ENVIRONMENTAL ASPECTS OF THE PETROLEUM INDUSTRY

- an overview -

UNITED NATIONS ENVIRONMENT PROGRAMME

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FOREWORD

From the first session of the UNEP Governing Council, held in June 1973, the importance of environmental issues associated with industrial development was recognized and a programme of activities on environmental problems of specific industries was initiated by the Executive Director.

A series of industrial sectors were chosen for examination by the Governing Council of which the petroleum industry was one. Consultations were undertaken with experts nominated by Governments, industry and international governmental and non-governmental organizations, culminating in a Seminar held in Paris in March 1977. There the state of the art of existing remedies, outstanding problems and possible avenues or research and development to resolve these environmental issues were assessed.

The International Petroleum Industry Environmental Conservation Association (IPIECA), organized the preparation and presentation of the industry papers for the Seminar and was a major focal point of contact between the petroleum industry and UNEP.

This report is a synthesis of the evaluation that has taken place, and gives an overview of the policy aspects of the environmental issues emanating from the petroleum industry, in order that appropriate actions may be focused on them.

The views expressed in this report do not necessarily represent the decisions or the stated policy of the United Nations Environment Programme, nor does mention of trade names or commercial processes constitute endorsement.

1. INTRODUCTION

Fossil fuels are the major source of energy in most if not all countries. They account for more than 90 percent of the world consumption of energy of which the share of oil is about half. Oil is by far the most versatile and can be used as fuel in all sectors : industry, agriculture, transportation, commerce and the home.

The world consumption of oil (excluding planned economy countries) in 1975 was about 6 million tonnes per day. Depending upon prices and rate of growth of demand, the consumption could be between 10 and 13 million tonnes per day (1), during the period 1985 to 2000. The proven reserves of oil in 1975 were estimated to be :

OPEC countries	62	billion	tonnes
North America	6	"	"
Western Europe	4	"	"
Planned Economy Countries	14	"	"
Others	6	"	"
Total world	92	"	"

From Workshop on Alternative Energy Strategies (1977)

It is evident that OPEC countries have nearly 80 percent of proven oil reserves of which about 50 percent are in the Middle East. Although offshore exploration and drilling continues to be made in different regions around the world, the chances of finding large concentrated deposits such as those in the Middle East are remote. It can therefore, be assumed that oil will continue to be transported by tankers over long distances to the centers of consumption and use.

Another point worth noting is that whatever the calculations and forecasts used for demand and proven-resource estimation, oil is a finite resource. Hence all practical measures must be used to conserve oil as well as prevent its wastage, which in turn will also contribute towards the enhancement of the environment.

The use of fossil energy poses an inevitable energy-environmental conflict, whatever the supply and use option. These environmental problems can be remedied to a certain extent with technological controls, but at a price which in most cases includes an increase in energy consumption. Some risks are

(1) – Worksop on Alternative Energy Strategies,(WAES) Energy Global Prospects 1985-2000, Mc Graw Hill Book Co. 1977.

inherent in any particular energy-technology choice, because complete environmental control is too expensive or is impractical. However, in many areas, environmental protection can be achieved at an acceptable cost.

The petroleum industry is the largest industrial sector and it can be divided into a number of major operations including exploration and production, transportation, refining and marketing, and involving logistic activities such as storage and distribution.

Although the end use of petroleum products gives rise to major environmental impacts, this issue is not directly the responsibility of the industry. The oil industry can however, through product specifications, again at a cost, influence the ultimate nature and extent of environmental intrusions.

In the following chapters, an overview of the major environmental problems and issues pertaining to the various main operations of the petroleum industry are presented and discussed, so that appropriate actions can be focused on them.

2. EXPLORATION AND PRODUCTION

When searching for petroleum hydrocarbons, one of the initial steps is to locate possible hydrocarbon bearing structures. Seismographs which measure shock waves reflected back to the surface from formations below are used for the determination of potential resources. The current practices employed in exploration and production activities and the associated possible environmental impacts have been reviewed (1). In exploration drilling on land and offshore these are :

2.1. Exploration Drilling

On land :

The main geophysical methods to determine prospects on land are by dynamite and vibrators, accounting for approximately 58 percent and 26 percent respectively of the total 592,966 Km land seismic line shot in 1974.

