can receive and process collected oil, oil/water and oil/debris mixtures.

3.1.1 Refining

Oil refineries are capable of handling liquids on a scale commensurate with their size and versatility. However, as mentioned in Chapter 2, oil spilled at sea, may undergo many physical and chemical changes and may become contaminated with seawater, sediments and debris, creating problems in the refining processes. For example, oil with a salt content of more that 0,1% and a water content of more than 2% cannot be refined using normal procedures, and as mentioned, some emulsions may contain up to 80% seawater. Therefore, before refining, the oil must be isolated from any contaminants, using techniques such as oil water separation, solid washing and solvent extraction. These techniques are described in the CONCAWE Report (1980a) but are not repeated here.

The capacity of refineries to handle collected oil varies widely and it is necessary to obtain local data. It is also essential that a clear mutual understanding about the allocation of costs associated with the refining of oil spill products be reached with the refinery concerned.

In South Africa there are limitations associated with refining collected oil. The first is that the greatest consumer demand is for lighter oil fractions, for the production of gas oil and motor gasoline, with resultant excesses of the heavier fractions from normal refining processes. These lighter factions are the first to evaporate during a spill. It is thus not economically viable for South African refineries to process weathered crude. For the same reason, oil refineries do not find it economical to reprocess heavy fuel oils.

3.1.2 Recycling

Recycling contractors are usually waste oil reclaimers and refiners, specialising in reprocessing waste oil. About 40 to 50% of their capacity is directed towards reprocessing lubricating oil and the remainder towards fuel oils. Most of this processing capacity is normally committed and would therefore not be available to handle large quantities after an oil spill. If there is suitable storage, however, it may be possible to direct certain quantities into such facilities. Information is needed regarding the capability of these contractors in South Africa. Tank farm operators should also be approached for information about storage capacity, availability and cost.

3.1.3 Fuel burning

Direct use or burning of collected liquid oils to fuel power stations or other installations is possible, but fuel quality specifications are stringent. Problems could be encountered with regard to:

- safety: light hydrocarbons may be present
- corrosion: due to high chloride content
- undesirable suspended solids.

Mixing recovered oil with coal for use in coal-fired power stations would seem to have possibilities, but development work would first be necessary (Breuel 1981). An additional problem that is envisaged is associated with air pollution: the effects of the different fuel on the anti-pollution equipment at these stations is unknown. In addition, problems resulting from the different thermal efficiencies and outputs of the different fuels are not mentioned in the literature.

3.2 STABILISATION OF OILY WASTE

Stabilisation (in this context chemical fixation and physical consolidation) can serve as an aid to storage and transportation, or as a means of disposal in its own right for oily sand. The approach involves binding the oily material with an inorganic substance such as quicklime (CaO). This forms an inert product which does not allow the oil to leach out. Laboratory testing undertaken by Waldie et al (1982) showed that oil can be retained in such stabilised material to the extent that hydrocarbon contents in leachates were down to 1 mg/l. It should be pointed out, however, that this value is considered to be lower than that achieved under normal on-site conditions, which cannot be controlled to the same extent as in the laboratory. Actual values reported from treatment sites in France (Institute of Offshore Engineering, 1982), range between 100 and 500 mg/l of hydrocarbons in soil and water samples collected approximately one year after landfilling with the stabilised material. The pH values of leachates sampled in the Waldie (1982) study were all above pH 11, which is to be expected if an alkaline medium is employed for stabilisation. How long these high pH values persist is not documented.

After chemical fixation, oily waste is assumed to remain in a stable form and biodegradation is not facilitated. It is unclear, in the literature reviewed for this study, whether the oil would leach from the stabilised material if the physio-chemical environment was altered in any way.

Waldie et al (1982) state that quicklime appears to be the best binding agent, but cement and pulverised fuel ash (PFA) are also mentioned as possibilities.

The mixture of binding agents and oily sand is a clean, easily handled material which can be readily transported and stored, or used directly as landfill, for civil engineering works or for road construction (where there is not a requirement for high load-bearing properties). It should, however, be noted that high quality products are generally not obtained from such operations. Waldie et al (1984), reported that mechanical testing of lime stabilised material on three landfills in France and tests undertaken in the laboratory indicated the Californian Bearing Ratio (CBR) index was greater than the value required for landfill material but below the minimum recommended for road foundations carrying heavy traffic .

The two suggested methods for treatment with lime are layering and drum mixing. The layering method requires use of a relatively large area of flat ground and is effected by spreading the waste to a depth of approximately 25 cm and mixing it with a pulverising mixer before the lime is applied. This breaks up the waste, provides aeration and reduces the water content. Lime is then added in several layers of a few centimetres, with several passes of a pulverising mixer to ensure mixing. The quantity of lime can vary from 5% to 20% of waste material by weight, depending on the percentage oil and/or water in the waste. The chemical reaction of lime with the oily waste is immediate in the case of quicklime, but is delayed with the hydrophobic quicklime (Waldie et al 1982). A second 20 cm layer of waste is then added and the process repeated until the desired height is reached (1 - 2 m). Corrosive lime dust can be problematic and protective clothing should be worn. After mixing, the material is compacted using standard highway construction equipment. Material from this layer process can be left in-situ or can be removed by trucks to another landfill or storage site. In the latter case, compaction on the initial site would be limited.

The second method is effected using a loading hopper, mixer and discharge hopper, as illustrated in Figure 3.2. This technique gives better containment of the easily windblown quicklime and improved dosing of the lime, thereby improving the efficiency of treatment. The main operating problems quoted by Waldie et al (1982) at a unit in France, used to process about 20 000 tonnes of waste from the *Tanio* spill which occurred off the coast of

France in 1980 were:

- clogging or damage to the rotating knife assembly at the feed end, caused by plastic bags, wood and larger stones present in the oily waste
- deterioration of conveyor belts
- clogging of the mixing drum by wall deposits
- corrosion of equipment.

Apparently, significant maintenance work was needed on the unit after one month operation on *Tanio* material.

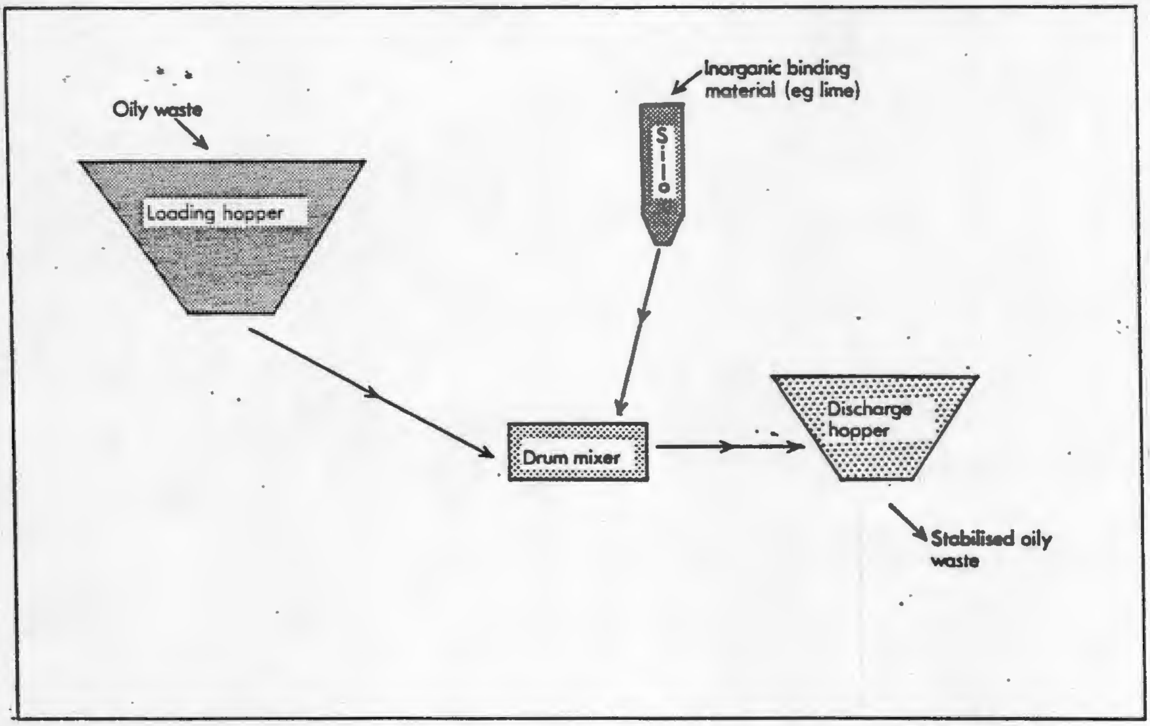


Figure 3.2 Simplified flow diagram for drum mixing stabilisation process.

In France, treated material was tipped and spread to form the bottom layer in the construction of new roads (Waldie et al 1982). But, laboratory tests showed that exposure to water caused such a deterioration in compression strength and CBR bearing ratio, that the lime treated material was considered unsuitable for roads carrying large amounts of traffic (Such and Le Roux 1980). They also investigated the use of lime treated hydrocarbon rich wastes from the *Tanio* incident as highway embankments. Some work was done on further stabilising this material by adding bitumen. The lime treated material was better than untreated waste in that it did not cause as much softening of the bitumen, but the resulting mixture was still inadequate in terms of water resistance.

Tarballs have been processed by heating the sand/oil mixture in a mixing vessel, then adding sand, gravel, filler and bitumen (the last if the mixture is too soft). This mixture can be used as foundation material for tertiary roads (CONCAWE 1980).

Collected oils have also been used for laying and binding dust on dirt roads, parking lots and coal tips (Breuel 1981). The addition of light distillates can improve the handling of heavy weathered wastes to facilitate spreading.

Areas where stabilised wastes are deposited or used for construction purposes should be investigated, to ensure that no contamination of clean water resources occurs.

In South Africa, the use of treated oily wastes in civil works has been undertaken in the past, for example in the construction of harbour walls at Richards Bay, and is receiving further consideration. It is necessary to establish whether there is a direct use for stabilised oily waste in road building, or whether it would have to be stored for extended periods before an opportunity for use occurred.

3.3 DESTRUCTIVE TECHNIQUES

Destructive techniques include biological degradation and destruction by heat (burning). Biodegradation is the metabolic utilisation of organic compounds by micro-organisms which require oxygen, nutrients, water and specified physico-chemical conditions such as moderate temperature and pH. The biological processes break down the organic portions of the waste, ultimately producing carbon dioxide, water and cell mass (humus) (American Petroleum Institute, 1985). Although Atlas (1981) cites some reports of anaerobic biodegradation of hydrocarbons in natural ecosystems, it is generally agreed (Bailey et al, 1973 and Ward et al, 1980) that anaerobic degradation by micro-organisms at best proceeds at negligible rates in nature. Latest evidence suggests that oxygen is the most critical metabolic factor and that increasing oxygenation will dramatically increase the growth of bacteria and the degradation of hydrocarbons (Brown and Cartwright, 1990). Although biodegradation is a natural process with few undesirable ecological side effects, very little mention is made of some of the intermediate breakdown products which may be singularly nasty. Oudot et al (1989), noted the vertical migration of organic carbon resulting from biodegradation and suggests that further work is needed to establish the impact of these metabolic intermediates on the quality of groundwater. Atlas (1981) suggests that the role of micro-organisms in forming persistent environmental contaminants from hydrocarbons such as the compounds found in tar balls are unknown and require further research. Biodegradation is relatively inexpensive, with low energy requirements and does not require elaborate equipment. It is applicable to oily debris containing sand, animal and plant remains. The disadvantages are that large areas of land or storage space are required and that microbial action can be inhibited by the presence of toxic compounds, exhaustion of dissolved oxygen or lack of nutrients. No energy is recovered from the oil but there is a possible increase in soil humus content.

There are four applications of biodegradation to oil spill wastes:

- stimulated biodegradation in ponds
- farming of oil and oily waste
- co-disposal with municipal waste (composting).
- direct landfilling or burial

3.3.1 Stimulated biodegradation in ponds

Stimulated biodegradation involves the disposal of oily waste into shallow, temporary ponds in the vicinity of the spill. Water is added to fluidise the mass and water soluble fertilisers, (for example, nitrates and phosphates) are added as nutrient sources. Aeration by mobile compressors can supply sufficient oxygen and effect mixing. This method was suggested by CONCAWE (1980a), and they report that some experimental work has been done. However, a comprehensive computer based literature survey undertaken for this report revealed no reference to any cases where stimulated biodegradation in ponds has been undertaken for the disposal of oily waste. (See reference list for a description of the literature survey.) It would seem that this technique could be applied during temporary storage or in areas where oxidation ponds are available.

A divergence from stimulated biodegradation in ponds has recently been suggested by Brown and Cartwright (1990), known as biopile treatment systems. Here, the oily sand or sludge is placed in windrows (cells) on an impervious liner over air infiltration lines. This type of technology is still at the developmental stage in the United States.

