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Oil farming for oily wastes

A guide for users

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Summary

The management of oily wastes is complex and requires detailed study and careful consideration of alternatives. Environmental standards for waste management are becoming more stringent and these trends demand that decisions about medium to long-term waste management options need to be made carefully.

The recycling of used oil is considered to be the ultimate aim for managing wastes which are potentially re-usable. This management option should always be fully investigated at every level and at every opportunity.

The land application method of disposal for low-concentration, emulsified oily waste (commonly known as oil farming) is one of many possible management options. In some situations, well-managed land application will be the most economic and environmentally acceptable option. In other situations an approved incineration facility may be preferable.

This paper is not advocating land application as the best oily waste disposal option, but merely to introduce the principle to those who may want to consider it. The information in this paper is not sufficiently detailed to be used as a complete guide to establishing a land application facility. Several excellent texts may be used as handbooks for land application and these are listed in the references at the end of this paper. Environmental consultants also are available in Western Australia for technical assistance. In addition, the land application method has been utilised by industry in Kwinana, and is being adopted by the Shire of Roebourne in the Pilbara region of Western Australia. Monitoring of these facilities will provide valuable information on the technique in contrasting soil types and climates.

1. Introduction

There are many types of oily wastes produced in Western Australia.

A simple definition for oily waste could be "any waste product containing oils and/or greases". This paper is specifically concerned with petroleum-based oils and greases. Other oils and greases (animal fats, vegetable oils) can often be disposed of in a similar manner to petroleum-based wastes, but recycling options are probably more economically viable for animal and vegetable-based waste products.

Petroleum based oils and greases are produced as wastes by industry (oil and gas refineries, power stations, workshops), service stations, car owners (oil changes) and as a result of accidents (release of oil from ships, road tanker etc) or leakages (beneath storage areas, refineries etc).

A number of oily wastes produced on a regular basis in WA have low levels of toxic impurities (eg heavy metal contamination) and may contain varying amounts of water and sediment. Many oily wastes are in the form of an extremely stable emulsion. Others can be easily separated from water by decanting.

Oily wastes which have high oil contents and are not emulsified may be reused as fuel or can be re-refined. Details on recycling used oil of this type are given later in this paper.

Emulsified oily wastes are perhaps the most difficult to treat because of their non-recyclable nature, their large volumes, and the diversity of sources from which they come.

There are now numerous technologies available for treating low-concentration emulsified oily wastes. These include physical treatment (eg surfactant - based separation, solidification, etc), biological treatment (eg activated sludges, land application), chemical treatment (various catalysts and reagents employed to coagulate or crack emulsions) and thermal treatment (incineration, pyrolysis).

Perhaps the most universally accepted, low-cost option for disposal of low-concentration emulsified oily wastes.is land application, a biological treatment process which utilizes natural micro-flora (bacteria, fungi, yeasts) to break down hydrocarbons into organic matter, carbon dioxide and water.

The land application treatment process will be discussed in detail here in preference to other treatments because of its suitability for use in many situations, its relatively low cost, its simplicity and its ability to be integrated with local authority waste management programmes. However, the land application method should not be used for disposal of re-usable oil or wastes from which oil can be easily separated.

It is likely that in some circumstances, other methods for treatment of oily wastes might be preferable to land treatment because of cost or for environmental reasons. It is therefore essential that any decision made on the type of waste treatment to be adopted must be preceded by a well-researched assessment of the environmental and economic costs and benefits of all practicable treatment systems. Factors affecting the decision-making process include:

- Waste composition (particularly the levels of toxic components such as PCBs, heavy metals).
- Availability of land with compatible surrounding land use.
- Soil, rainfall characteristics and hydrogeology.
- Special environmental considerations (eg groundwater and surface water catchments for human consumption or for stock, rare or endangered flora and fauna, scenic values, etc).
- Cost of site establishment, transport of wastes, operation of facility and rehabilitation.
- Possible "in-plant" modifications which might be introduced to reduce the waste volume and/or concentration.

Although some work has been done on the biodegradation of highly toxic "intractable" wastes such as polychlorinated biphenyls (PCBs) which may be found in some oily wastes, this paper will not discuss the subject in detail due to the specialised nature of hazardous waste management.

2. Recyclable oily wastes

Most oils from engine sumps and other used lubricants can be recycled (ie. re-refined or used as fuel). Oils extracted from corrugated plate interceptor units in industry are recycled. In some areas of Western Australia these used products are being sold to used oil buyers who purify the used product so that it can be re-sold, mainly as fuel. For quantities greater than 220 litres, used oil buyers are currently paying about 20 cents per litre as well as around $6 per 220 re-usable drum . The value of the used oil and the drums combined makes this method of disposal very attractive economically and environmentally.

