OIL POLLUTION ABATEMENT

by
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ABSTRACT

To minimize the posibilities of oil pollution, preventive as well as represive action should be considered and eventually carried out simultaneously.
Preventive measures are considered in this case for offshore operations. Several repressive methods as well as clean up methods for oil-on-the waters are reviewed.
Parameters partinent to the location of the spill related to the methods to be applied should be seriously considered.

I. INTRODUCTION

The potential dangers and possible harmful effects of oil pollution necessitate action should be taken simultaneously along two lines:

- preventive action to minimize incidental pollution.
- repressive action in case of occurrence of oil pollution.

The basis for selecting methods of action should include the following types of information in order to protect aquatic species, especially those types important from the economic and environmental points of view:

- the role of the marine environment in the national economy vis a vis its geographical position.
- the potential transnational character of marine pollution in South East Asia.
- locations of sensitive environments such as mangrove communities, coral reefs, estuaries, areas of upwelling, aquaculture.
- the species which are expected to be present in the affected or probably affected areas, together with details of the abundance of these species and their biological cycles.
- the effects of the types of oil spilled and their control methods on these organisms and their environment.
- hydrographical data
- in drafting local and regional contingency plans for purposes of storing important equipment, an assessment should be made of probable impact areas.

II. PREVENTIVE MEASURES

A. Offshore Platforms

Several complementary safety-protection and pollution-control system are utilized offshore. Surface and subsurface safety valves are installed in each well, designed to provide redundant basic protection by automatically shutting off wellflow if an abnormal condition develops (fig. 1).

Oll leaks are collected through deck curbs, gutters and dripping pans into a sump.

B. Tankers

Accidental oil spill resulting from the operation of tankers, barges and terminals are to be divided into two major catagories. :

- spills resulting from collision and groundings. Many endeavors are being made to safeguard busy waterways such as two straits of malacca and to design new traffic schemes which will minimise the possibility of such spills occurring.

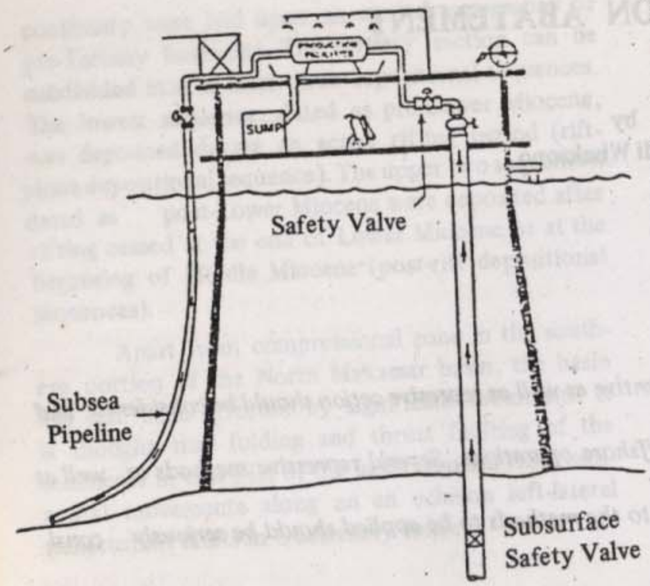

Figure 1 : Safety and Pollution Control Systems Offshore Production Platform.

Source : Warner 1973

— spills from tanker discharges and transfer operations.

Dirty water ballast problems can be avoided by introducing reggregated ballast tanks in tankers, discharge of dirty ballast water can be minimized by using the Load-on-Top method. To separate oil from water in dirty ballast water, onshore sloptanks should be used, as well as oil-water separators on board tankers themselves. In this way it should be possible to cope with the problem of permitted dicharge of 60 1./mile sailing.

C. *Effluent Standards*

In order not to overload the aquatic environment and surpase environmental criteria, continuous discharges are standardised. Their pollutant concentrations are not allowed to surpase a certain limit.

Tanker discharges are maximised at 601/mile for a moving ship. Platform discharges are berween 30–90 ppm.