3.3.2 Landfarming

Farming of oil and oily debris requires adequate, inexpensive land within reasonable transport distance of the spill site. The land to be used should be located so as not to contaminate groundwater or surface water supplies. Soil permeability should be low. A site for landfarming oily waste is prepared by removing brush, timber and rocks larger that 30 cm. The top soil is loosened by a bulldozer, ripper or plough, and runoff diversion channels constructed to prevent surface drainage flowing through the area. The oily debris is then spread over the surface in a layer not exceeding 20 cm in thickness. The maximum application rate quoted (CONCAWE 1980a) is 400 tonnes of oily waste per hectare, but can be as low as 100 tonnes per hectare. The contaminated material should not contain more than 20% oil. Figure 3.3.2 illustrates the landfarming technique. If possible, the oily waste should be allowed to weather (days to weeks) until it no longer appears wet and sticky, before being thoroughly mixed in with the soil with a plough or rotovator. Mixing should be repeated at increasing time intervals, monthly at first to seasonally after two years. Soil pH must be adjusted to over 6,5 with lime and, fertilisers (10 parts N and one part P per 100 parts oil) added as nutrients to enhance oil biodegradation rates. Seeding with commercial bacteria cultures to improve bioremediation is receiving widespread attention at present. Frequent application of oily waste on the same site can be undertaken in the case of debris with a low oil content (CONCAWE 1980b).

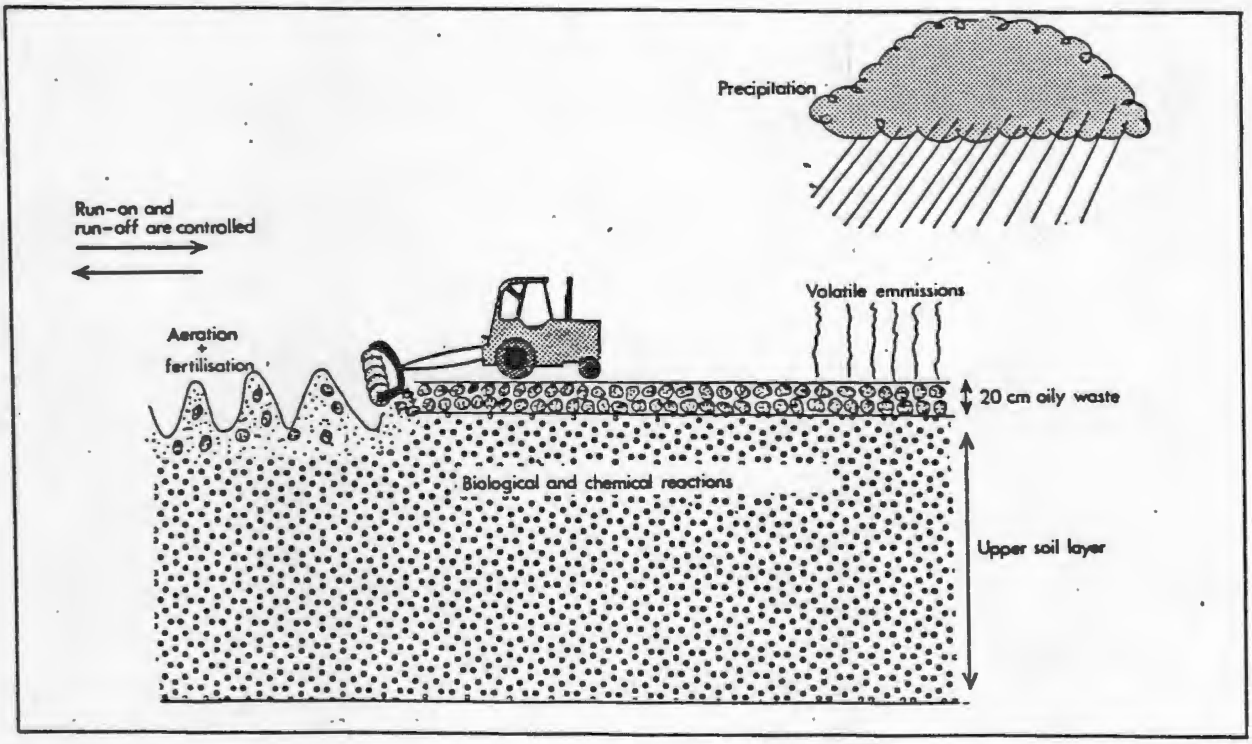


Figure 3.3.2 Diagram illustrating landfarming of oily waste.

Since the early 1970's, landfarming has attracted increasing attention and is a commonly used method for disposing of oil refinery waste (American Petroleum Institute 1985?). Also known as *sludge farming*, refineries use the same piece of land for continuous application of oily sludge at suitable time intervals, indicated by hydrocarbon analysis of soils.

Besides the possibility of water contamination, there is a potential for accumulation of heavy metals in the soil over time. In 1980, CONCAWE concluded that provided simple safeguards are observed, sludge farming is ecologically the most suitable and cost effective method of disposal for normal oily sludge and for soil which has been contaminated with oil.

It has recently been reported by Brown and Cartwright (1990) that regulatory agencies throughout the world are reviewing the traditional sludge farming practices at refineries. Although theoretically sound, sludgefarming is often undertaken without sufficient control over parameters which are key to timely and uniform biodegradation of oily waste. The result is that the uncontained landfarm itself becomes a major source of contamination at the refinery.

However, landfarming of oily waste following a marine oil spill, is somewhat different. In this context, we are dealing with a once-off occurrence, and therefore accumulative effects are unlikely to occur. Land may be returned to its normal use after biodegradation is complete, but food crops should be analysed for heavy metal content.

If this method of disposal is to be used, it is suggested that natural sorbents like straw be used during clean-up, since they break down more rapidly than synthetic commercial sorbents.

Landfarming was applied after the *Venpet-Venoil* incident off the Cape South Coast in 1977 and the farmer on whose land the disposal was undertaken, reports that the land was productive within one year. It is suggested that this site be investigated to ascertain possible environmental implications of the disposal operation.

3.3.3 Co-disposal with municipal waste

Co-disposal is defined as the disposal of chemical wastes in an admixture with domestic waste, so that full advantage is taken of the attenuation and biochemical processes operating within a landfill, to reduce the environmental impact of the chemical waste to an insignificant level (Rushbrook 1988).

Co-disposal of oil spill wastes with municipal solid waste will bring about fairly rapid degradation of oily waste, as temperatures in the tip are high due to exothermic bacterial activity (CONCAWE 1980). As temperature increases, the viscosity of the oil will fall and percolation rates of the oil will increase. In this case, application of too much oily waste could contaminate groundwater. In addition, the resultant leachates could contain metal binding organic molecules (for example heterocyclic compounds containing N, S or O) with the potential to complex certain trace metals (eg Cadmium), thereby increasing mobilisation of metals within the tip to subsurface water resources. However, as domestic tips have inherent pollution potential, they are usually located such that the potential for groundwater pollution is minimal, and surface water diversion practices limit surface water pollution.

The usual practice is to spread the oily material thinly over the surface of the domestic waste tip or slightly thicker in strips at a rate up to 2% of total tonnage tipped, on at least 3m of dumped refuse, as illustrated in Figure 3.3.3.

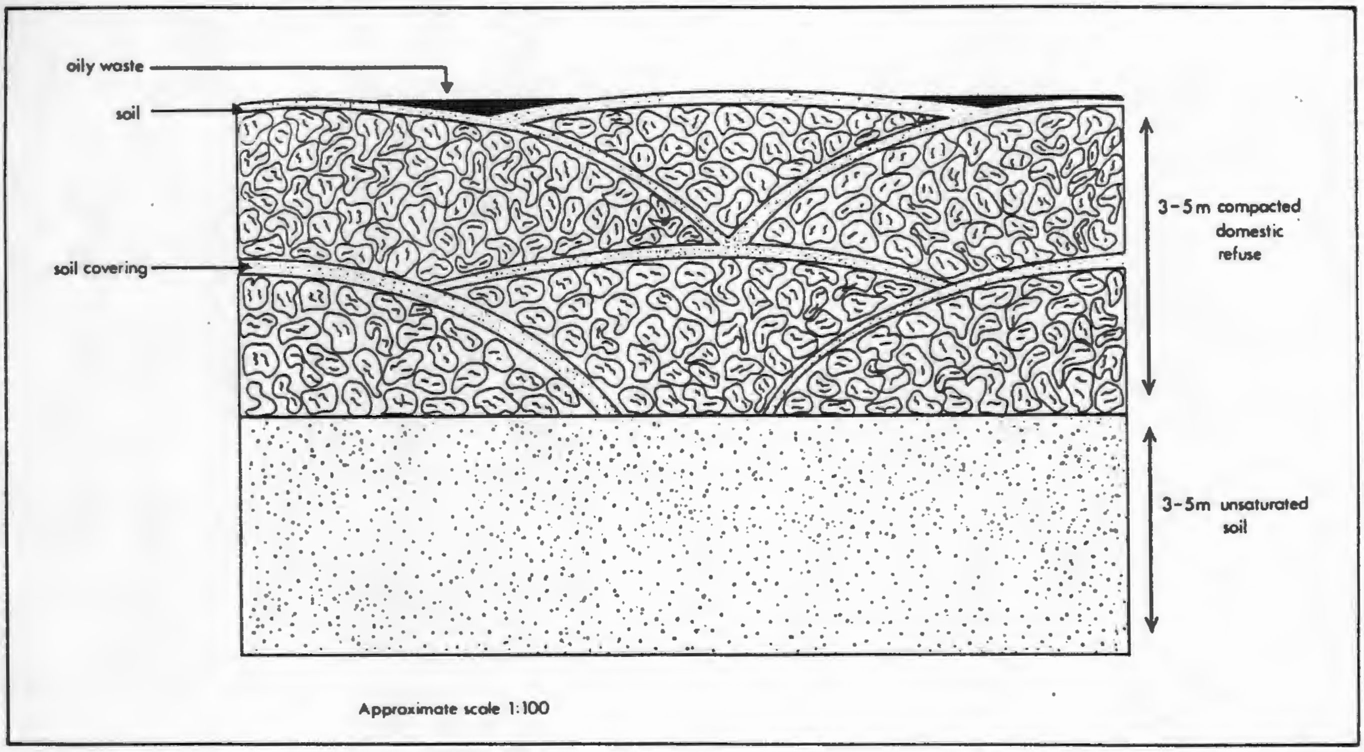


Figure 3.3.3 Cross section illustrating co-disposal with municipal waste.

The capability of a local authority to deal with recovered oil in this way will be limited by the extent of their domestic waste tips, and in general, acceptable tonnages will be small compared with the quantities requiring disposal following a major pollution incident. An inventory of local tip sites along the coast, taking into account their capacity and pollution potential, should be generated for oil spill disposal planning.

3.3.4 Direct landfilling or burial

Direct burial without treatment has been undertaken in the past but according to CONCAWE (1980a) it is not a preferred option, due mainly to problems of hydrocarbon contamination of groundwater. However, singular circumstances may sanction direct burial of oily waste following an oil spill.

One such case is reported by Pizarro (1989). Clean-up operations following the grounding of the crude oil carrier *Cabo Pillar* at Punta Davis, Chile in 1987 resulted in the collection of thousands of plastic bags of oily waste. He reports that 1200 bags per day were collected, although the overall quantity is not mentioned. Attempts to burn the oil with debris did not succeed due to high water content and low temperature. Being a "desolate zone" it was decided to bury the bags. Because the coast is covered with peat, Pizarro reports that it was impossible to make any holes to bury the bags, so some natural holes over the peat were chosen as disposal places. Although the site was visited a year later, to assess recovery from the spill, the impact of the disposal operation was not monitored.

Burial of low grade oily sand in the back beach area has been undertaken after certain incidents, with supposed success. For example, after the *Alvenus* incident in the Calcasieu River Bar Channel (Louisiana) in 1984, moderately contaminated sand (ie with an oil content of less than 10%) was spread in the back beach area, adjacent to existing sand dunes (Alejandro and Buri, 1987). Lightly oiled sand was spread in the non-tidal, midbeach area. Chemical and physical analyses were made of the oil prior to disposal, to ensure that placement of the oil contaminated sand would present no severe environmental problems. These analyses revealed that the oil contained no toxic components and that water soluble fractions were no longer present in the weathered oil. All sites were built with protective berms. They report that there is no evidence of leaching from the lightly oiled sand that was spread above the non-tidal portions of the beach.

If, this type of burial is to be considered as an option - preferably for low grade, weathered, oily waste - care would have to be taken to ensure vegetated dunes are not destabilised and that oily waste will not be uncovered by exceptional high tides or dune migration.

Landfilling of oily wastes in constructed or natural excavations, using a combination of liners and leachate collection systems is a method currently used worldwide (API, 1985). Landfilling isolates the waste rather than decomposing it and future land use of the site is restricted. The API also reports that landfills are difficult and costly to design, operate and maintain.

3.3.5 Destruction by heat

Destruction by heat can be undertaken by direct burning of collected oily waste on the beach or by incineration in a purpose-designed facility.

Direct burning of uncontained oily debris in situ is not recommended, except in remote areas and when the wind is blowing off-shore, since it usually causes atmospheric pollution and safety problems associated with fire hazards. When oil is burnt in the open, it tends to spread and be absorbed into the ground. In addition, a tarry residue may remain since it is rarely possible to achieve complete combustion (ITOPF 1984).

Oil spill contingency planning for Mauritius is discussed by Murday and Gundlach (1989). They note that disposal of oily waste poses a particular problem, but with due consideration to atmospheric conditions, burning is considered appropriate. However, they suggest the identification of suitable sanitary landfill sites for the disposal of both oily and domestic wastes is preferred.