Buyers of used oil are generally restricted to the Perth-Bunbury region and this means that transportation costs from other regions will reduce the profits made and hence the incentive to utilize this option. However, backloading rates (ie transportation of products to Perth from country centres where trucks would otherwise be returning empty) for bulk volumes of used oil are such that at present prices, the price paid for used oil and drums is usually (depending on quality of used oil) slightly more than the cost of transporting it to buyers up to 1,500km from the waste producer. In fact, this is precisely the situation in the Pilbara region where larger mining companies and one local authority (Shire of Roebourne) utilize this option. In regions more than 1,500km from Perth, the sale of used oil may still be economical if large waste oil producers are able to negotiate cheap back-loading rates, or if alternative opportunities are utilized (eg sale of used oil to ships as bunker fuel, transport of bulk volumes of used oil by ship to oil refineries in the south west, sale of oil to local oil-fired power stations). Where the sale of recyclable waste oils is not practicable, (eg where quantities are low and source is remote) oil may be used as a dust suppressant by spraying a thin film onto heavy traffic work areas (eg in light industrial areas and around mine-site workshops) to suppress dust. This option must be exercised with care to avoid excessive use of oil or accidental spillage especially in environmentally sensitive locations (eg near wetlands, water resources). Oil spraying should cease whenever rain is likely.

3. Land application of non-recyclable oily wastes

"Land application" is one term used to describe a biological treatment method which utilizes naturally occurring soil microbes to biodegrade oils contained in liquid wastes. Other common terms for land application include "land farming", "oil farming", "sludge farming" and "land treatment".

This technique has been used in the United States, Canada, Europe and many other countries for more than twenty years. In many different climates, soil types and situations, the technique has proved itself to be efficient, environmentally sound and economical. (1,2,3,4) The method has recently been adopted by the Shire of Roebourne near Karratha, Western Australia (see Figure 1).

3.1 Soil biology of land application technique

In undisturbed soils, the number of micro-organisms per gram of soil may be between 4 million and 520 million with bacteria accounting for 3 to 500 million (5).

When aerated, treated with oily waste, water, and if necessary, fertilizers, micro-organisms can multiply up to 10 times their original number (6).

Twenty eight genera of bacteria, 30 genera of filamentous fungi and 12 genera of yeast representing a total of more than 100 species of soil micro-organisms have been identified as biodegraders of hydrocarbons in the soil (7). Some of these species (eg species of the genera *Pseudomonas*) are so well known that they are marketed and sold as "oil-eating bugs' for use by industry.

The essential soil micro-organisms for biodegradation of oils are found in almost any soil. The factors affecting their abundance (and hence ability to degrade oil) are as follows:

- Aeration - aerobic digestion of hydrocarbons is the major means of biodegradation. Hydrocarbons degrade to carbon dioxide and water via intermediate organic acids, ketones, aldehydes, alcohols and other hydrocarbon derivatives. Effective aeration is achieved by cultivating the soil (with

Figure 1: Karratha land application site. Oil contaminated water is applied here using the vehicle's own boom-spray. This method has since been modified by using an offset boom-spray towed behind the vehicle to avoid splash-back and bogging. The bund walls and fencing prevent unlawful dumping and aid in flood control.

ploughs or rippers and rotary hoes depending on soil types) in the same way as with intensive agriculture though very regularly (say every 2-4 weeks depending on soil types, climate). The mixing that occurs during aeration is also valuable as it exposes fresh surfaces through shearing.

- Temperature - microbiological degradation can take place at temperatures between -2°C and 70°C, but the optimum temperature range is 20°C to 35°C. At temperatures above 37°C in the soil, volatile fractions of oils may increase to lethal levels for biological activity [7]. Biodegradation occurs in the top 20cm of the soil profile. Temperatures below the top 5cm would normally be expected to be below the critical 37°C level except for periods in the height of summer (January, February, March). Temperatures may be moderated by maintaining soil moisture.
- Water - the water content of soil must be such that it is constantly available to microbes, but at a level where it does not impede aeration. The optimum levels of moisture are said to be less than 20% of the weight of the soil [7].
- pH - a soil pH near neutrality is considered adequate, but a tendency for the biodegradation process to make the soil more acid has led some researchers to favour slightly alkaline soils.
- Salinity - optimal salt levels for most terrestrial species of microbes are below concentrations with electrical conductivities of **4 mmhos/c m** at 25°C [7]. However, performance at much higher levels is not well known.
- Nutrients - the levels of nitrogen and phosphorus in most Western Australian soils are low to very low. Nitrogen seems to be the limiting factor in most circumstances, and in particular, the Carbon:Nitrogen ratio is considered very important in optimising biodegradation. The C:N ratio of the soil and the waste should be established early. Optimal C:N ratios are between 20:1 and 25:1 with levels lower than 23:1 being preferred. Other nutrients (P,K), and trace elements are also important for maximizing biodegradation. Generally, attainment of nutrient levels suitable for agricultural crops would be equally beneficial to land application of oily wastes. Improvement of soil nutrient status for land application is therefore the same as that for agricultural application of fertilizers [3, 9].