Refinery discharges are not the same for inland and coastal refineries, standards for inland refineries are usually more stringent. These standards are related to the technological capability of process and equipment and to other factors.

Progress in technology, combined with efficient training and education programs in environmental protection for operators, foremen and managers, guarantees the success of these pollution prevention measures.

III. REPRESSIVE ACTION TOWARD OIL-ON-THE-WATER

Abatement of accidental spills can be carried out in three phases :

— curtailment of the spill,
— containment of the spill,
— clean up of the spill.

A. *Curtailment*

The main purpose is to stop at the source or at least to minimize a further outflow of the oil into the marine environment. It is advisable that, during and offshore well blowout and the subsequent fire, the fire should be allowed to consume the outflowing oil, while relief wells are being drilled.

Outflowing oil from a grounded tanker should be contained, while the remaining oil in the tanker should be transferred to another tanker, as was the case with the grounded tanker "Showa Maru".

B. *Containment*

The main purpose is to contain the further spreading of the oil over the water surface. Neither conventional anchored nor towed booms can contain 100% spilled oil in the wind and wave conditions normally encountered in the open sea and with relative currents above one knot.

1. Floating Booms

These booms extend downward into the water (skirt) and upward into the air (freeboard) to keep the oil from flowing under and slopping over.

Typical booms have a flotation chamber filled with air, foam or some other flotation material. A skirt is fitted so as to keep the boom upright and so that it can act as a barrie between wave troughs.

The boom is fitted with sturdy oil-light joints for joining sections. There are at present more that 80 different oil spill containment devices being marketed, primarily for use in harbors, bays, near-shore and ocean waters.

In the past few years several improvements have been incorporated in booms, such as :

- increase of boom freeboard to prevent oil splash over in rougher weather,
- flexibility to permit the boom to follow the water surface profile more closely.

Several booms are able to operate in open seas, such as the Exxon bottom tension boom (fig. 2) which is able to contain oil in seas with waves 5 ft high and with 1–2 knot currents. Another comparable boom is used by the US Coast Guard in their High Seas Oil Containment Air-transportable System. This boom has the strength to withstand 10 ft waves, 40 knot winds and 2–3 knot currents (Dennis, 1975).

In practice it has been frequently observed that at relative boom-water velocities exceeding two knots the present available oil containment systems are ineffective. These conventional devices are generally current-velocity limited.

In recent years, however, several promising new concepts are being developed with changes in the basic boom design. Tank tests with these High Current booms (Shell, Texas A & M Univ. etc) show that oil cantainment is succesful with currents up to three knots.

2. Air-Curtain

The air-curtain concept for containing small oilspills-for instance in a harbor during the loading or offloading of a tanker use a pipe located below the water surface with numerous small holes spaced