Incineration can overcome problems associated with direct burning by containing the oily waste and facilitating the high temperatures necessary for total combustion. A number of portable incinerators have been developed, such as the rotary kiln and open hearth types which are most appropriate for oils with a high solid content (ITOPF 1984). Simple portable burners or kilns can also be assembled on site using 44 gallon drums, with air supplied tangentially from a compressor or fan blower. Combustion in the kiln is self-sustaining if the feed material contains at least 25% oil and no more than 50% water (ITOPF 1984).

Boakang (1989) reports that when the Panamanian tanker *Feoso Ambassador* ran aground off the coast of China, 300 tons of crude oil spilled from the damaged tanks. Floating oil and oily debris from the beaches were collected and disposed of by complete incineration in brick kilns. He makes no comment, however on any problems encountered or the suitability of the process.

Municipal incinerators are unlikely to be able to treat wastes with low calorific value or those which contain sea water, because of corrosion problems. Liquid oily wastes with higher calorific values (3000 to 5000 Kcal/kg) blended at a rate of 1% to 5% can be treated, but skilled staff are required for the burning of heterogenous waste (ITOPF 1984).

Industrial waste incinerators can handle all classes of waste but may not be able to cope with large quantities of oily waste in addition to their normal loads. This means that storage facilities for oily wastes will be required.

Hospital incinerators were used to process some of the oily waste following the *Exxon Valdez* incident in Alaska (Hodgson 1990). To date, very little has been published regarding the disposal operations of this case and results or problems of disposal recorded. Even the most recent environmental impact assessment and response report of the *Exxon Valdez* (Maki, 1991 and Kelso and Kendziorek 1991) make no mention of the disposal operations.

CONCAWE (1984), warn that incineration is not a simple universally applicable process. Incinerators are usually designed (and licensed by local authorities) for a known and well defined quality and quantity of feed. Other incinerators are designed specifically for solids, liquids or fairly constant mixtures which cannot readily be changed. They add that incineration of oily sludges is expensive and requires constant supervision. The documents (CONCAWE 1984 and 1990) provide all the necessary technical information regarding incineration of oily waste.

If incineration is to be considered, it is necessary to establish the availability and capacity of both municipal and industrial incinerators at the oil spill contingency planning stage.

CHAPTER 4

FACTORS AFFECTING OIL SPILL DISPOSAL PRACTICES IN SOUTH AFRICA

A review of the general disposal techniques for oily waste undertaken in Chapter Three, indicated that the application of some particular techniques in South Africa, will be subject to local constraints and conditions. This chapter considers the suitability of the oil disposal practices to the South African Environment, taking the following into account:

- legal constraints
- availability of facilities
- financial considerations
- environmental implications

4.1 LEGAL CONSTRAINTS

There are a number of statutes which need to be taken into account when considering options for the disposal of oily waste. In general, such legislation is aimed at protecting the bio-physical environment and human health, but reducing expenditure (especially foreign expenditure) and promoting public safety are also considered by the legislation. This section examines the legislation affecting the different disposal options under the sub-headings: recovery for re-use; terrestrial disposal; and burning.

4.1.1 Recovery for re-use

Recovery for re-use includes re-refining, recycling and fuel burning. The main statute dealing with this type of disposal is the Petroleum Products Act (No. 120 of 1977), administered by the Minister of Mineral and Energy Affairs. It is the intention of this Act "to provide measures for the saving of petroleum products and economy in the cost of distribution thereof ....". In terms of oil disposal, this Act is directed towards encouraging the recycling of mineral oils in order to effect savings in foreign expenditure for imported oil.

Regulations made in terms of the Act (R 797 of 18 April 1980) provide the instrument by means of permits, for the purchase, sale, supply, acquisition, possession, disposal, storage, transportation, recovery and re-refinement of used mineral oil.

Section 5(3) of the Prevention and Combating of Pollution of the Sea by Oil Act, (No 6 of 1981), gives the Minister of Transport or Environment Affairs authority to order a supplier of any service to dispose of, process or treat any material as required for the removal of pollution. This means that functions related to the disposal of oily waste following an oil spill at sea may be delegated, for example to local authorities, refineries or waste disposal or reprocessing contractors.

The Customs and Excise Act (No 91 of 1964) provides for the levying of customs, excise and sales duties; for a fuel levy and the prohibition and control of the importation, export or manufacture of certain goods. In terms of this Act, the Commissioner of Customs and Excise, of the Department of Finance, has the authority to charge duties, levies, surcharges, etc., on imported goods listed in Schedule 1. Therefore, clearance is required from the Commissioner, for any oil transferred from a foreign vessel during casualty salvage operations. The Commissioner may seize the cargo and demand licensing of warehouses for the storage or manufacturing (reprocessing) of this oil. According to the report (RSA 104/1990) even flotsam and jetsam falls under this Act and places a question mark over spilt oil collected from the surface of the sea.

In terms of Schedule 1, crude oil is listed as a "free" good whilst a high duty (40%) is imposed on the refined product, diesel. It the past, attempts have been made to allow farmers (for example) to collect small quantities of fuel oils collected during salvage operations, thereby avoiding disposal costs and transportation costs which would be high in remote areas, and simplifying disposal operations. However, in terms of this Act, the procedure has been disallowed by the Directorate of Customs and Excise as an import levy had to be paid, which was not acceptable to the farmers. This has resulted in fuel having to be shipped to the nearest harbour and handled through waste processing operators, at a greater cost overall.

The Directorate of Customs and Excise also administers the Import and Export Control Act (No 45 of 1963) which falls under the Director of Import and Export Control of the Department of Industries and Commerce. In terms of this Act, the Minister may, by notice in the Government Gazette, prescribe that no goods of specified class shall be imported, or that a permit be required, and may prescribe the quantity, value, price and conditions as to ownership, possession and disposal of such goods.

When the *An Hung* ran aground off the Cape South Coast in 1990, these last two Acts proved responsible for impeding salvage operations. An Inquiry was called to investigate the mishandling of the response to the casualty. The report of the Commission of Inquiry (RSA, 104/1990) concluded that "some of the practices, functions, concepts and legislation of Customs are anachronistic (outdated) and a reappraisal is now overdue. This was in fact confirmed to the Commission by their Senior legal advisor, and they are in the process of revising their legislation."

4.1.2 Terrestrial disposal

The term "terrestrial disposal" is used in this section to cover disposal of oily waste as stabilised landfill, by landfarming, by co-disposal with municipal waste, by direct burial, stimulated biodegradation in ponds and, to a lesser extent, use in civil works. The same statutes, in general, will apply to these methods of disposal.

Legislation affecting the dumping of oil on land affords protection to the biophysical environment, and public health and safety. The term "biophysical environment" is used to include the physical landscape, ie. topography, geomorphology, and geology; as well as renewable resources such as soil, freshwater systems, marine resources, atmospheric quality and indigenous fauna and flora; and also land usage.

The biophysical environment is protected, by regulating the places where disposal can take place and by restricting the pollution or destruction of natural resources. The following statutes are applicable to oil disposal:

- National Parks Act
- Lake Areas Development Act
- Water Act
- Environment Conservation Act
- Sea Fisheries Act
- Dumping at Sea Control Act
- Conservation of Agricultural Resources Act
- Provincial Nature Conservation Ordinances

In terms of the regulations issued under the National Parks Act (No 57 of 1976), it is an offence within a National Park, to discard any article or refuse of whatever nature, except in receptacles and containers provided for this purpose by the National Parks Board of Trustees (43(c) of Regulations GN R2006 of 6 October 1978, read with ss 1 and 24(8) of the National Parks Act), (Rabie 1981). This Act would preclude the disposal of oil or oily waste in any National Park or, Lake Area as the following Act prescribes.

The Lake Areas Development Act (No 39 of 1975) provides for the establishment of lake areas under the control of a Lake Areas Development Board. The Wilderness Lake Area has been the first and so far the only declared Lake Area (Proclamation 90 of 13 May 1977 and Proclamation 233 of 22 Sept 1978), (Rabie 1981). The Minister Environment Affairs may make regulations regarding the use of the sea-shore and the sea within a lake area, or providing for the control, generally of the sea-shore and of the sea and of any lake or river within a lake area (s 23(1)(c)(d) of the Lake Areas Development Act). Such regulations have been published with respect to the Wilderness Lake Area (R311 of 22 Feb 1980). In terms of these regulations, no person may in a lake area, place, dump or let out any refuse, effluent or objectionable matter (Reg 6(1)(h)).

The Water Act (No 54 of 1956) as amended (Water Amendment Act No 96 of 1984) makes provision for the prevention of the pollution of water by seepage or drainage (i.e. rainwater, surface water, seawater and groundwater) and for the purification, treatment and disposal of water used for industrial purposes and, effluent produced by such use. These provisions are binding to the State as well as the private sector. Regional standards for effluent quality have been promulgated in terms of this Act (GN R553 of 5 April 1962), and provide the basis for water pollution control. The Minister of Water Affairs is empowered by this Act to make various regulations, one of which relates to the registration of sites where poisonous matter is disposed (of). Exemptions may be granted by the Minister. A licence is required to operate a waste disposal facility which is not covered by the definition of "a mine". All seepage is classed as effluent and must conform to the "Effluent Standards" (R553 of 5 April 1962). If seepage does not meet the standards, a permit is required in terms of section 12 and 21 of the Act as amended. In terms of these standards, only 2,5 mg/l of oil is permitted in "general areas" and no oil is permitted in effluent discharged in "special areas". Although there is no standard for hydrocarbon concentration, the regulations prevent the tainting of smell or taste of water resources. A "minute" concentration (ug/l) of hydrocarbons can be detected in water by taste or smell (Freeze and Cherry, 1979). Therefore, this means that extreme care should be taken when selecting the disposal option and specific site. The impact of the disposal operation on freshwater systems in particular, should be stringently identified, and seepage into groundwater systems should not be overlooked. Communication with officials from the Department of Water Affairs is therefore required for the identification or selection of disposal sites.

The Environment Conservation Act (No 73 of 1989) aims to provide for "the effective protection and controlled utilisation of the environment and for matters incidental thereto". In terms of Part IV of this Act, a permit is required from the Minister of Water Affairs, to operate any disposal site. Part V of the Act identifies, among others, waste disposal and chemical treatment as activities which may have a substantial detrimental effect on the environment, and as such require written authorisation by the Minister of Environment Affairs or a local authority. The Act empowers the Minister of Environment Affairs to make regulations regarding waste management concerning among others, utilisation of waste by way of recovery and the location, planning and design of disposal sites, as well as regulations regarding environmental impact reports for waste disposal activities. To date, no regulations have been promulgated within these terms. It appears that consultation with the Ministers of Water Affairs and Environment Affairs is necessary prior to any disposal operations being undertaken.

The Sea Fisheries Act (No 12 of 1988) makes it an offence to dump or allow to enter or be discharged into the sea, anything which is or may be injurious to fish, fish food or seaweed, or which may disturb or change the ecological balance in any area of the sea. The Act also makes provisions for the Minister of Environment Affairs to make regulations prohibiting or regulating the dumping in the sea (ie below the high water mark) of any particular substances or materials not complying with specified requirements. No such regulations have as yet been made. This Act would be applicable to burial of oily waste within the shore area, and would require that the impact of such disposal on living marine resources be fully investigated, prior to such disposal operations.

The Conservation of Agricultural Resources Act (No 43 of 1983) succeeds the Soil Conservation Act (No 76 of 1969) and addresses the problem of soil erosion. This Act regulates certain activities associated with soil erosion, and those applicable to the disposal operations are listed below:

- cultivation of virgin soil
- cultivation of land where slope exceeds 20%
- disturbance of wetland ecosystems, ie prohibiting drainage, cultivation or destruction of vegetation
- regulation of flow pattern or run-off
- occurrence of veld fires
- restoration and reclamation of eroded, disturbed or denuded land.

Activities associated with landfarming or burial of oily waste will be regulated by this Act. Careful site selection and if necessary, control measures are required to prevent or minimise soil erosion.

Public health and safety are controlled by the:

Health Act
Sea Shore Act
Hazardous Substances Act.

It is the aim of the Health Act (No 63 of 1977) to promote a safe and healthy environment, with local authorities being assigned the responsibility to prevent nuisance, offensive or dangerous activities which would affect public health. In terms of this Act, the local authority must also prevent the pollution of any water intended for the use of the inhabitants of the district. The Minister of National Health and Population Development has wide powers to make regulations which may presumably also be relevant as regards the control of pollution of the sea shore or the sea (ss 34, 37, 38, and 39 of the Health Act). This Act seems to overlap with the Water Act (No 54 of 1956), the Sea Fisheries Act (No 58 of 1973) and the Sea Shore Act (No 21 of 1935). It therefore appears necessary that the disposal of oily waste be undertaken with the approval of the Minister of National Health and Population Development.

The Sea Shore Act (no 21 of 1935), makes specific provision for the protection of human health against pollution of the sea shore or the sea. The Minister of Environment Affairs may make regulations for the prevention or, the regulation, of the depositing or the discharging upon the sea shore of anything liable to be a nuisance or danger to health (s 19(1)(d)).

At this stage (1991), the Hazardous Substances Act (No 15 of 1973) does not apply to the disposal of crude oil. But, the Minister of National Health and Population Development may declare any substance which may cause injury, ill health or death to human beings as a Group I or Group II hazardous substance. He may make regulations regarding, among others, the transportation, storage or dumping of these substances. Substances such as gas oil, naphthalene (crude or refined) and natural gasoline are classified as Group II substances (R 2825 of Dec 84), and regulations (R 73 of Jan 85) have been promulgated in terms of this Act for the conveyance by road tanker of these substances. These regulations specify measures to be taken when transporting these substances, and within such terms would affect the transportation of certain classes of oily waste to the disposal site.