The use of dynamite in shot holes is restricted to areas where little or no damage can be caused by the explosion. Also, care has to be taken to ensure that the drilling of shot holes will not affect ground water supplies nor cause any lowering of the water table. In more populated areas, the vibrator

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(1) – Van Eek, W.H. "*State of the Art of Environmental Conservation, Exploration and Production*" Paper prepared for and presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry. UNEP/ISS 5/2, Paris, 29 March - 1 April 1977.

which causes fewer shock waves and less vibration than explosives should be used instead. Unless seismic lines follow existing roads, vegetation will have to be cleared along the lines. Depending upon the fragility of the ecosystem that surrounds the exploration, an environmental impact assessment may have to be undertaken, in order to determine what the effects could be, so that appropriate measures can be taken to minimize any damage.

If the available data are encouraging a drilling site is chosen, taking into consideration, geological as well as economical, safety and environmental factors. Possible environmental effects by the drilling operation are caused by :

– the drilling mud which is pumped through the inside of the drill pipe and returned up the annulus to the rig floor, lifting the drill cuttings to the surface, lining the walls of the borehole, providing a hydrostatic head to control hole pressure, lubricating the drilling bit etc. The characteristics of the drilling mud vary widely but can be generally classified as either oil based or water based;

– oil and lubricants from engines, generators and other machinery.

Any spillage of drilling mud and oil is gathered in a system of special drains, if necessary separated from rain and wash and properly disposed of as waste.

Special muds may contain chemicals which are considered environmentally harmful ; for instance soluble chromates, bactericides, corrosion inhibitors ; or if these are alkaline due to the use of sodium hydroxide. In such cases, the mud is, upon collection, stored and used again. If there are remnants unsuitable for re-use, and which cannot be directly disposed of, special facilities will have to be constructed, washing off the chemical solutions from the mud before disposal. If the mud is a stable colloidal suspension, washing does not help and an environmentally acceptable means has then to be found for disposing the whole mud, for example by evaporation and/or underground burial.

Alternatively, other types of mud, emulsified with crude oil, diesel or kerosene may be used and the surplus properly stored for reuse or disposal, by burning for example.

Noise levels, can be reduced, if necessary, by insulating the rig or the noise emission sources with sound absorbing materials. Diesel engines, turbines or equipment that emit gas and/or steam at high velocity can also be fitted with exhaust mufflers.

Offshore :

Marine seismology can now be carried out with minimal impact on marine life. The destructive effect of shock pressure on fish is known and is caused mainly by a negative peak pressure which is stronger, the shallower the charges are shot at sea. Recent techniques, like the airgun and gas-exploder are used to replace dynamite, which was traditionally used but could cause harm to marine life. The gas-exploder detonates a small gas charge in a heavy rubber sleeve which instantly inflates, producing minute sound waves whose echoes are detected by the ship's seismograph. The low frequency sound waves are not harmful to marine life and the exhaust gases are vented to the surface through a hose. Dynamite which uses small charges set off in deep waters is a method reported to cause no harm to fish life. However, this technique is not now in general use.

In 1974, the marine seismic lines by dynamite, air gun, gas-exploder and various other methods were estimated to be 5 percent, 63 percent, 21 percent and 11 percent respectively of the total seismic line of 1,326,363 Km.

In swamps, estuaries and mudflats a combination of land and marine techniques is usually used and depending on the fall and rise of the tides, the method which will create the least impact is chosen. The aquapulse method is one such technique. Intertidal marshlands and estuaries are especially rich ecosystems, providing spawning grounds for fish and other marine life. Waterfowls are also found in these areas. Environmental precautions and protection measures must be taken to minimize the impacts of exploration and production activities, particulary those of dredging and pipe laying, platform and pipeline construction, as well as activities giving rise to oil discharges with the subsequent use of dispersants. Changes in drainage patterns on offshore shallow areas and salt marshes, leading to changes in sedimentary patterns are inevitable when dredging and pipe laying operations occur. However, the impact on intertidal marshlands by the oil industry has to be seen in perspective, since other industrial and development activities can also lead to significant ecological changes. Hence, a comprehensive environmental management plan is needed to regulate all significant man-made activities in these regions.

Offshore activities can, if not controlled, result in littering the sea bed which may interfere with trawling operations. The laying of pipelines can present particular problems in this respect. It is important for similar reasons to ensure that abandoned sub-sea wells are left so that nothing protrudes above the sea bed.

The main potential problem in offshore as well as inland drilling and workover operations is blowout, and this topic is discussed in greater detail in the following section. If annular pressures have to be released in order to avoid cratering, then the flaring arrangements used should be able to burn off hydrocarbons. Preventive and precautionary methods to guard against damage by natural hazards, especially caused by bad weather conditions, should also be exercised in offshore production activities.