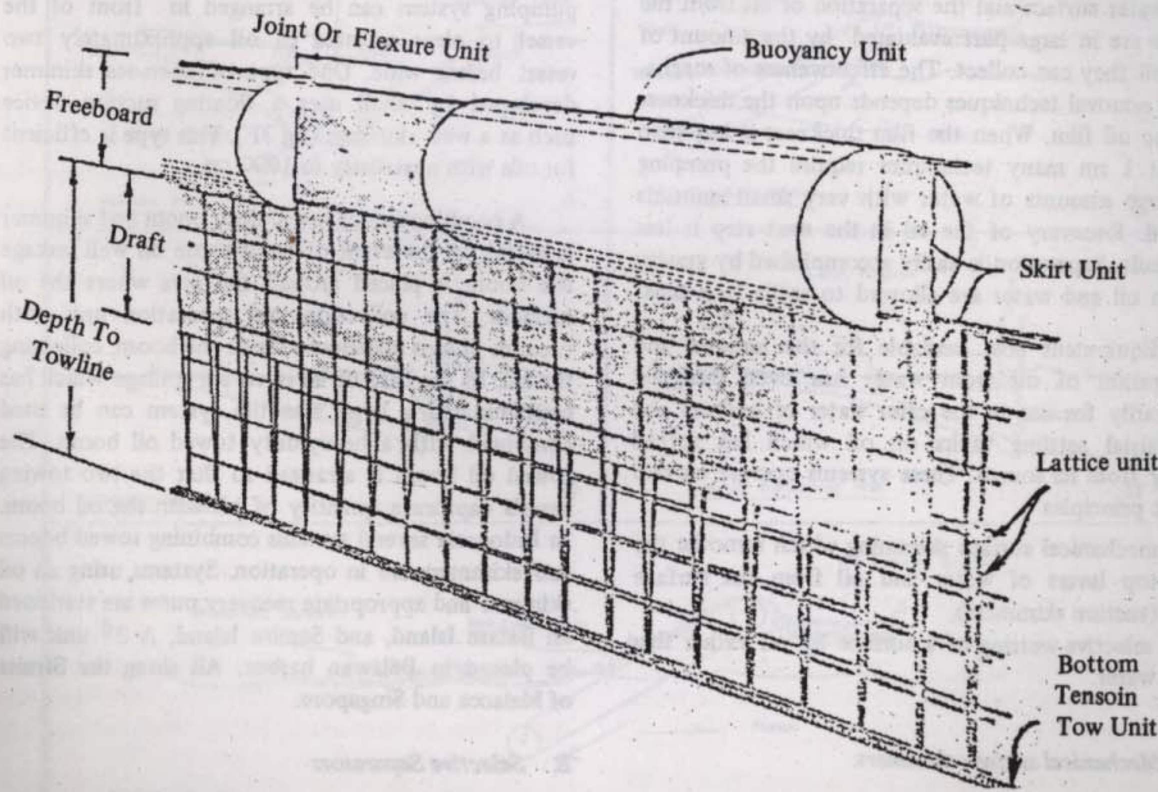

Figure 2 : Schematic of the Exxon Company U.S.A. "Bottom Tensoin" Boom

Source : Glaeter 1973.

along its axis through which air is pumped. The rising air bubles from these holes create an upward flow of water by mementum transfer. This upward flow generates a flow gradient on the water surface which retards the spreading oil.

An air-curtain capable of withstanding a current of 1 knot will require approximately 1 horsepower of air compressor power for every 3 feet of air-curtain length.

Air-curtains which are permanently installed under the water surface but are only intermittently operated appear to be particularly suitable for protecting entrances to harbors and marinas near oil habors or terminals.

IV. CLEAN – UP

Techniques for mechanical removal of oil from the water surface and the separation of oil from the water are in large part evaluated by the amount of the oil they can collect. The effectiveness of mechanical removal techniques depends upon the thickness of the oil film. When the film thickness is less than about 1 rm many techniques require the pumping of large amounts of water with very small amounts of oil. Recovery of the oil in the next step is less difficult. Separation is easily accomplished by gravity when oil and water are allowed to settle in a tank.

Equipment now available for the removal and separation of oil from water has been designed primarily for use in the calm water of harbors and industrial settling tanks on oil which has spread away from its source. These systems operate on two basic principles :

- mechanical surface skimming which removes the top lavers of water and oil from the surface (suction skimmers),
- selective wetting of a surface by oil rather than water.

A. Mechanical surface skimmers

The mechanical surface skimmers usually are self-propelled special-duty barges, or catamarans which are capable of separating a small amount of oil from a large amount of water. The top lavers of oil and water from the water surface are removed by suction pumps, overflow dams, or scoops, and the oil is then separated from the water by gravitational action.

These units have been designed initially for use in the calm water of harbors. Recently, however, floating open-sea skimmers have been reported to work well in waves up to 6 ft. (fig. 3, B, D, F, H). To be succesful it is necessary firstly to concentrate the oil on the surface through the use of towed booms which sweep a large area, and then to use systems in which the oil inlet responds rapidly to changes on the surface and conforms to the shape of the wave field or is insensitive to changes in water level. High capacity pums can remove the oil and water from the floating suction heads and discharge it into the first of several settling tanks on a small coastal tanker. Multiple floating suction heads with floating suction lines attached to the pumping system can be arranged in front of the vessel to clear an area of oil approximately two vessel beams wide. One type of open-sea skimmer developed by Shell uses a floating suction device such as a weir skimmer (fig 3F). This type is efficient for oils with a viscosity to 1000 cp.