4.1.3 Burning

Burning includes open air burning as well as high temperature incineration in purpose-designed facilities. Fuel combustion is recognised by Fuggle and Rabie (1983) as one of five pollution producing activities. The burning of oily waste has the potential to result in pollutants such as particulate matter, sulphur oxides, carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen and, odours.

The principal act governing this type of pollution is the Atmospheric Pollution Prevention Act (No 45 of 1965). The Act is administered by the Department of National Health and Population Development, and permits are required for certain activities scheduled in the Act (Schedule 2). In addition, no fuel burning appliance is permitted, unless it can be operated continuously without emitting "dark smoke". Any fuel burning appliance designed:

- to burn pulverised solid fuel
- to burn solid fuel at a rate > 100 kg per hour
- to subject solid fuel to any process involving application of heat, unless emission of grit/dust is effectively limited to the satisfaction of the local authority

is prohibited.

Control of smoke emanating from fuel burning appliances is facilitated by the allowance for emission standards in the Act. This control is generally left in the hands of the local authorities. If any occupier of nearby premises makes representation to the local authority about smoke being a nuisance, the local authority can serve notice on the person responsible, calling for abatement within a certain period (s 17(1)). It is unlikely that such action would be taken by a local authority during a single burning occurrence, but should it be necessary to continue burning operations over a period of time, this section of the Act may be used to prevent burning of oily wastes. Local authorities may make smoke control regulations regarding emission control and smoke control zones, and these should be investigated before the burning of oily waste is considered. Exemptions may be provided by the Minister or the relevant local authority.

In terms of the Health Act (No 63 of 1977), certain forms of air pollution may amount to a nuisance. The Minister of National Health and Population Development may make regulations to regulate, control, restrict or prohibit any activity which constitutes a nuisance. The abatement notice procedure is prescribed for instances where, in the opinion of the local authority, a condition has arisen which is offensive or a danger to health unless immediately remedied and to which the provisions of the Atmospheric Pollution Prevention Act do not apply (Section 27).

It appears then that burning of oily waste may be permitted if it can be undertaken in such a way as not to create a nuisance, for example when the wind is blowing offshore. A permit would be required from the local authority or the Minister of National Health and Population Development.

4.2 AVAILABILITY OF FACILITIES

The compilation of a successful disposal management plan for oily waste, requires good co-operation between local authorities, the oil response team of the Sea Fisheries Research Institute (SFRI) (as identified in the Oil Spill Contingency Plan, DEA, 1987) and local industry. The Head: Pollution Section of the SFRI, as DEA On-Scene Co-ordinator of the oil response team (DEA, 1987), will make recommendations in consultation with other relevant Government Departments regarding the most suitable disposal option for oily waste following an oil spill at sea. For this reason, a thorough inventory of all available facilities is required by him, together with an indication of the capacities and limitations of these facilities. This section records the facilities available in South Africa for the following disposal options:

- recovery for re-use
- terrestrial disposal
- burning

4.2.1 Recovery for re-use

The requirements concerning facilities for recovering oil for re-use, for example the location and capacity of refineries and recycling installations are addressed in this section. In addition, the limitations (constraints) imposed by the quality of the oil (ie degree of contamination) which can be treated by the specific installation, together with their storage capabilities are quantified.

In South Africa, there are definite limitations associated with the **refining** of oil spill wastes at local refineries. Firstly, there are only four coastal refineries in the country, one located in Cape Town and three in Durban. Thus the decision process regarding disposal of oily waste will have to take into account transportation costs to these refineries, by road or sea. Secondly, discussion with management at Caltex Refinery in Cape Town revealed that it is the lighter fractions of the crude (eg petrol and diesel) which are in the greatest demand in South Africa, with heavier fractions, eg bitumen, being over supplied. During an oil spill, the lighter fractions are the first to evaporate (and dissolve), leaving behind the heavier, tarry fractions. Refineries would therefore not find it profitable to process weathered crude. Thirdly, crude contaminated with more than 2% water or >0,1% salt is not suitable for refining (see section 3.1.1), due to corrosion and other problems. Separation and blending techniques could mean that oil with up to 10% water may be considered.

Thus it appears that only crude oil which is still contained on board a tanker in distress and which is pumped off the vessel would be suitable for processing at a refinery.

In terms of **recycling** by waste oil contractors, a higher degree of contamination by seawater (up to 80%) and sand (up to 10%) can be tolerated, the determining factor being that the oily waste is "pumpable". (This information was supplied by the Manager of Fuel Firing Systems in Durban). Simple separation techniques prior to treatment can also be considered for oily waste containing greater amounts of water and sand. The same criteria apply to some fuel burning installations: for example those producing asphalt, (Much Asphalt Ltd. in Cape Town). However quantities of oily waste which can be processed are limited, and companies undertaking salvage operations of shipping casualties have reported (pers. comm. J. Cook, Atlatech) that time delays regarding the collection of the oily waste often cause handling and storage problems. In addition, Customs and Excise duties often make the deal unattractive to recycling contactors. A list of companies known to be interested in waste oil, together with their contact personnel is currently being compiled by the Pollution Section: SFRI in Cape Town.

At present, Fuel Firing Service Pty Ltd (FFS) offer the greatest facility for handling waste oil. They are located in Durban and have their own 1000 ton vessel and a fleet of road tankers for transportation, with rail tankers also being an option. They have storage for approximately 10 000 tons of oily waste and are able to process about 10 tons per day. Almost any hydrocarbon, no matter how contaminated (up to 80% water) can apparently be recycled (FFS brochure by Kinnear Newby & Ass. RSA, undated). They are prepared to pay between R50 and R200 per ton for oily waste, minus the transportation costs, and the recycled product is sold as liquid fuels for marine and industrial furnace applications (pers. comm. Manager FFS, 1990).

The company, Much Asphalt Pty Ltd, has manufacturing plants in Cape Town, Port Elizabeth and East London. They burn heavy fuel oil for the production of asphalt, and the manager of the company is of the opinion that they could probably use crude oil as well (pers. comm 1990). Up to 10% water content is considered acceptable and as long as the oil is "pumpable", sand should not pose a problem (pers. comm. Chris Lange, Much Asphalt Pty Ltd, Port Elizabeth, 1990). On average, each of these plants burn approximately 35 tons a month, and have storage for up to 300-500 tons. The quantity they would be able to accept, would depend on their existing stocks at the time of a spill.

There are other small waste oil recyclers who deal mostly with lubrication oil but who may be able to process small quantities of other types of waste oil, ie a few hundred tons of crude oil. These are companies such as Oilkol, Oil Distribution Co. and Oil Exchange, all of which have operations in Durban and Cape Town.

4.2.2 Terrestrial disposal

As in section 5.2.1, the term "terrestrial disposal" is used in this section to cover landfarming, co-disposal with municipal waste, direct burial, stimulated biodegradation in ponds and to a lesser extent, disposal of stabilised oily waste as landfill or for use in civil engineering works.

Landfarming (as described in Section 3.3.2) requires relatively flat, inexpensive land with reasonable access which can remain unproductive for at least two years and is not a groundwater recharge area. It is anticipated that this land will either be provided by the State, local authorities, or hired from local farmers, and will have to be acquired at the time of the spill. Cape Town Municipality have agreed in principal to use land adjacent to their waste disposal sites for landfarming, should the need arise in their area.

Codisposal with municipal waste requires an inventory of all the available tip sites adjacent to the coast, together with their capacity to handle oily sand and debris. An inventory of available municipal refuse sites, together with their sizes and life expectancies, is available from the Water Pollution Control Division, Dept. of Water Affairs. It should be noted that the use of these refuse sites for the disposal of oily waste will reduce their lifespan and should only be considered in emergency cases, where other methods of disposal (for example landfarming) are not possible or where quantities of oily waste are insignificant in comparison to the capacity of the dump site. Refuse sites, particularly those of small local authorities will certainly not be capable of handling large volumes of oily waste.

Stimulated biodegradation (in ponds) requires impermeable containment facilities which can either be constructed at the time of the spill or are readily available. The only facilities of this nature which have been made available, are oxidation ponds at Bushman's River Mouth, in the Cape Province. There are five such oxidation ponds, three with a capacity of 6 536 m^3 and two with a capacity of 11 180 m^3 (DEA Dias Zone Oil Spill Contingency Plan, 1987).

Stabilisation (with lime), of oily waste and disposal either as landfill or for use in civil engineering works, appears to offer limited scope in South Africa. Such material was used in the construction of the harbour walls at Richard's Bay, but an engineer from a large construction company, was of the opinion that further research was required by the construction industry in South Africa before the use of large quantities of such material is considered. He expressed concern about the storage of large quantites of the stabilised material until a use could be found for it in the vicinity of the spill site, or alternatively the costs associated with transporting the material to a site where it could be used (pers. comm. Civil Eng., Murray and Roberts Ltd.,1990) The heavy machinery required for this type of treatment is available in South Africa, but more information is required regarding the operational procedures for such a system.

4.2.3 Burning

Direct, open air burning can be undertaken if lighter, easier-combustible fractions are present (for example gas oil), but black smoke and a tarry residue will usually result. Therefore, incineration in high temperature purpose-designed facilities is the preferred option. However, additional fuel, such as diesel, is usually required to ignite the oily waste and to maintain the burning process in some cases. In South Africa, municipal and industrial incinerators are uncommon, and those concerns approached (including hospitals) by the Sea Fisheries Research Institute were either unwilling or were unable to commit themselves to providing their facilities. This was due firstly to their concern about producing black smoke and secondly to their inability to cope with additional quantities of waste material, as they were running close to their maximum capacity. The Cape Town harbour has an incinerator designed to burn domestic refuse and oily sludge from ships. However, due to a fall off in harbour traffic and the relaxation of health regulations it is no longer operational. Harbour authorities (ie Portnet) are investigating the possibility of re-instating the facility (with an approximate capacity of 400 kg per hour) on a commercial basis at some stage in the future (Pers. Comm. from Harbour Engineer, Portnet, Cape Town, 1990).

The oil pollution store, maintained by the Sea Fisheries Research Institute, has a clean burning incinerator which is capable of burning approximately 4 tons of oily waste over a period of 24 hours. A water content of up to 60% or an oily sludge can be burnt using this facility, but diesel oil is required for ignition and combustion. The capability exists within the Pollution Section of the Sea Fisheries Research Institute to construct additional incinerators should the need arise.

4.3 FINANCIAL CONSIDERATIONS

Section 9 of the Prevention and Combating of Pollution of the Sea by Oil Act (No. 6 of 1981) provides that the owner/insurer of any ship, tanker or offshore installation may be held liable for the cost of any measures taken or caused to be taken by the Minister of Transport/Environment Affairs in terms of the Act, after a spillage of oil. The owner is, however entitled to limit his liability in certain circumstances. The sum total of loss, damage and costs incurred may therefore not be met in full. Furthermore, provision is made to ensure that all costs and measures taken are reasonable and cost effective in the circumstances prevailing at the time. Should the source of the oil not be identified, the Minister of Transport may at his discretion refund up to 50% of the clean-up costs incurred by local authorities.

Financial considerations therefore play an important part in the selection of oil disposal options. Financial costs which may be incurred for oily waste disposal include transport costs to the disposal site, storage costs, the cost of treatment and the cost of land to be leased.

The distances the oily waste will have to be transported, will vary considerably, depending on the type of disposal that is adopted. Treatment at a refinery may involve transport over the greatest distances. The refineries are located in Durban and Cape Town which are approximately 1800 km apart by road. Assuming a point half way between the two, the greatest distance would be 900 km. An estimate received from Wasteman Pty Ltd (Pers. Comm. Mr Manekom, 1990) places a cost of approximately 50 cents per km per ton for the transport of liquid/solid oily waste by road haulage. However transportation by sea is also an option. Waste oil recyclers and fuel burning installations are located in Durban, East London, Port Elizabeth and Cape Town, with possible smaller operations taking place in other centres. Maximum distances would probably vary between 200 to 500 km.

Co-disposal with domestic refuse would require transportation to the nearest municipal waste site, and it is not anticipated that the oily waste would need to be transported more that 200 km, if this disposal option is undertaken.

In most cases, land-farming would be undertaken as close as possible to the site, and transportation to the site is not expected to exceed a maximum distance of approximately 100 km.

Burning would usually only be considered in remote areas, presumably where access is limited and not conducive to the removal of oily waste from the site by means of heavy haulage. Under these conditions, it is expected that burning would be undertaken at or close to clean-up operations.

These are the assumptions that have been used to determine the transportation costs presented in Table 4.3.

Storage costs will be incurred prior to processing by refineries, recyclers and fuel burning installations. Such costs will be commensurate with the amounts of oily waste received and processed by these installations and are related to their individual storage facilities.

There are two components to the cost of treatment of the oil or oily waste. First there are reprocessing costs incurred by the refineries and recyclers. These costs will, however, be recovered from the resale or use of the product. There would be no costs to the insurer (or authority) but rather benefits, in terms of payment for the oil/ oily waste (pers. comm. FFS, Durban and, Caltex Refinery, Cape Town, 1990).

Secondly there are costs incurred directly by the insurer (or authority responsible for disposal costs). These include the leasing of land for landfarming, the landfarming practices, charges levied by municipal authorities for co-disposal, and the cost of commercial incineration or the cost of fuel required for burning.