2.2. Appraisal drilling and development of oil and gas fields

The exploration drilling phase is followed by testing, to evaluate the prospect. Once oil has been found, appraisal drilling will begin, followed by the drilling of producers and the installation of surface facilities. It is usual, before the first exploration well is drilled for an outline of the production plan to be made, indicating how the field will be developed. Possible environmental impacts can then be identified and preventive and/or corrective actions taken.

On land :

In 1974, outside of planned economy areas, 42,874 wells were drilled for a total length of 65,358,419 meters, inclusive of wild cat wells and in 1975 the figures were : 47,930 wells and 70,619,180 meters of footage.

The main environmental control needed is to prevent the discharge of untreated effluents. Oil spillage prevention is mainly good housekeeping and maintenance, and care must be taken to ensure that oil is not washed over to surrounding areas by rain. Flow lines should be regularly checked, especially if there is corrosion, and producers should be equipped with safety valves set in the well and with fail-safe valves at the X-mas tree and flow lines. Another environmental consideration is with produced water, which is water drawn from the reservoir associated with the oil or to a much lesser extent gas. The ratio of water produced with the oil can vary by several orders of magnitude depending on such factors as the volume and mobility of the water in contact with oil and degree of depletion of the reservoir. Produced water is frequently reinjected at the same site.

Well-cluster development is probably the best method to contain environmental pollution. With a more compact form of cluster system, individual well flow-lines are contained in the cluster area and fail-safe and anti-corrosion methods become simpler. Oil, gas and water separators, storage tanks, compressors and crude transport pumps are all concentrated in the same area and only one oil line has to be laid, preferably underground, unless the oil is immediately transported from the site by truck or rail.

Air pollution may occur when sour crude or gas is involved during drilling, producing and transportation operations. In the U.S.A. the Texas Railroad Commission revised its existing rule 36 on March 15, 1976 imposing new employee and public protective measures on all drilling, production and fluid handling operations, for concentration of 100 ppm or 0.01 percent volume of hydrogen sulphide H_2S. Special precautions are laid down in the new rule where the 100 ppm radius of exposure exceeds 50 ft or 15 m. During drilling and workover activities the means to ignite the gas in the event of a blowout has to be available.

However, this creates the problem of SO_2 emission which although not as noxious as H_2S, has a relatively high density and tends to settle. High temperature disposal could alleviate this problem.

Noise nuisance can be abated and controlled more effectively in cluster systems, as acoustic screens may be installed around noise generating sources more easily.

Surface subsidence due to underground compaction is a phenomenon which is also being assessed and taken into consideration. In shallow unconsolidated sands subsidence can take place as a result of oil withdrawals. This may occur as the pressure in the oil or gas reservoirs declines. The affected area should be kept under surveillance to monitor the extent of the subsidence and allow implementing protective measures if needed. The area may have to be protected with dykes to prevent flooding from nearby lakes or seas – while ditches and canals should be dug to keep the subsiding area well drained. Such a system should also assist in localizing oil spillages. Subsidence may also take place in well-consolidated sands at greater depths. This can be of importance if the reservoir extends over a large area and if the oil and or gas is produced from thick sands. Assessment and forecast of subsidence is of importance in order to plan the corrective measures that should be taken.

Offshore :

Generally, appraisal drilling will be carried out in the same manner as exploration. In shallow waters these appraisal wells are often included as above-water producers, by means of individual well jackets. In deeper waters, individual jackets are expensive and the choice of either abandoning the well or completing it as an underwater producer has to be made.

In shallow, quiet waters, as for example the Lake of Maracaibo in Venezuela, wells have been drilled from individual platforms or jackets while gathering stations are placed at regular distances on separate platforms to service a number of wells. Therefore, producing wells and production facilities are completely segregated. In rougher waters, even though shallow, it has become standard practice to select sites for production platforms from which a number of wells can be directionally drilled. Well platforms and producing facilities were originally kept separated, as for instance in the Gulf of Mexico, during the early development period.

As exploration and production has moved into deeper and also rougher waters, larger and heavier platforms are required. With increasing costs, more wells from the same platform are needed in order to reduce to a minimum the number of platforms required. For the same reason, platforms for drilling and production have not been designed separately, but are combined. The risk of mishap is greatly increased, due to this concentration as well as to other factors. However, technological advances with elaborate automation and safety

systems have kept pace with the demands for oil and gas production in deeper waters.
Prevention against water pollution is most important and is similar to that of land drilling ; spillages of oil and mud flush should be avoided. Modern offshore rigs are well equipped to avoid these problems (1).