3.2 Limitations

Factors affecting the success of land application are principally associated with the composition of the waste and the nature of the land application site.

Excessive levels of heavy metals, salt or toxic contaminants in the waste will inhibit biodegradation.

Shallow groundwater tables, especially under well drained soils (eg sandy soils) will increase the risk of undesired off-site export of hydrocarbons as will impervious soils on slopes in times of flood. However, management techniques can be employed to minimise the effects of these limitations. For example, sandy soils can be treated by addition of organic matter or by creating an impervious layer (ie a plastic liner or clay with a permeability rating less than 10^{-7} cm/sec) above the level of the water table. Sites likely to experience high run-off can be treated with diversion drains around the land application site, contour banks and collector pits at the lowest point(s).

4. Establishment of land application facility

As stated in the introduction, no waste treatment process should be adopted without a reasonably thorough investigation of other options. Longer term needs should also be taken into account to avoid the potential for over-capitalisation on processes which are only environmentally acceptable and/or efficient in the short term.

4.1 Preliminary investigations

The first step in the information gathering process is to establish the following facts about the waste:

- Average oil content.
- Average and maximum levels of heavy metals, cyanide, sulphides, salts phenols, benzene, toluene, xylene and other toxins which are likely to affect the efficiency or "environmental performance" of any land application process.
- Total waste volumes.and waste generation rate, on a daily, weekly and monthly basis.
- Water content.
- Solids content (affects the way in which waste can be applied to land).

The above information is required regardless of what type of treatment process is selected. If it is decided to use the land application method, the second stage is to select a suitable land application site. Where possible, several sites should be assessed initially to determine the most suitable.

The assessment process should be almost identical to that for selection of sites for a landfill operation (ie maximise accessibility to site, minimise environmental risks, put into context of town planning etc). In addition the following factors require particular consideration:

- Soil type - Well aerated, well structured soils are best, but management can alleviate specific difficulties. Organic matter content and hydraulic conductivity are important factors affecting soil suitability.
- Slope of land (very gentle grades of 1% or less are ideal). - Completely flat land will have the potential to pond water while steeper slopes will require extra management for run-off.
- Groundwater - Shallow groundwater will be more readily contaminated than deeper groundwater. Monitoring of hydrocarbon movement through the soil profile will need to be more strictly controlled for shallow potable groundwater than for non-potable, deeper groundwater resources.
- Surface run-off - The design of the site should cater for contingencies such as extreme flood events. Drains to divert flows away from the upslope side of the facility will reduce run-on. Bunding and downslope interceptor drains will also assist. Clay soils will be more susceptible to surface flows than sandy soils.

4.2 Pre-commissioning sampling

The following sampling programme should be undertaken prior to commencing any land application of oily wastes to establish baselines for the monitoring programme:

- Nutrient status, heavy metal content, hydrocarbon levels and salinity of soil to a depth of 30cm (a minimum of three samples are required).
- Establish depth to groundwater, quality of groundwater and seasonal variation in water table. Also sample groundwater for hydrocarbons, heavy metals.
- Sample soil profile to water table (and below, if water table is less than a few metres) to establish relative permeability of soil horizons (relatively impermeable layers may act as a barrier to groundwater recharge and/or as a means of hydrocarbon transport laterally through the soil).

4.3 Site preparation

The site should be surveyed and contours mapped so that surface flows can be managed by appropriate design. Application of oily waste can be achieved by various methods from reticulation in sophisticated systems to boom sprays from the rear of trucks in simpler operations. If trucks are used, long strips of land are easiest for application to minimise turning. Fencing and/or bunding of the site should be used to prevent illegal dumping of waste. A conceptual layout of a typical landfarm is indicated in Figure 2.

Topsoil should not be removed from the site. It should remain in situ with any grasses and herbs to be turned in by cultivation immediately prior to, or following the first application of waste.Cut-off drains, interceptor drains and bunds should be over-designed so that they can be top-soiled and re-vegetated. This will ensure that the site-works are stabilised against soil erosion and are not visually intrusive.