Establishing the costs of stabilisation of oily waste for civil engineering works is not easily accomplished, as the infrastructure and experience for this procedure are at present lacking in South Africa. Only the cost of the lime is available (R878.45 per 1,5 tons unslaked quicklime - Cape Lime Pty Ltd, 1990), and heavy equipment costs can be assumed to be similar to those for landfarming.

Landfarming costs were recently investigated for the disposal of oil from the *Petingo*, a bulk carrier which ran ashore near Richards Bay in July 1990, releasing some 1650 tons of heavy fuel oil into the sea. It is estimated that 500 tons of this oil came ashore. Approximately 5000 tons of oily beach sand were collected and deposited behind the primary dunes, with a view to landfarming the waste on a 2 ha site. Tenders were invited from contractors for the "farming" operation, to take place over a period of about one year. The price quoted was R 120 000. This figure is related more to the area to be farmed rather than the amount of oily waste. At this particular site it is thought (by the author, in terms of the references cited in section 3.3.2) the oily waste was placed too thickly on the disposal site, and for this reason the costs per ton have been amended accordingly for use in this study. Had waste application been 400 tons per heactare, the cost of land treatment would have been R 150 per ton, but the application rate would vary according to the oil content of the waste. In this particular case, State land was used, but in some situations, it may be necessary to lease land from local farmers or other landowners. The costs of leasing land would be determined with respect to the existing yield of such land. This would vary between approximately R 200 per ha per annum for veld with a low livestock carrying capacity, through to R 2500 per ha per annum for maize/wheatlands. Up to R5000 per ha per annum is reached for irrigated land planted to vegetables, but this type of land would not normally be considered for landfarming. (Agricultural Technical Services, Economic Section, Stellenbosch, 1990).

In terms of co-disposal with municipal waste, Cape Town City Council charge a permit fee of R 30 per 5 kl (± 5 tons) of toxic waste (1990), but there is a limit to the volume of waste that can be handled in this way. Costs to local authorities for solid waste disposal at existing sanitary landfill sites are estimated at approximately R30 per ton and up to R50 per ton is quoted for costs at composting facilities (Pers. Comm. Tworeck, Dept Water Affairs, 1991). The volume of waste that can be handled in this way will depend on the location of the spill and the capacity of the local municipal refuse sites.

According to Noble (1976), a range of modern incineration equipment is available in Europe and the United States and incineration is a widely used means of disposal in these countries. He reports that incineration costs in South Africa are very high indeed, due to heavy capital expenditure and high running costs. Commercial incineration costs as estimated by Portnet (1990) are of the order of R250 per ton.

Table 4.3 indicates values for various disposal operations where it has been possible to establish costs.

TABLE 4.3 DISPOSAL COSTS

DISPOSAL METHOD	MAX KM TRANSPORT	COSTS PER TON OF OILY WASTE	ACCEPTABLE WASTES
Refinery	800 km	R 227 paid by refinery	uncontaminated, fresh crude only.
Recycling and Fuel burning	200 to 500 km	R 50 to R 200 paid for oily waste	Fresh-moderately weathered and contaminated crude, HFO and lube oil.
Codisposal	200 km	R 6 for permit R 40 cost to local authority	Limited quantities only.
Landfarming	100 km	R 100 to R 400 for first year	Large volumes of oily sand.
Lime stabilisation	100 km	R 30 to R 125 for lime. R 200 for plant hire.	Large volumes oily sand.
Incineration	200 km	R 250 commercial costs	Limited quantities oily sludge.
Burning	50 km	R 10 for fuel, increasing with decreasing volatility of waste	Limited quantities oily sludge.
Direct burial	50 km	R 50 for plant hire	Limited quantities oily sand.

4.4 ENVIRONMENTAL IMPLICATIONS

The environmental implications associated with the various disposal techniques for oily waste are mentioned haphazardly in the literature. In order to compare alternative disposal methods it is necessary to assess the potential environmental impacts in an equitable manner. All aspects of the biophysical and socio-economic environment should be considered for each of the disposal options. A list of environmental parameters has been formulated in order to focus thinking and prevent any omissions. These parameters are: biota, water resources, soil, atmospheric quality, land use, public health and safety and, existing services.

When considering the disposal options in terms of their impacts on the above environmental parameters, it is important to note that it will only be possible to address certain site specific impacts at the time of the spill. Local conditions prevailing when and where the spill occurs will undoubtedly influence the significance of impacts of the disposal operations. At this stage, it is therefore only possible to address the general, potential environmental impacts. Where necessary, some of the environmental impacts recorded in the literature survey in Chapter 3 are repeated in this section.

4.4.1 Recovery for re-use

When considering recovery for re-use, it is the additional impacts the disposal will have on the environment that need to be defined. For example, a refinery may under normal operating procedures generate unpleasant odours, but these are of no consequence to this study. If, however, there was a significant increment in these odours due to treatment of oily wastes, it is these incremented effects that would require identification. The most significant impact of recovery for re-use is the pressure that will be placed on existing services. Refineries and recycling operations usually run close to their design capacity and therefore storage, processing and distribution facilities may experience additional pressure if oily wastes are added to their process stream. It is unlikely that any additional pollution potential in terms of the bio-physical environment will arise, for example, additional water pollution.

4.4.2 Stabilisation of oily waste

Treatment of oily waste with lime is likely to result in localised lime dust contamination. This could result in short term, local contamination of water, soil, biota and atmosphere. Lime dust also poses health risks to operators, but this can be minimised if protective clothing is worn. Disposal of the stabilised material either through use in civil works or as landfill, may produce leachates with the potential to pollute groundwater and surface water, although the pollution potential is certainly reduced by the use of binding agents (Waldie 1984). The greater the quantities that are treated and the higher the oil content of the material, the greater the pollution potential. It is unknown at this stage whether pressure would be placed on existing services or facilities, as the availability of facilities and the demand for treated wastes in South Africa requires further investigation.

4.4.3 Stimulated biodegradation in ponds

This disposal option will result in localised atmospheric pollution, caused generally by the evaporation of aromatic hydrocarbons, until the lighter fractions have evaporated. The potential for soil, water and biotic contamination would only occur if the ponds leaked, or were flooded. Spontaneous combustion could present safety risks.

4.4.4 Landfarming

The manner in which landfarming is undertaken will have a direct bearing on associated environmental effects. Large quantities of oily waste will require large areas of land with the risk for possible habitat destruction. It is important that the site for landfarming be carefully selected, to ensure that conservation priorities are heeded. For example, as reported in section 4.3, veld with a low livestock carrying capacity may seem financially suitable to lease for landfarming operations. However, such land, although agriculturally unproductive, may have considerable conservation value (pristine fynbos, for example).

Other potential environmental impacts include contamination of surface or groundwater resources, should seepage or spillage from the site occur. Mitigatory measures such as construction of bund walls and careful site selection (ie where no water resources are threatened) would reduce the effects of these impacts.

Soil erosion due to bad "farming" practices could also occur, but good management of the operation would reduce the likelihood of this occurring.

Evaporation of lighter hydrocarbons would have local effects on air quality and, land usage of the site would be curtailed until such time as degradation of the oil was complete. Land could be returned to its original use once biodegradation is complete, ie after a maximum of three years. Metal accumulation in the soil is not considered a problem where a once-off operation is undertaken and a positive impact of increased humus content of the soil is likely to result.

4.4.5 Codisposal with refuse

Domestic refuse sites themselves have inherent pollution potential, and therefore are usually located so as to minimise groundwater pollution. Surface water diversion practices prevent surface water pollution. However, overloading of oil could result in the potential for additional groundwater contamination if the hydration balance of the landfill is positive. In addition, resultant leachates could contain metal binding organic molecules with the potential to complex certain trace metals (eg cadmium), thereby increasing potential mobilisation of metals within the site to subsurface water resources.

Evaporation of volatile hydrocarbons could result in localised deterioration of air quality but a major impact would be the pressure placed on the existing disposal facility. Local authorities of smaller coastal towns often experience problems with their regular refuse disposal operations, and although they might be able to accommodate small quantities of additional material, the expected lifespan of the disposal site could be reduced. Safety hazards with regard to spontaneous combustion could be enhanced if wastes with high calorific values are disposed in this way.

4.4.6 Direct burial

Direct burial is not a preferred option, due mainly to the potential for groundwater contamination (CONCAWE 1980). However, as mentioned in section 3.3.4, burial in the back beach area has been undertaken successfully in the past. However, the potential for water contamination would be more persistent as rates of biodegradation would be considerably slower than landfarming for example. Destabilisation of vegetated dunes could occur and the possibility exists for oil to be uncovered by exceptional high tides or dune migration. Land use could be restricted for an extended period of time. However, in certain instances, this type of disposal could be acceptable for low grade, weathered oily waste, if sound environmental practices are enforced during the site selection and operating procedures.

4.4.7 Burning and incineration

Direct burning of oily debris has the potential to release pollutants such as particulate matter, sulphur oxides, carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen and, odours. There is a potential safety risk as well. When oil is burnt in situ, it tends to spread and be absorbed into the ground, and a tarry residue may remain since it is rarely possible to achieve complete combustion (ITOPF 1984). In remote areas, burning may be considered for small quantities of oily waste if off-shore winds are blowing, but it is not a preferred option from an environmental point of view.

Incineration converts waste to a less bulky, less toxic or less noxious material (CONCAWE 1990). Incineration should induce as complete combustion as practical and air pollution control devices should minimise the emission of air pollutants. Safety remains a hazard for the operators and pressure on existing facilities could occur due to the lack of commercial incinerators available.

4.4.8 Review of environmental implications

The environmental implications associated with the various disposal techniques of oily waste, mentioned in the literature are documented in the preceding sections. In order to ensure that all aspects of the biophysical and socio-economic environment are considered as objectively as possible, and to compare the different techniques with regard to environmental effects, a matrix approach has been adopted.

The matrix consists of a list of environmental characteristics and a list of activities, plotted at right angles to one another along two edges of a simple ruled grid. According to Fuggle and Rabie (1983) this cross tabulation of environmental characteristics and human actions provides an easy way of focusing thinking on to particular issues and provides a useful means of displaying and summarising a lot of information. In this case, it has also been used to compare the different alternatives for disposing of oily waste.

It is important to note, that the environmental impacts cannot be addressed in terms of local parameters at this stage. The environmental parameters noted in section 4.4, namely:

- biota
- water resources
- soil

- atmospheric quality
- land use
- public health
- safety
- existing services

are used for the matrix.

The disposal of oily waste could possibly effect the **biota** in the vicinity of the disposal operations. Predators could be poisoned by eating oiled birds etc, vegetation may need to be cleared, or subterranean flora and fauna may be destroyed.

Water resources could be affected by hydrocarbon contamination due to seepage into groundwater or run-off into surface water supplies. Complexation of some heavy metals (eg Cd) by organic solvents and leaching into groundwater could also occur during the co-disposal practices.

Contamination of **soil** by hydrocarbons or heavy metals should also be considered, especially with regard to cultivation of crops subsequent to disposal activities. Soil erosion is also a consideration, especially during landfarming operations.

Atmospheric quality can be affected by evaporation of light volatile hydrocarbons or the release of particulate matter and noxious gases during burning.

Existing or future **land use** may be jeopardised in cases where large areas of land are required for certain types of disposal.

Public health could be affected due to water, soil or air pollution, but is omitted from the matrix to avoid duplication.

Although public **safety** is an issue, it is assumed that only the safety of personnel involved in the disposal operations is really at risk, inhalation of oily fumes is known to have carcinogenic effects. Spontaneous combustion of hydrocarbons is a recognised problem, and therefore fire is a major risk. Lime dust during stabilisation operations also poses a health risk.

Certain disposal practices may put pressure on **existing services** such as roads, disposal sites, municipal tips, incinerators, refineries and reprocessing installations.

The matrix has been compiled in such a way that where one activity has a potential moderate or short term negative impact on an environmental element, the appropriate block is coloured yellow. Where there is no anticipated impact the block is coloured green. If the disposal operation is expected to have an unavoidable or significant impact, the relevant block is coloured red. This colour coding system is used in Section 5.3. Where the impact is uncertain or is dependent on the specific operational circumstances, a question mark (?) is used. The completed matrix is given in Figure 4.4.8.

Although a real potential exists for negative environmental impact, and although some of the effects may be longterm, it is important to note that the disposal operation is a once-off occurrence and should not be viewed as a continuing process with the potential build up of environmental problems. It is to be expected that some pressure will be placed on the environment, but appropriate mitigatory measures can often alleviate these effects.

From Table 4.4.8, it is evident that in terms of environmental costs, recovery of oil for re-use is the most desirable method of disposal, followed by stabilisation of oily waste and destructive techniques. However, the legal, financial and logistical constraints also need to be taken into account when selecting the most cost-effective method of disposal. These are addressed in Chapter 5.