Excess non-toxic water based muds as well as drill cuttings from these muds may on occasion be pumped directly from offshore platforms into the sea. However, if the drilling mud contains toxic substances in relatively large quantities, the surplus mud should be collected and disposed of onshore. In the North Sea development, the problem of disposal of large quantities of oil emulsion muds was overcome by burning the mud with about 13 percent diesel oil. Only charred drill solids or ash remained after the burning. Oil wet drill cuttings from shale shakers, desanders and desilters cannot be disposed of at sea until treated to remove the adhering oil film.

Water segregated from the produced oil, unless returned to the formation, is carefully cleaned from oil before discharging it into the sea. With an underwater well, minor oil spillages can be expected from routine operations. The connection from a rigid well at the sea bottom to floating facilities is more vulnerable than when the underwater installation is connected to a fixed production platform. However, it is no more vulnerable than when the oil is pumped via a single point mooring into a tanker.

With offshore production, the impact of on-shore activities on the environment should also be considered. The United Kingdom's experience indicates that, for example, concrete platform construction has been environmentally demanding.

2.3. Well Control

The major requirements for efficient well-control during drilling and workover operations have been reviewed (2) and these are :

- accurate prediction of subsurface conditions
- proper well design
- early and reliable detection of subsurface events
- training of all concerned
- safer drilling systems
- effective supervision.

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(1) – Westaway, M.T. *"Environmental Impact of Offshore Development"*. Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry, Paris, 29 March - 1 April 1977.

(2) – Van den Hoek, A.W.J. *"Drilling Well Controll"* Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry, Paris, 29 March - 1 April 1977.

Environmental pollution caused by routine operation of exploration and production activities can be controlled. To minimize blow-outs and accidents, a strict well-control programme is necessary, as a preventive measure. Therefore, before starting to drill a well, especially a wildcat well, a well-control programme is drawn up and implemented. Some of the measures are :

– daily and weekly equipment tests, with written reports of the results ;
– clear instructions on procedures to be followed to kill a well;
– regular exercises (test drills) for drilling and production workover crews.
– set down round-trip procedures for swab and surge possibilities. In this respect the mud quality is important and daily calculations should be made to estimate pressure fluctuations in the hole, caused by the tripping speed of the driller's choice;
– information on how quickly gas bubble will rise in the hole through the mud after closing-in the blow-out preventor;
– the annular pressure at which the annulus should be opened up in order to avoid cratering around the surface casing in the event of a threatening subsurface blow-out;

Additionally, blow-out/contingency plans are also being made, in case of an actual accident. Basically blow-outs can occur either at the surface or subsurface. Surface blow-out can be stopped under favourable conditions at the surface. If it is not possible to shut off a surface blow-out, then the difficult decision should be taken as to whether the oil ought to be ignited to prevent futher oil spill pollution, whilst measures are taken to kill the blow-out well by drilling one or more relief wells. In the case of a single blow-out, it may be possible to use an oil-containment boom together with oil skimmers to limit the extent of oil pollution. How effective the boom is depends on wind and wave conditions : experience to-date has not found booms greatly successful. Indeed any oil that escapes beyond the containment barrier can seldom be recovered any more by oil skimmers ; if conditions warrant one might consider spraying with dispersants. This method of oil-spill control is discussed in greater length in chapter 5.1.

A blow-out plan will also include :

– alternative sites for the drilling of relief wells. Also, procedures should be established on how to locate and obtain drilling rigs in case of an emergency;
– evacuation plans if there are residents around the wells ;
– emergency procedures for instance assigning duties, liaison with and use of safety pollution abatement equipment;
– procedures for controlling air pollution;
– procedures for controlling oil pollution;
– liaison arrangements with governmental environment officers to ensure that any action taken is consistent with the best environmental option."

The contingency plan for a given site should be specific for the actual location. The evaluation of ecologically vulnerable areas that may be endangered by the mishap is considered essential, so that selective pollution combat measures can be appropriately chosen.

Government approval for the operation and the contingency plans will have to be obtained before the actual work can start.

To minimize the possibilities of mishaps and accidents, in addition to a well-control programme and blow-out plan, oil well programmes should be made more universal through applying a standard system of units. In addition, drillers and tool pushers should obtain accredited certificates of competence while regular emergency drills should be held at the platforms.

In this respect, the Commission investigating the blow-out on the Bravo production platform in the Ekofisk field concluded that the incident must be ascribed to a series of circumstances which, to varying extents, were direct or indirect contributory causes. The blow-out occurred due to a combination of (1) :

- insufficient manufacturer's instructions for the use or applications of the downhole safety valve, and inadequate marking of the bypass blanking plug and removable mandrel;
- the modified workover programme utilized a downhole safety valve set in a static well which could not be pressure tested because the well was static;
- shortcomings in the organization of work on board the platform for installation of blow-out preventer;
- failure in following the established work programme;
- critical situations were misconstrued;
- insufficient management and supervision of work;
- unreasonably long working hours for some personnel.