A combination of heavy-duty boom and skimmer is useful. In the event of an offshore oil well leakage the boom is placed around the area where the oil surfaces. The collection and separation unit with vacuum pumps maneuvers inside the boom, collecting the oil. In the case of an open sea spillage which has contaminated a large area the system can be used combined with a heavy-duty towed oil boom. The towed oil boom is arranged so that the two towing vessels capture a quantity of oil with the oil boom. In Indonesia several systems combining towed booms and skimmers are in operation. Systems using an oil skimmer and appropriate recovery pums are stationed an Batam Island, and Sambu Island. A 3[d] unit will be placed in Belawan harbor. All along the Straits of Malacca and Singapore.

B. Selective Saparators

In selective separators a hydrophobic, oleophilic polymeric material, such as polypropylene or polyurethane, is brought into contact with the oil

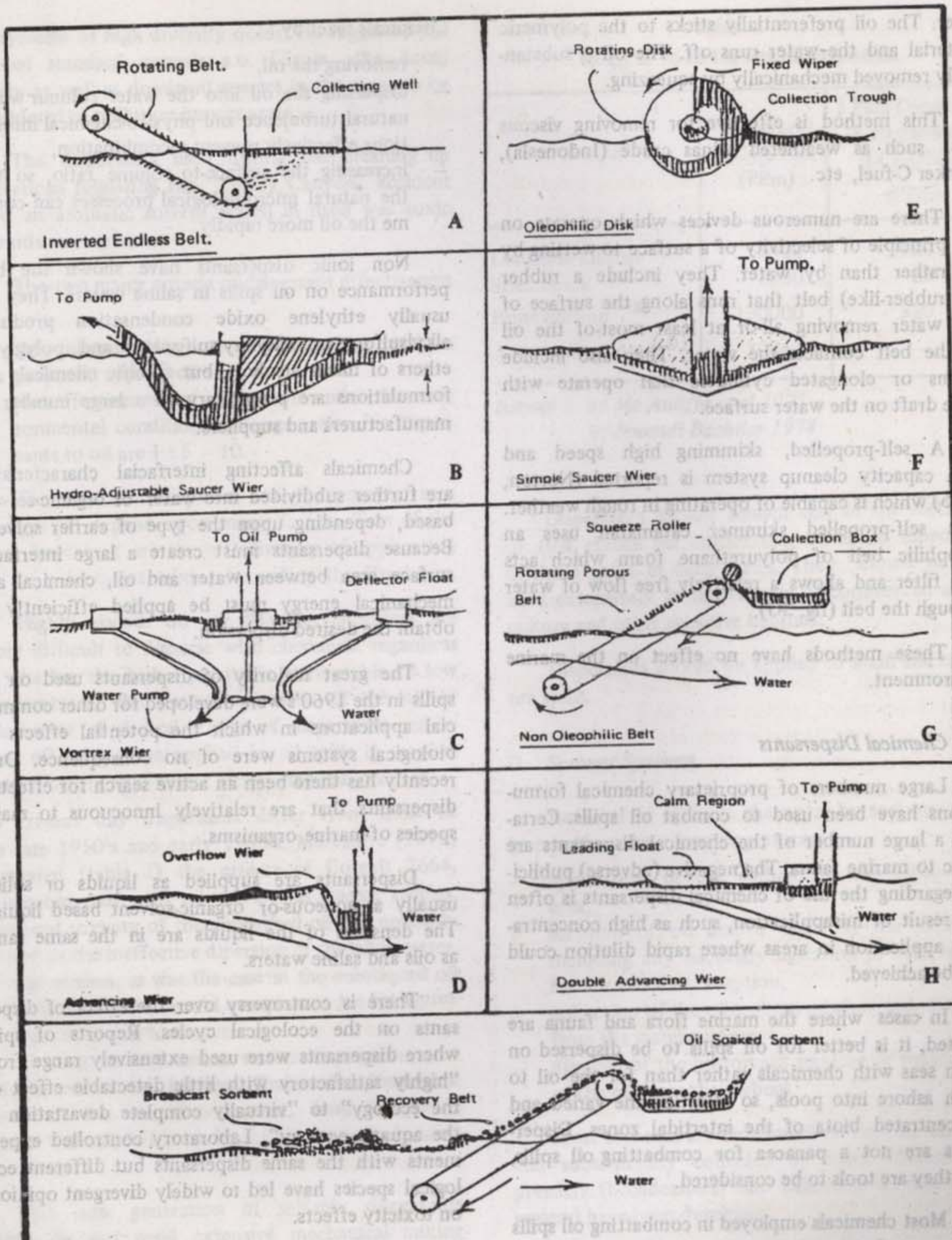

Figure 3 : Types of Cleaning Devices

layer. The oil preferentially sticks to the polymeric material and the water runs off. The oil is substantially removed mechanically by squeezing.

This method is effective for removing viscous oils, such as weathered Minas crude (Indonesia), Bunker C-fuel, etc.

There are numerous devices which operate on the principle of selectivity of a surface to wetting by oil rather than by water. They include a rubber (or rubber-like) belt that runs along the surface of the water removing all-or at least most-of the oil as the belt contacts the water. They also include drums or elongated cylinders that operate with little draft on the water surface.

A self-propelled, skimming high speed and high capacity cleanup system is reported (Norton, 1975) which is capable of operating in rough weather. This self-propelled skimmer catamaran uses an oleophilic belt of polyurethane foam which acts as a filter and allows a relatively free flow of water through the belt (fig. 3G).

These methods have no effect on the marine environment.

C. *Chemical Dispersants*

Large numbers of proprietary chemical formulations have been used to combat oil spills. Certainly a large number of the chemical dispersants are toxic to marine fauna. The negative (adverse) publicity regarding the use of chemical dispersants is often the result of misapplication, such as high concentration application in areas where rapid dilution could not be achieved.