Table 4.4.8 Matrix showing negative environmental impacts

	ENVIRONMENTAL ELEMENTS / DISPOSAL OPTIONS	Biota	Water resources	Soil	Atmospheric quality	Land use	Safety	Existing services
RECOVERY	Refinery	None or minimal	None or minimal	None or minimal	None or minimal ?	None or minimal	None or minimal	Potential moderate/short term
	Recycling	None or minimal	None or minimal	None or minimal	None or minimal ?	None or minimal	None or minimal	Unavoidable/significant
	Fuel burning	None or minimal	None or minimal	None or minimal	Potential moderate/short term	None or minimal	None or minimal ?	Unavoidable/significant
STABILISATION	Lime treatment	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term
	Landfilling	?	Potential moderate/short term	Potential moderate/short term	None or minimal	Potential moderate/short term	None or minimal	?
	Civil works	?	Potential moderate/short term	?	None or minimal	None or minimal	None or minimal	Potential moderate/short term
DESTRUCTION	Biodegradation in ponds	?	?	?	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term	None or minimal
	Landfarming	Potential moderate/short term	?	Potential moderate/short term	Potential moderate/short term	Potential moderate/short term	None or minimal	None or minimal
	Codisposal	None or minimal ?	Potential moderate/short term	None or minimal	Potential moderate/short term	None or minimal	Potential moderate/short term	Unavoidable/significant
	Burial	Potential moderate/short term	Unavoidable/significant	Unavoidable/significant	Potential moderate/short term	Unavoidable/significant	?	?
	Burning	?	?	?	Unavoidable/significant	None or minimal	Unavoidable/significant	None or minimal
	Incineration	None or minimal ?	None or minimal	None or minimal	Potential moderate/short term	None or minimal	Potential moderate/short term	Unavoidable/significant

KEY

- None or minimal
- Potential moderate/short term
- Unavoidable/significant
- ? Unknown/depends on operation

4.5 SUMMARY

This chapter has examined the suitability of current oil disposal practices to the South African environment, taking legal constraints, availability of facilities, financial considerations and environmental implications into account. These four factors, together with the types and quantities of oily waste described in Chapter 2 will form the basis upon which the decision regarding the most suitable means of disposing of oily waste following an oil spill at sea will be made. Chapter 5 describes the formulation of the decision strategy.

CHAPTER 5

Formulation of a Decision Strategy

The purpose of the formulation of this decision strategy for the disposal of oily wastes in South Africa, is to aid the decision-maker in selecting the disposal option which has the greatest net benefit to those affected by the operation. In South Africa, it is the responsibility of the appointed government official (ie Head: Pollution Section, Sea Fisheries Research Institute, Department Environment Affairs), to decide on the most suitable disposal system (DEA, 1987). His decision will, however, require consensus among other authorities including insurers, other government departments (Water Affairs, Customs and Excise,) local authorities and conservation bodies. It is important then, that the decision strategy be suitable for use by these sectors.

The objective of this chapter is to present the criteria which affect the selection of disposal options for oily waste in such a way so as to facilitate a comparative analysis of the reasonable alternatives. The method that has been selected to achieve this objective is relative rather than absolute, and although it is designed to aid the bureaucratic decision process, it cannot in itself ensure that correct decisions are taken.

5.1 METHOD FOR COMPARISON OF ALTERNATIVE DISPOSAL OPTIONS

In order to compare the different disposal options for oily waste, factors affecting the disposal of oil following a marine oil spill, as discussed in the preceding chapters have been isolated, namely: legal constraints, quality of oil, quantity of oil, availability of facilities, environmental impacts, financial considerations.

The first factor, ie legal constraints, has been omitted from the analysis as the DEA On-Scene Co-ordinator will ensure complete adherence to relevant statutes and permit requirements. The next three factors affecting the disposal of oily waste, ie quality of oily waste, quantity of spilled mass and availability of facilities are combined on a graph to illustrate the technical feasibility of the different disposal options. The environmental impacts and financial considerations are then superimposed on the technical feasibility study as described in the following sections.

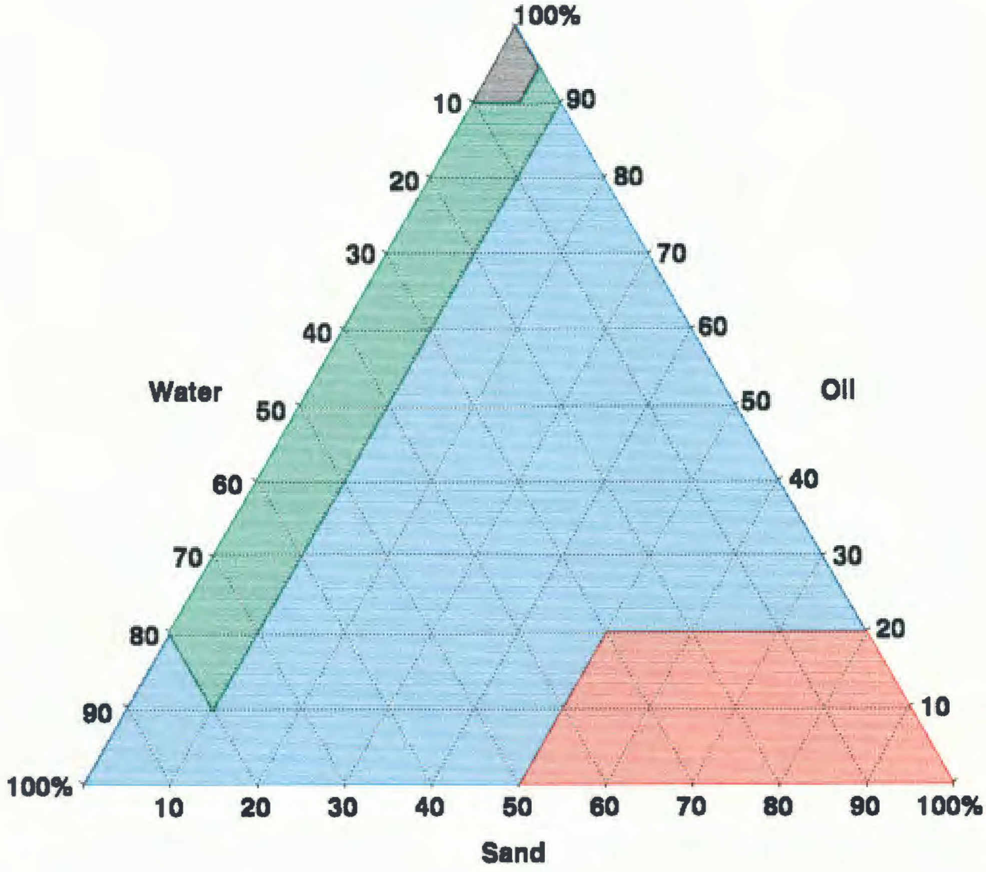
5.2 TECHNICAL FEASIBILITY OF DISPOSAL OPTIONS

The composition and viscosity of the oily waste will have a direct bearing on the type of disposal operation. The types of oily waste were described in Section 2.2 and are plotted on a three-phase diagram according to composition in terms of sand and water (see Fig 5.2.1). This has been done to provide a classification so that the nature of the oily waste can be plotted on a linear scale on following graphs.

As discussed in section 2.3, the amount of oily waste likely to require disposal following an oil spill at sea can vary considerably and will have a direct bearing on the disposal operation. For example, co-disposal with municipal waste will be limited by the availability and size of local landfill sites. However, it is virtually impossible to establish quantities of oily waste with any precision following clean-up operations and often rough estimates are all that are available. It is also evident that quantities of spilled mass which may be handled in one instance may differ considerably in another, depending on the circumstances of the spill, for example its location. It stands to reason then, than the cut-off point in terms of quantities which any disposal option might handle is arbitrary, and therefore broad categories, small, medium and large quantities are all that can really be estimated.

For this study small is taken to be less than 500 tonnes of oily waste, medium between 500 and 10000 tonnes and, anything over 10000 tonnes constitutes a large quantity.

Fig. 5.2.1 Triphase representation of composition of oily waste



KEY

1. Oil contaminated with <10% seawater & <5% sand
2. Oily sludge contaminated with <10% sand, & up to 80% seawater
3. Sandy sludge possibly requiring simple treatment before disposal
4. Lightly oiled sand

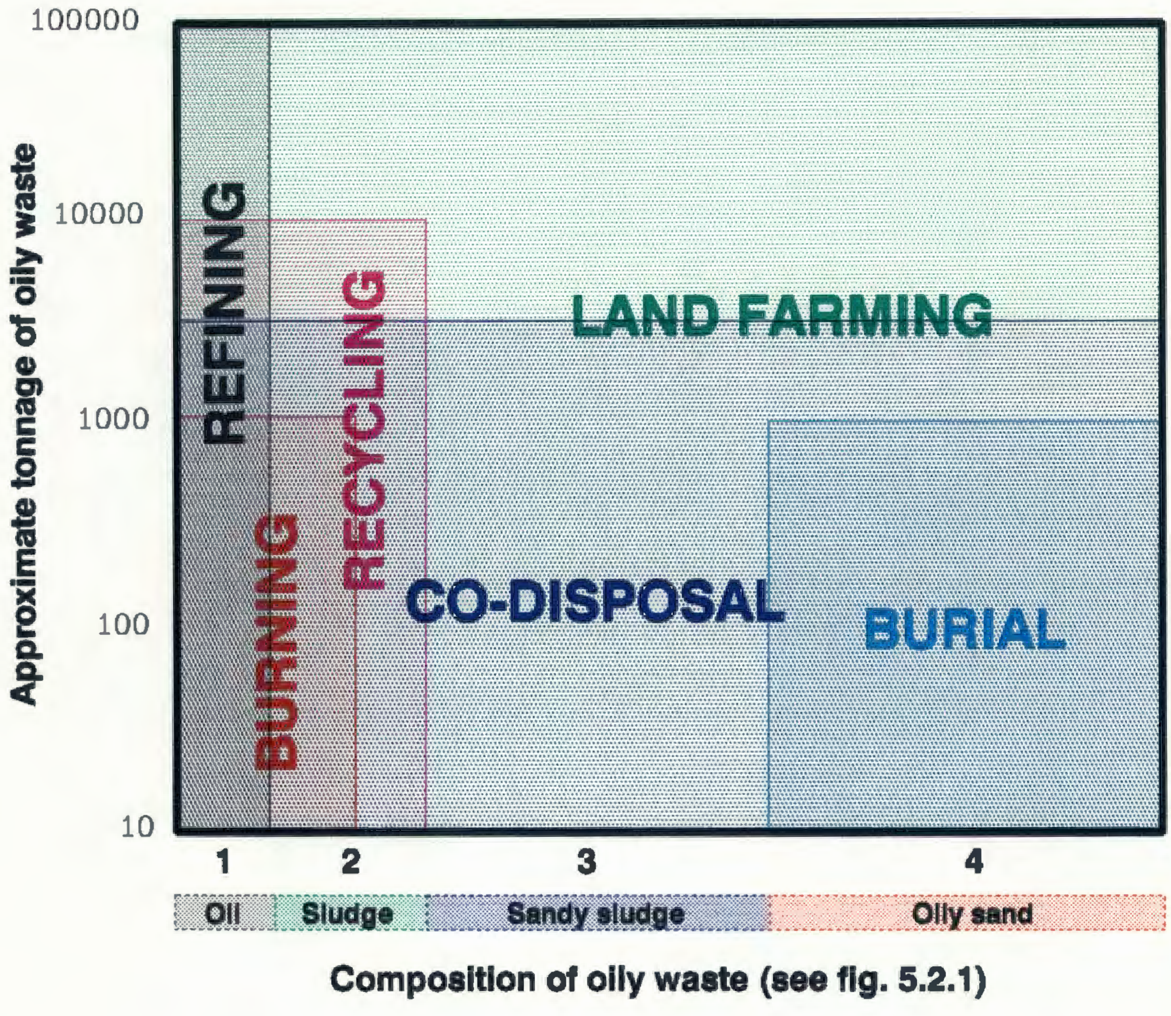
The facilities available for disposing of oily waste in South Africa were discussed in Section 4.2 and the capability of these facilities to handle specific disposal requirements forms a major criterion for the technical feasibility of the different disposal options in South Africa.

The following criteria apply:

- Refineries cannot handle oil which has more than 2% water content, but by blending with uncontaminated crude, a water content of 10% is acceptable (see Section 4.2.1).
- Oil recyclers can process oil which contains up to 80% water and about 10% sand, but quantities in excess of about 10 000 tons would require longterm storage (see Section 4.2.1)
- Oil with a water content in excess of 20% will not burn and special facilities would be required to burn oil containing sand. Facilities are not available for the burning of medium to large quantities (see Section 4.2.3).
- It is possible to dispose of all types of oily waste on municipal landfill sites, but in many cases, only small quantities can be accommodated, and some landfill sites are not equipped to deal with toxic wastes (see Section 4.2.2).
- In general, it is possible to landfarm all types of oily waste and large quantities can be treated in this way (see Section 4.4.2).
- Stabilisation of oily sand with lime for use in civil works or landfills is considered an option, although at this stage it is felt that further investigation is required into the demand for such products and the availability of processing facilities (see Section 4.2.2) Therefore the option is considered together with landfarming as the technical requirements are similar for both processes.
- Although it is technically feasible to bury large quantities of any type of oily waste, the disadvantages (as discussed under environmental implications, Section 4.4.6) are such that even at this stage, only small quantities of lightly contaminated oily sand are considered suitable for burial.

Quantity and quality of oily waste and the availability of facilities have been combined to provide a graphic representation of the technical feasibility of the different disposal operations, as shown in Figure 5.2.2. On this graph, quantities of oily waste are plotted on a log scale on the vertical axis and composition of the oily waste, (as determined from Fig 5.2.1) is plotted on the horizontal scale. It should be noted that this is merely a technical feasibility determination and that financial and environmental aspects are considered in the following sections.