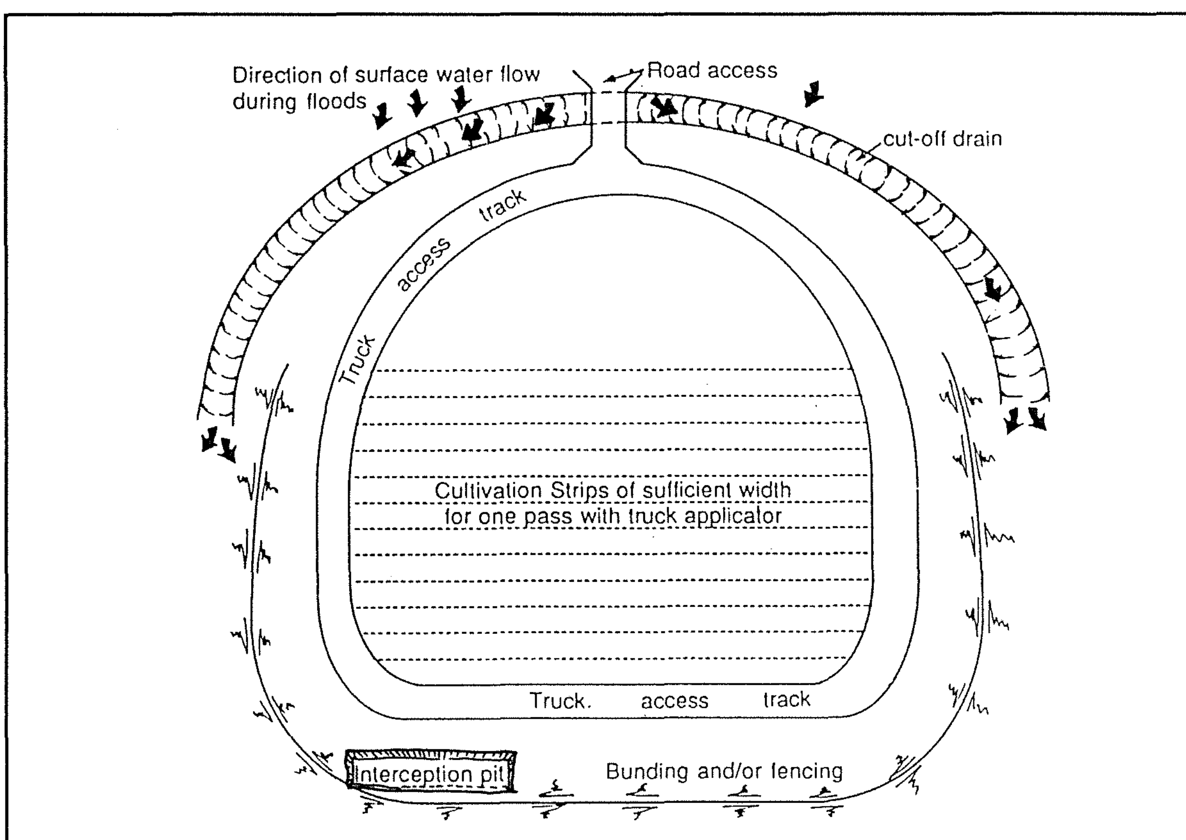

Figure 2: Conceptual layout for a land application facility

4.4 Waste application

The rate of oil degradation will be largely dependent on the suitability of the soil and climatic conditions. Application of fertilizers can increase biodegradation rates. Studies in the United States, Canada and Europe suggest that up to 400 tonnes of oil per year can be biodegraded on one hectare of land. (2,8) The optimum application rate and frequency of waste application for each site can be determined only by trial and error, by detailed pilot studies, or by using available models. It is recommended that where possible, a pilot project with trial plots be established before full-scale land application, particularly for large operations. The on-going savings in running an efficient operation will quickly pay for a pilot project. If necessary waste managers should consider hiring consultants to design a trial and assist with establishing a full scale facility.

Generally, waste application is carried out at consistent rates to ensure adequate supply of carbon to the soil microbes at all times. Dramatic changes in oil application rates may cause fluctuations in microbe populations.

Suggested optimal concentrations of oil per unit weight of soil immediately after each application are around 3% with re-application of sludge after the residual oil content drops below 1% (T Bulman, personal comment). Optimal frequency of application will depend on how long it takes for the oil content to drop to 1%. This would normally take around one month, but will vary depending on soils, climate and management.

Application of oily waste should be followed by regular harrowing/ploughing (perhaps fortnightly) to ensure adequate aeration and mixing of the top 15-20cm of soil. Optimum moisture content of the soil is said to be around 15-20% by weight, (8), but this would depend on soil type. More regular cultivation may increase degradation rates. This would be an advantage if land area is limited. Trials would assist in this determination.

Nitrogen and phosphorus levels also need to be maintained to maximise degradation of hydrocarbons and this could be periodically applied in the form of fertiliser. Giddens (10) proposes the application of ammonium nitrate at the rate of around 150kg/ha. Lewis (2) suggests nitrates and phosphates should be applied at rates of 20-30mg per kilogram of soil two or three times per year. This roughly equates to around 80-120kg/ha per annum

The life of a land application facility will depend on the extent to which components of the oily waste build up in the soil. Generally, land application sites, if managed conservatively could be utilised for many years. However, specialist advice should be sought on the expected rate of build-up over time of heavy metals and other potentially toxic waste components.

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