In cases where the marine flora and fauna are limited, it is better for oil spills to be dispersed on open seas with chemicals rather than for the oil to wash ashore into pools, so affecting the varied and concentrated biota of the intertidal zones. Dispersants are not a panacea for combatting oil spills, but they are tools to be considered.

Most chemicals employed in combatting oil spills rely on surfactant characteristics to disperse floating oil into finely divided globules throughout the upper layers of the water body.

Chemicals react by :

- removing the oil,
- dispersing the oil into the water column where natural turbulence and physico-chemical interactions effectively prevent recombination,
- increasing the surface-to volume ratio, so that the natural microbiological processes can consume the oil more rapidly.

Non ionic dispersants have shown the best performance on oil spills in saline waters. They are usually ethylene oxide condensation products, alkylsulfonates, alkylarylsulfonates and polyglycol ethers of linear alcohols, but specific chemicals and formulations are proprietary to a large number of manufacturers and suppliers.

Chemicals affecting interfacial characteristics are further subdivided into water- or organic-solvent based, depending upon the type of carrier solvent. Because dispersants must create a large interfacial surface area between water and oil, chemical and mechanical energy must be applied efficiently to obtain the desired dispersion.

The great majority of dispersants used on oil spills in the 1960's were developed for other commercial applicatons in which the potential effects on biological systems were of no consequence. Only recently has there been an active search for effective dispersants that are relatively innocuous to major species of marine organisms.

Dispersants are supplied as liquids or solids, usually as aqueous-or organic-solvent based liquids. The densities of the liquids are in the same range as oils and saline waters.

There is controversy over the effect of dispersants on the ecological cycles. Reports of spills where dispersants were used extensively range from "highly satisfactory with little detectable effect on the ecology" to "virtually complete devastation of the aquatic ecology". Laboratory controlled experiments with the same dispersants but different ecological species have led to widely divergent opinions on toxicity effects.