Fig. 5.2.2 Technical feasibility of disposal options



As an example, Figure 5.2.2 illustrates that in terms of technical feasibility only very slightly contaminated oil can be refined (ie the black section of the graph). However, it is possible to landfarm all types and quantities of oily waste (ie the green section of the graph).

5.3 CONSIDERATION OF FINANCIAL AND ENVIRONMENTAL IMPLICATIONS

It is not only technical feasibility which dictates the selection of the most suitable oily waste disposal option. Financial and environmental implications also play an important role in the decision strategy. The costs associated with the different methods of disposal are outlined in Section 4.3 and the environmental implications are discussed in Section 4.4.

In order to consider the technical feasibility of each disposal option with the corresponding financial and environmental implications, each disposal option, represented by a polygon in Figure 5.2.2, is treated individually. This is illustrated in Figures 5.3.1 to 5.3.6. Two identical polygons are produced, the first is shaded in terms of the financial optimum and the second in terms of environmental effects (the latter is determined from the matrix presented in Figure 4.4.8) as follows:

Financial optimum	Environmental effects
● - financially productive	● - environmentally sound
● - reasonable costs incurred	● - potential for moderate detrimental effects
● - financially unacceptable	● - unavoidable significant environmental impacts

The variables on the x and y axes remain quality and quantity of oily waste respectively.

Figure 5.3.1 represents refining and, consultation with refinery managers (1990) revealed that refining oil with a water content in excess of 5% is considered financially unacceptable. It is financially sound to refine oil which contains less than 2% water, and that in between, may be profitable if a certain degree of separation of water from oil or mixing with other oil can be achieved. These assumptions are based on current (1990) costs and prices and may change in the future. In terms of environmental effects, refining of all types and quantities of oil is considered acceptable.

Technical feasibility (from Fig. 5.2.2)

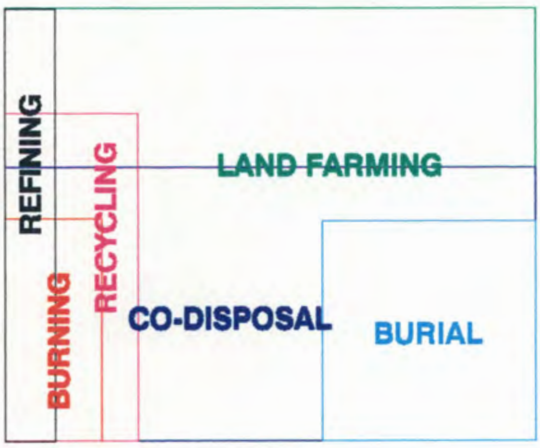


Fig 5.3.1 REFINING

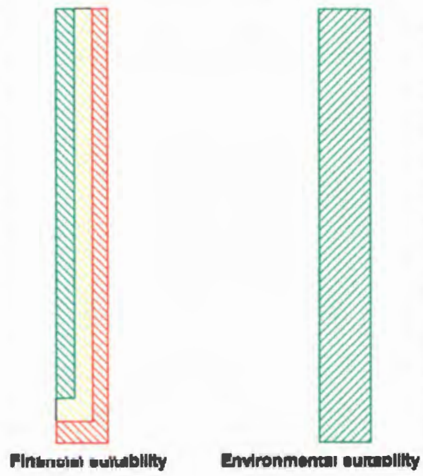


Fig 5.3.2 RECYCLING

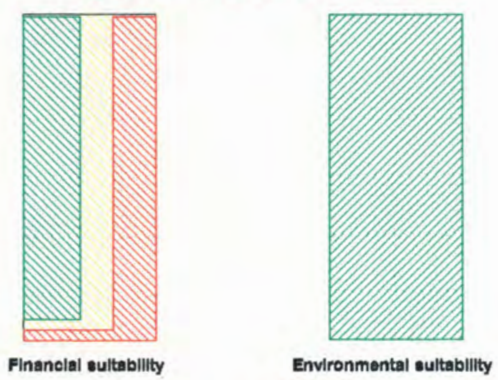


Figure 5.3.2 represents **recycling** and **fuel burning**. As the oil becomes more contaminated with water or sand, the less financially viable becomes the operation. The actual cut-off point is arbitrary and determined by the actual process and circumstances at the time of the spill. However, recycling and fuel burning remain an optimum environmental consideration.

Figure 5.3.3 represents **landfarming** (and stabilisation). In many ways this is a costly operation and it would not seem economically viable to farm small quantities ie less than 500 tons of oily waste. However, conditions prevailing at the time and the location of the spill may influence this assumption. For example, if there are no municipal landfill sites close by, the only alternatives may be to farm or bury small quantities of oily sand. Also, where costs associated with burial and landfarming are coloured equally as yellow, ie a cost is incurred, it should be pointed out that landfarming costs are higher than burial costs, but they are still considered acceptable by insurers (pers. comm. Moldan 1990). The more liquid the oil, the more difficult the operational conditions and hence increased costs. Potential environmental effects include water pollution and utilisation of land, both increasing with increasing quantities of oily waste and the former increasing with decreasing sand content of the oil.

Figure 5.3.4 represents **co-disposal** and, although this is a relatively inexpensive method of disposal for oily waste, it is highly dependent on the capacity of local facilities. The lower the viscosity of the oil and the lower the sand and water content, the greater the potential for contaminated leachate, if the hydration balance of the landfill is positive. The greater the quantities of oily waste that are disposed in this way, the greater will be that potential for pollution and the possible shortening of the lifespan of the refuse site will mean additional pressure on existing services.

Technical feasibility (from Fig. 5.2.2)

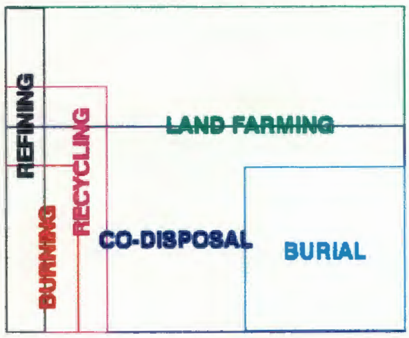


Fig 5.3.3 LAND FARMING

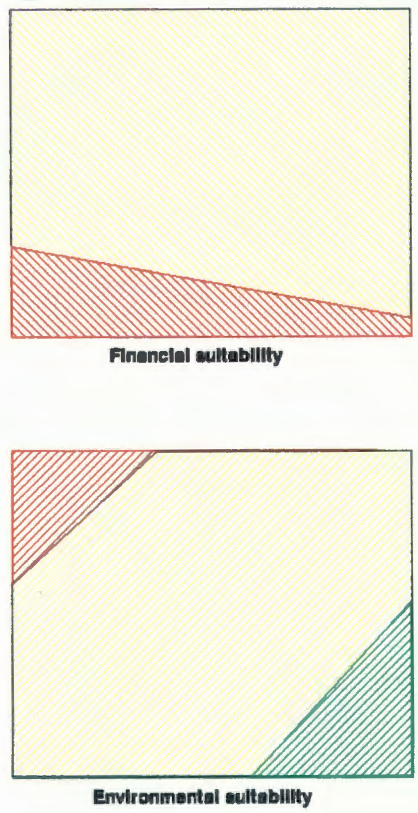


Fig 5.3.4 CO-DISPOSAL

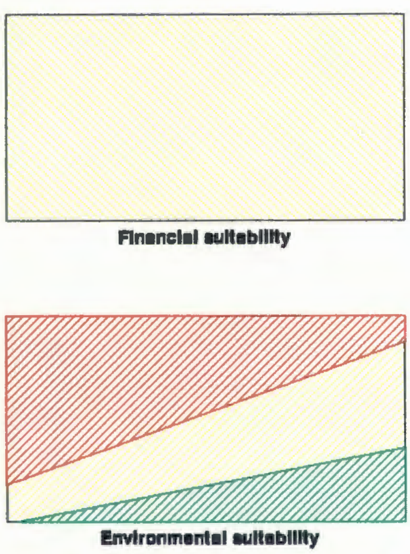


Figure 5.3.5 represents **direct burial**, which is only considered for small quantities of oily sand. Costs are lower than landfarming, but the potential for environmental contamination is more persistent. Obviously, the lower the oil content in the sand and the lower the quantities, the more acceptable the operation, as long as the site is very carefully selected.

Figure 5.3.6 represents **burning or incineration.** It is more costly to burn contaminated or weathered oil, as an added fuel source becomes necessary. In terms of environmental effects, the larger the quantities that are burnt, the greater the potential for atmospheric pollution. There is also a safety hazard for the operators.

Technical feasibility (from Fig. 5.2.2)

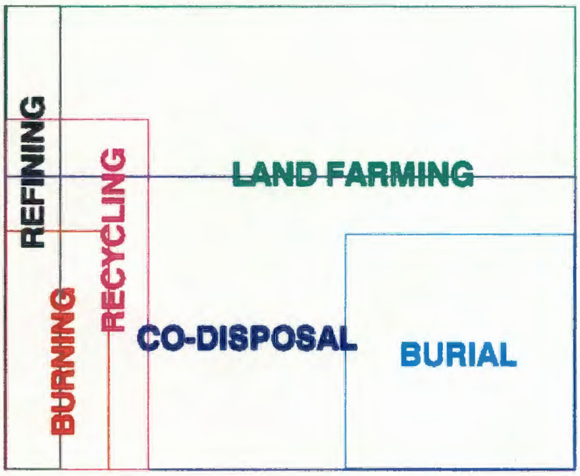


Fig. 5.3.5 BURIAL

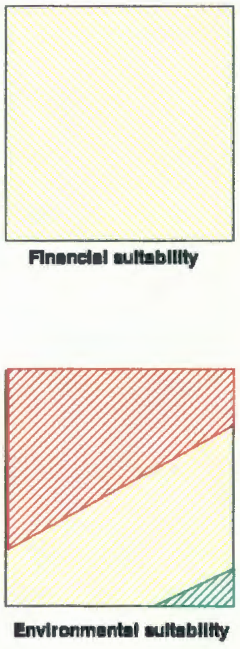
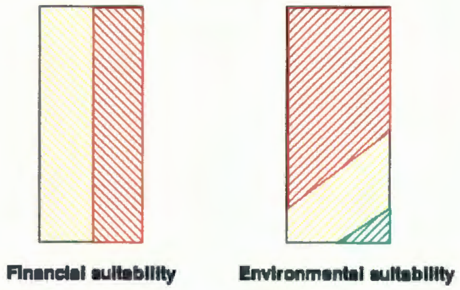


Fig 5.3.6 BURNING



5.4 SYNTHESIS OF FINANCIAL, ENVIRONMENTAL AND TECHNICAL FEASIBILITY

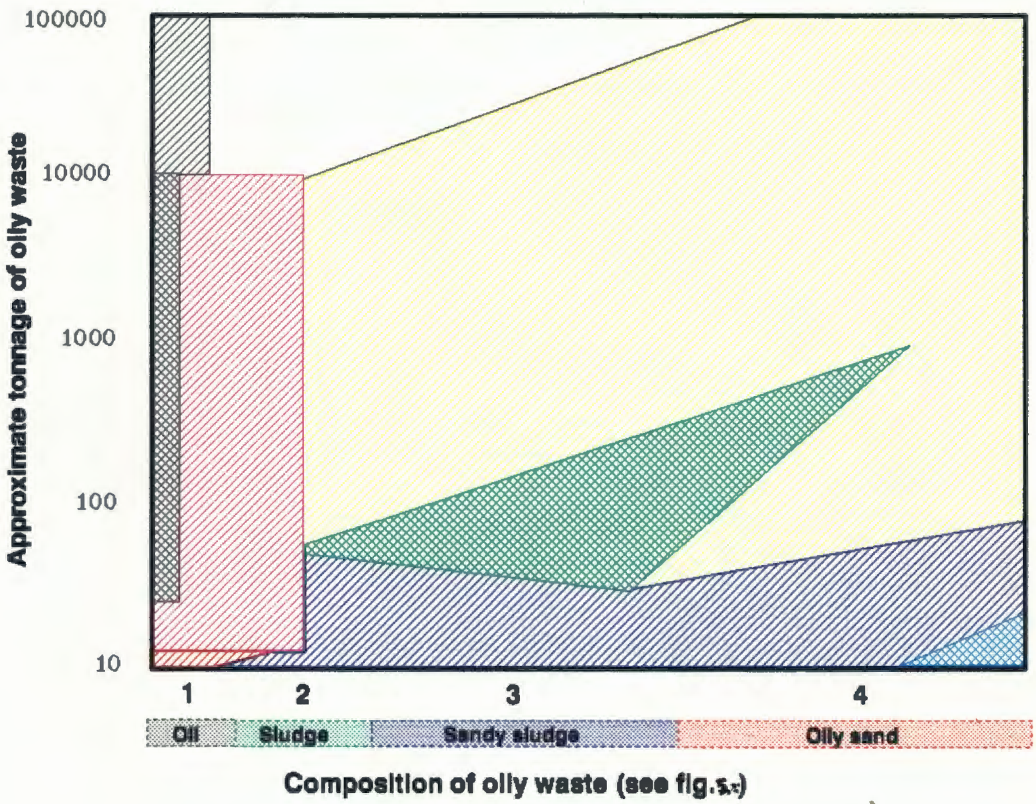
The synthesis of financial, environmental and technical components has been undertaken graphically to provide a composite visual representation, (see Figure 5.4.1). This has been achieved by overlaying the financial and environmental plots on the original technical feasibility diagram. But, the environmentally and financially unacceptable cases (ie the red sections of the graphs) have been omitted completely. In addition, where two disposal options overlay each other, the more environmentally or financially favourable option has been selected. For example, consider 500 tons of oily sludge, where the options are recycling or landfarming. In the particular area of the graph recycling is environmentally sound (green) and financially restrictive (yellow), whilst landfarming is environmentally moderate (yellow) and financially restrictive (yellow), and therefore recycling is selected as the preferred option. It should be pointed out that the assumption of equal importance between financial and environmental costs is inferred. In practice, it is the "$" which usually influences the final decision, but with increased environmental awareness worldwide and, public pressure, it is hoped that due environmental consideration will also motivate the decision.