Sumardi (1976) criticised the use of laboratory toxicity test results to be extrapolated to field conditions, especially in tropical areas where marine ecosystems of high diversity occur. He suggested the use of standard animals a.o. Tilapia the Acom Peters as well as dominant species in the areas to be considered as pollution impact areas.

The dispersants used during the cleaning up operations following the "Torrey Canyon" accident used an aromatic solvent which in itself was toxic towards marine biota.

The two major criteria of dispersant effectiveness are :

- the inherent dispersant effectiveness with a particular type of oil and.
- the effectiveness of applicaton under the environmental conditions. Average ration for dispersants to oil are 1 : 5 – 10.

The time for dispersal and the completeness of dispersal depend upon many factors. Two of the most important are the effectiveness of application and of subsequent mixing for aiding the dispersion.

Highly viscous oil or oil-water emulsions are more difficult to disperse with chemicals, regardless of whether the high viscosity is attributable to low temperatures, the natural viscosity of the oil or weathering of the oil. Usage of dispersants can be most effective when applied to oil spills in tropical waters, before appreciable weathering has occured.

Present day dispersants differ from those in the late 1950's and early 1960's. McAuliffe (1975) compared (table I) the effects of Corexit 7664, in combination with oil, on several marine species. Increased toxicity of the emulsified oil was probably related to the ineffective dipersion of the oil in water. In open waters, as was the case in the mentioned oil spill, rapid dilution would compensate for the increased toxicity in the bioassays.

For use in Indonesian waters dispersants must first be tested by Lemigas (Indonesian Petroleum Institute) for the Government. Irwandi (1974) tested Corexit 9517 on its LC50 towards *Anadara granosa L.*

The new generation of self-mix dispersants which do not need extensive mechanical mixing and which disperse the oil into submicron droplets might give more correct correlations between bioassays and field applications (Canevari, 1975).

Table 1

LC_{50} at 96 hr for saveral organisma

Test Annual	Dispersant LC_{50}/96h (PPm)	1 Part Dispersant + 10 parts Oil LC_{50}/96 h (PPm)
Longnese killfish a)	13400	320
Stickleback a)	2500	89
Brine Shrimp a)	130000	320
Anadara Granosa L b)	30863	---

Source : a) Mc Auliffa at al 1975
b) Irwandi Bachtiar 1974

Dispersants should remain one of the methods of first choice for combatting oil spills, especially offshore spills in deep water. They should not be used extensively in the vicinity of commercial aquaculture and other sensitive habitats.

Dispersants should be applied to small and medium spills.

D. Sorbent Systems.

Removal of oil from the water by sorbents may be considered as a four-step process :

- application of the sorbant to the oil-covered area,
- sorption of oil and/or water by the material, including any necessary agitation or time required for efficient sorption,
- collection of the oil-sorbent mixture and removal from the water-surface,
- disposal of the oil-sorbant mixture or separation of the oil from the sorbent.

Most sorbents are distributed on the oily surface and subsequently collected by hand. Mechanized preaders (broadcasters) and collection devices (harvesters) have been developed.

Burning, burial and removing of the oil from the sorbent have been the principal methods for disposal of the oil-sorbent mixtures.

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Table 2

Open sqa near a aquacultur

Type of oil : Spill size :	Crude Oil sml	Weatheral crude sml	Bunker Oil sml
<u>Curtain ment</u>			
Anchored boom			
towed boom			
floating boom			
air certain			
<u>Clean up</u>			
Skimming			
weir			
oleofilie belt			
Solbents			
straw			
synthetic			
Combustion			
Simking			
Dispersing			
Others			

Fill in :
nr = not recommended
1 – 3 = priority

Source : after Beynon 1975

The best sorbents are porous materials having large areas available for sorption in the internal pores. There are 4 types of sorbent materials in use :