This final compilation, ie Figure 5.4.1 provides an indication of the most suitable disposal option for a particular type and quantity of oily waste collected after a spill off the South African Coast. It should be used as a general guideline and, at the time of the spill, many other factors may affect the final decision.

Figure 5.4.1 also suggests that under the general conditions assumed in its compilation, burning and burial are not favourable options. Although this is considered true within these terms, specific circumstances at the time of the spill may exclude the implementation of the more favourable options, with burning or burial providing the only realistic and practically achievable means of disposal available.

From Figure 5.4.1, it also becomes evident that there is no easy solution to the disposal of large quantities of oily sludge in South Africa. There is no one disposal option which would be suitable for this type of disposal, but the problem could be resolved by using two or more disposal methods; (for example, recycling, incineration and landfarming). Also, by treating the waste prior to disposal, for example separation of water/sand from the oil using gravity methods, emulsion breaking or solvent extraction, the actual volumes to be disposed of could be reduced, but the costs could be prohibitive.

Fig. 5.4.1 Synthesis of Financial, Environmental, and Technical Disposal Feasibilities



KEY

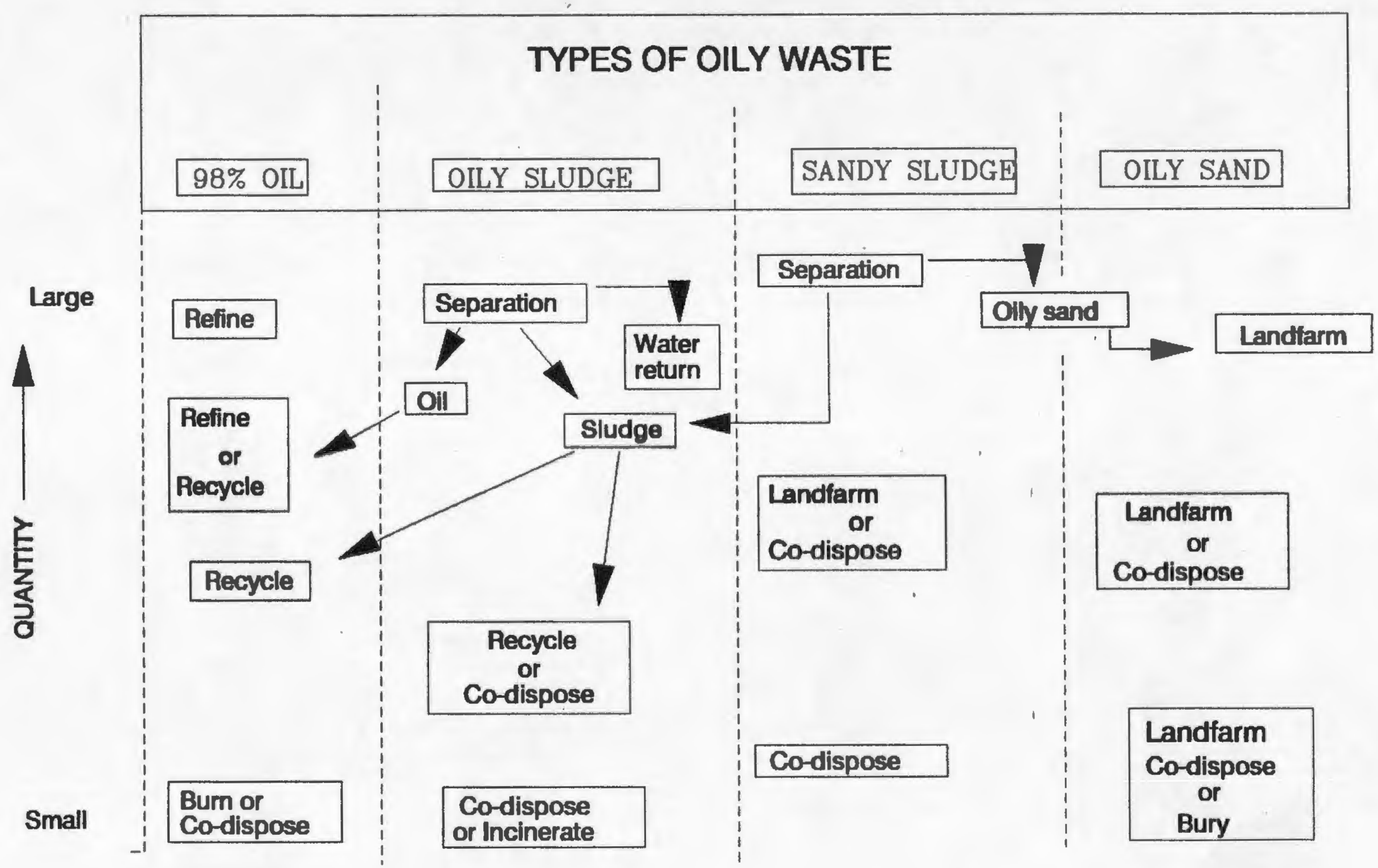
- Refining
- Refining or Recycling
- Recycling
- Burning
- Burial or Co-disposal
- Co-disposal
- Landfarming or Co-disposal
- Landfarming
- Problem area (see section 5.4)

5.5 THE DECISION STRATEGY

Having described the approach to the selection of a disposal option, the final stage is to present the decision maker with a framework within which the decision process can be undertaken. Figure 5.5 presents a decision tree which enables the decision maker to follow the various paths towards finding the correct solution to the disposal problem. Conclusions drawn from Figure 5.5 are as follows:

- Large quantities of unweathered and very slightly contaminated oil transferred from a tanker in distress should be sent to a refinery. Medium quantities of such crude oil or heavy fuel oil should be handled by a refinery or recycling contractor/s. Small quantities can be burned or co-disposed with municipal waste if recycling is unsuitable.
- Large quantities of oily sludge will need to be treated to separate the oil from the water. The recovered oil, if suitable can be sent to a refinery or recycling contractor. Remaining moderate quantities of sludge can be recycled or co-disposed with municipal refuse. Small quantities of oily sludge can be co-disposed or incinerated.
- Separation should also be undertaken for large quantities of sandy sludge. The resultant moderate quantities of oily sludge can be treated as suggested in the preceding paragraph. The remaining large quantities of oily sand can be landfarmed. Moderate quantities of sandy sludge can be landfarmed or co-disposed with municipal refuse. Small quantities of sandy sludge can be co-disposed or landfarmed.
- Large quantities of oily sand should be landfarmed. Moderate quantities can be landfarmed or co-disposed. Small quantities of oily sand can be landfarmed, co-disposed or buried.

Figure 5.5 FLOW DIAGRAM ILLUSTRATING DECISION STRATEGY



CHAPTER 6

CONCLUSIONS

The report identifies the need to plan for the disposal of oily waste following an oil spill off the South African Coast. The aim of the study was to ensure that the disposal of oily waste collected during clean-up operations following an oil spill at sea, is undertaken in the most environmentally acceptable and economically efficient way, by providing a strategy to facilitate the decision making process. This chapter outlines the main conclusions of the study. References to those sections of the study that provide detailed support of the conclusions are given. The conclusions of the study are discussed in accord with the three objectives outlined in section 1.4, followed by a discussion of the decision strategy reached in chapter 5.

The first objective of the study was to **explore the types and quantities of oily waste likely to require disposal following a major oil spill off the South African Coast.** In chapter 2 it was shown that the dominant factors affecting the type and volume of oily waste collected after an oil spill are: amount of oil spilt, type of oil, sea conditions, weather conditions and distance of the incident from the coast. Processes such as spreading, evaporation, natural dispersion, emulsification, oxidation, biodegradation and sedimentation were shown to significantly alter the characteristics and the volume of the oil. The complexity of the interaction of these factors made it difficult predict the types and the quantities of oily waste likely to require disposal following a major oil spill off the South African Coast. This meant that disposal methods capable of handling quantities of oily waste ranging from a few hundred tons to many tens of thousands of tons needed to be investigated in the study. In addition, the disposal methods needed to be able to accommodate various types of oily waste such as, fresh oil transferred from a vessel in distress, oily sludge containing up to 80% water collected during clean-up operations at sea and, oily sand collected during clean-up operations on the beach.

The second objective of the study was **to describe current methods of disposal and the environmental implications of each.** A computer-based literature search, undertaken on recent international developments in disposal techniques for oily waste revealed that, although there were many publications documenting clean-up aspects of marine oil spills, the disposal of the collected oily waste was rarely discussed in any detail. Three broad categories of oily waste disposal techniques, namely recovery for re-use, stabilisation and destructive techniques were identified by CONCAWE (1980), and are described in chapter 3. The recovery techniques, namely refining, recycling and fuel burning were found to be the most environmentally suitable. Destructive techniques such as landfarming, co-disposal with municipal waste, burning and burial were found to have inherent pollution potential, but mitigatory measures and careful site selection would minimise harmful effects.

The third objective of the study was **to assess the disposal techniques in terms of their suitability to South African Conditions.** It was identified in section 4.1 that a number of statutes protecting the bio-physical environment and human health and, controlling foreign expenditure needed to be taken into account when considering options for the disposal of oily waste in South Africa.

The oily waste disposal techniques identified in chapter 3 were reviewed in section 4.2 in terms of the facilities available in South Africa for such disposal. It was found that there are definite limitations regarding the availability of facilities for the disposing of oily waste in South Africa. There are only four refineries and because of their locations, it may be necessary to transport recovered oil large distances. It was recognised that oil recycling contractors could only handle limited quantities of oily waste. In terms of stabilising oily waste with a material such as lime, for use in civil works, it was concluded in section 4.4.2 that more research is required in conjunction with the construction industry in South Africa before this method of treatment and disposal can be considered. Co-disposal was shown to reduce the life of municipal refuse sites, and local authorities of small towns were only able to accept limited quantities of oily waste on their landfill sites. Commercial and industrial incinerators were found to be scarce in South Africa and it was perceived that there was a reluctance to accept oily waste.

In section 4.3, the cost of disposing of oily waste in South Africa was established for each of the disposal techniques. It was shown that transport costs, processing/treatment costs, leasing of land, charges levied by local authorities and fuel for burning make up the bulk of the costs for the disposing of oily waste. Recovery of oil for re-use was verified as the most cost effective method.

Having addressed the above three objectives, it was possible to develop a decision strategy to facilitate the selection of the most suitable option for the disposal of oily waste following an oil spill off the South African Coast. The method is described in section 5.1 and is followed through to section 5.4. The method was developed to provide a comparative analysis of the reasonable alternatives and is relative rather than absolute. A series of colour coded graphs were used to provide a visual representation of the criteria determining the selection of the most suitable disposal option for a particular type and quantity of oily waste. The specific conditions prevailing at the time of a spill, for example the location of the spill, could not be included. For this reason, the arbitrary boundaries on the graphs are admissible. Flexibility about the boundaries was necessary to accommodate case specific conditions at the time of the spill. The final graph i.e. Figure 5.4.1 was used to indicate the most suitable disposal option for a particular type and quantity of oily waste collected after an oil spill off the South African Coast. As suggested in section 5.4, the graph should be used as a general guideline as many other factors will affect the decision at the time of the spill.

The most enlightening conclusion drawn from Figure 5.4.1 was the fact that there was no single disposal method capable of handling large quantities of oily sludge in South Africa. This conclusion was achnowledged by SFRI as a particular area of concern (pers. comm. Moldan, 1990). However, by using two or more disposal methods in parallel or by treating the waste (for example by separation techniques), a solution could be found.

Conclusions from section 5.4 and in particular from Figure 5.4.1 are reported in section 5.5. Specific disposal techniques are suggested for different types and quantities of oily waste following an oil spill off the South African Coast. A decision tree is provided in Figure 5.5 to assist the decision making process.

On reflection, certain limits of the study can be recognised. The first reservation is the implementation of the decision strategy. The Head: Pollution Section of the Sea Fisheries Research Institute is responsible for making recommendations for the most suitable disposal option (see section 4.2), but the insurers or owners are responsible for the costs incurred (see section 4.3). The study assumes equal importance between financial and environmental costs associated with the disposal of oily waste. In practice it is the "$" which usually influences the final decision.

It should also be noted that this study relates to the *status quo* in South Africa and the dynamic socio-political regime of the moment has not been addressed with regard to decision-making in the future.

The study does not include the detailed factors which will affect the selection of the most suitable disposal option for case specific oil spills in South Africa. It is therefore recommended that the study should provide a starting point for the compilation of local disposal plans for each of the 26 coastal zones for which Oil Spill Contingency Plans have been compiled (DEA 1987).

Bearing in mind these limitations, the study does achieve its aim of facilitating the decision making process for selecting the most suitable option for the disposal of oily waste following an oil spill off the South African Coast.

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