- Solid inorganic sorbents such as silica and talc, treated or untreated. Although talc has an affinity for oil, washing with water will result in oil leaching. Application and collection, however, form problems which are difficult to circumvent.
- lightweight porous inorganic sorbents such as expanded perlite (Ekoperl), glass wool, mineral wool, Fuller's earth and verniculite. Ekoperl has been applied to beaches and open water, either manually or by helicopter. Harvesting will form a problem.
- natural organic sorbents such as peat, tannery waste, bark, sawdust, paper, rope, bagasse and straw. These have been used for oil removal from beaches and open water. Straw continues to be the classic natural sorbent for oil. Harvesting is the limiting factor. Several mechanical systems are available for mechanical pickup.
- polymeric sorbents, such as polyurethane and polyethylene foams, polystyrene, polypropylene filters and polyester plastic shavings.

These are in increasingly common use in dealing with oil pollution. Although polymeric materials are more costly that natural sorbents, they have the advantage of being available for re-use.

Furthermore, it is possible to control the properties of polymeric sorbents (as, for example, with high tensile strength polyurethane foam), thus makking their distribution, recovery and reuse easier and simpler as compared with the natural sorbents.

The relative effectiveness of sorbent materials is as follows :

porous inorganics remove oil 2 to 6 times the weight of sorbent

polymeric materials remove oil 5 to 10 times the weight of the sorbent

natural organic materials remove oil 5 to 40 times the weight of the sorbent.

The main drawbacks of this system are :

- the generation of large quantities of waste material that require controlled disposal,
- the broadcasting system without using off-the-shelf equipment,
- the harvesting equipment.

In locations where chemical dispersants or sinking agents are not applicable because of their ecological effects, sorbents can play an important role, their choice over mechanical skimmers and suction devices being limited only by technical and economic considerations. This method is applicable to all types of oil (polyurethane foam) and to both thin and thick slicks.

E. Physical sinking

In contras to sorption, sinking involves only one process, i.e. the distribution of a particulate material over an oil slick to sink the oil. Almost all materials used to sink oil have been natural or byproduct inorganics, either uncoated or coated to make the particles hydrophobis and oleophilic.

The problems of sinking are significantly different from those of sorption and include toxicity, ecological effects and resurfacing ot the oil, causing secondary pollution.

Treated sand, either as carbosand or as diamine-treated sand are effective in removing oil from the water surface.

Carbosand, where the sand is coated by a thin layer of carbon, has been used for many years. The oil is not easily removed from the sand and the effectiveness towards thin slicks is low.

The diamine (Shell) process seems more effective than the carbosand method.

Other sinking agents are; gypsum, chalk (strarated or not), Fuller's earth, cement dust, vermiculite and clay.

The reported effectiveness varies from 0.2 to 6 parts of sinking agent for each part of oil. The effectiveness depends also upon the type of agent, its surface properties, distribution method, the type of oil, (viscosity, density, thickness) and the environmental conditions.

Serious questions have been raised about the ecological effects of sinking methods, especially since it is known that decay of hydrocarbons in bottom-sediments is very slow and the spreading of oil-containing bottom sediments is very probable (Blumer, 1971; Michael 1975).

One can consider this method for application for major oil spills with thick oil layers where lager extensive equipment is required to combat spills over many square miles.

This method however is not recommended for use in astuaries, in intertidal areas, near aquacultures or near sensitive environments (coral, reefs, mangrove communities, upwelling areas).

F. Combustion

Under certain circumstances burning offers an inexpensive and quick method for the removal of oil, gasoline or LNG slicks on the surface of the water which can be competitive with other methods. However, precautions must be taken to ensure that no increased fire hazard to property is produced.

A thin layer of floating oil on a large body of water is difficult to ignite because of conduction heat losses into the water. For heavy oil using a steady state burning rate of 4 mm/min on calm water the or critical thickness is estimated to be about 1.3 mm. A number of materials are claimed to enhance the burning of oilslicks, such as :

- Cab-O-Sil and Aerosil
- Ekoperl, a granular material prepared by treating perlite with a silicone coating to render it hydrophobic and oleophilic,
- Oilex Fire, which consists of Oilex plus a hydro-ignitable chemical, probably a peroxide,
- Pyraxon, which consists of powder and a liquid

which are applied simultaneously to the oil slick. The powder is a mixture of a small amount of oxidant (prabably sodium chlorate) and a catalyst and it floats on the oil surface. The liquid is a combustible organic solvent which lowes the viscosity of the oilslick and burns.

Burning should be considered for thick (more than 1/4 inch), small to moderately heavy and light oil spills on calm water and where the fire cannot threaten. or damage nearby structures. When oil has spread on the water it has been shown to be impractical to destroy a significant portion by burning, even with assistance of incendiary materials and burning aids.

Burning is not recommended in estuaries, harbors or the open sea hear offshore platforms.

G. Shoreline restoration

Shoreline restoration demands either the physical removal of the upper layers of the beaches or processing each grain of contaminated sand and every square inch of oil--coumered rock surface a process made very difficult by the physical adhesion and absorption of the oil. Because the inshore and intardital reqions are much more biologically productive than the open ocean and because many of the organisms that inhabit these regions are much less mobile than the swimming fishes, shoreline clening can be biologically devastating. Socio-economic losses from such devastation can be enormous, particularly in areas where littoral commercial fisheries exist.

In all the major oil pollution accidents of recent years, the methods of restoring the shoreline have been essentially the same-brute force and manual labor. In every use hundreds of men and a great deal of machinery were used to deploy available material (sorbing agents like straw, Ekoperl, sawdust. etc and dispersants of both the solvent and water-based varieties).

Construction equipment, pumping machinery and vehicles were also used. In many tropical countries many shorelines are inaccessible. Restoration of these beaches is difficult to carry out.

In general sorbing agents are directly useful on the beach only of there is free above the sand. When applied on the floating oil behind the surf zone during an advancing tide, these materials can absorb much of the oil and thus reduce the depth of penetration of the sand by oil.

When large scale pollution occurs, large quantities of oil may be deposited in thick layers in shallow tidal pools or on the surface of beaches. Under these conditions almost any kind of heavy-duty pump and storage-tank system can be used to remove the oil. Liquid pump equipment such as septic tank cleaning equipment, is less disirable because the pumps often become fouled by the debris in the oil. Vacuum trucks are proven to be effective. They operate by pumping the air out of a large tank, then sucking the oil into the tank without pumping any liquid.

V. REMMOENDED METHODS AND PRACTICRS

As mentioned in the preceding paragraph every method has its limitations, either inherent to the method or in relation to the particular location of the spill.

As part of national or regional contigency plan concerning the code O_2 conduct for oilspill abatement, each method has to be evaluated againts the particular environment which might become polluted.

Sinne-sea-fisheries and other forms of marine bioindustry are to be developed in these regions, oil spil abatement programs should also be related to these programs.

Where oil spill abatement equipment is expensive and where logistics and availability at the right moment are importance, storing of relevant equipment at strategic positions is essential.

Parameters to be considered for these oil spill abatement programs are :

- methods to be chosen :
  - method of containment
  - method of cleaning
- location :
  - open sea (more than 1 km offshore)
  - open sea close to the shore (less than 1 km offshore)

– open sea close to areas to be protected (mangrove communities, coral reefs, spawning grounds, areas of upwelling, aquaculture, estuaries, scenic beaches, etc)
– bays, inland waters
– harbors
– human settlements
– type of petroleum product
– etc.

Using the table (sea Table II, after Bayon 1975), it is possible to give appropriate weight to each possible mathod in a particular environment by the allocation of a value based on priority (from 1 to 3). In this way a list of the best methods of combatting oil spills can be drawn up for any location and for any size of spill (whether small, medium or large) according to the type of oil most frequently encountered a in particular area.

These methods are already closely related to the particular characteristics of that environment.

Fire is bad when it is uncontrolled, but fire is necessary.

Water is bad when it causes flooding, but water is essential in our life;

Oil is bad when it pollutes, but oil is necesary in our economy.

If we manage the environment well the development of a marine bioindustry simultaneously with the development of hydrocarbon based industries, including the energy industry, can be carried out harmoniously.

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