Some of the conclusions that can be drawn from this incident, in order to minimize accident in exploration and production activities are the need for :

- an adequate manning and supervision plan, especially on workover operations;
- regulations concerning the qualifications of personnel;
- adequate technical training, including safety consciousness and environmental awareness;

(1) – The Bravo Blow-out : The Action Command's Report. Norges Offentlige Utredinger. NOU. 1977 : 57. Dec. 1977.

– establishing working hours including working periods in relation to rest periods for all personnel working and supervising on the drilling platforms.

Countries that are likely to be affected in case of oil spill emergencies arising from exploration and production should have their own contingency plans encompassing adequate policy, materials and equipment available in readiness. An administrative mechanism with the necessary authority and responsibility should be set up, so that measures to combat as well as to prevent oil spills can be effectively coordinated and implemented.

3. TRANSPORTATION OF PETROLEUM PRODUCTS

Petroleum products are transported by sea and land, with by far the largest quantities going by sea. Hence, a major source of oil pollution of the marine environment is caused by transportation.

3.1. Marine Transportation

Since 1954, the amount of oil transported by sea has increased nearly seven fold, from 250 to 1,508 million tons in 1975. Crude oil has shown a larger increase, from 150 to 1,273 million tons. The world tanker fleet in 1975 consisted of 7,024 vessels totalling 281,596,987 tons dwt, of which about 40 percent in tonnage were vessels of 200,000 tons dwt and above. Vessels known as "T-2 tankers", of 16,000 tons dwt and with a speed of 14.5 knots were the most widely used, but during the last decade there has been an increase in the construction of VLCCs (very large crude carriers). The decline in oil demands in 1974 caused a tanker surplus, resulting in the laying-up of about 100 million tons dwt at the end of 1975. This surplus is expected to remain until at least the 1980's.

The need to predict possible spillage during the transport of petroleum is becoming increasingly important in spill prevention and control, spill contingency planning and the preparation of environmental review reports. An analysis (1) of information compiled from the literature on world-wide tanker oil spills during 1969-1972 indicated that such spills can be expected to occur within 80 Km from land on average once in every 1,000 vessel port-calls. The average size of these spills, within 80 Km of land would be 973 tonnes and the average spill about 12 tonnes per million tonnes transported.

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(1) – Beyer A.H. and Painter L.J. "*Estimating the Potential for Future Oil Spills from Tankers, Offshore Development and Onshore Pipelines*". Proceedings 1977 Oil Spill Conference (Prevention, Behaviour, Control, Clean up). Sponsored by : American Petroleum Institute, Environmental Protection Agency and the United States Coast Guard. New Orleans, Louisiana, March, 1977.

In addition to marine transportation, petroleum hydrocarbons are introduced into the sea through various other pathways. Marine transportation is responsible for about one-third of the total input of petroleum hydrocarbons into the oceans (see section 6.1). Control measures for oil pollution from ships will thus reduce an important source, but would not eliminate pollution of the sea.

Oil pollution arising from maritime transportation can be broadly classified into two categories :

– deliberate or operational,
– accidental.

During 1969-1973 there were 82 serious tanker accidents (1) attributed to the following major causes :

Strandings, groundings and collisions	25
Fire and explosion	27
Heavy weather and structural damage	22
Others	8
	82

The development of international control measures to prevent oil pollution by ships has been comprehensively reviewed (2) and this is summarized below.

The 1926 International Conference on Pollution of the Sea by Oil convened by the United States and held in Washington, may be regarded as the first multilateral effort to conclude an international agreement for the control of pollution from ships. Since then attempts were made in 1934 by the League of Nations resulting in a 1935 Draft Convention, which was reviewed in 1950 by the Economic and Social Council of the United Nations. In the light of these activities the Government of the United Kingdom convened in April/May 1954 an international conference in London. The resulting instrument, the International Convention for the Prevention of Pollution of the Sea by Oil and the conclusion of the 1954 Oil Pollution Convention was a significant achievement. This was particularly so, in that it was the maritime community which first tackled the problem of pollution and took control measures at international level when the world community in general was not particularly conscious of the need for environmental protection.

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(1) – Walder C.A. *"Environmental Aspects of the Transportation of Oil by Sea"*. Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry. Paris, 29 March - 1 April, 1977.

(2) – Sasamura Y. *"Environmental Impact of the Transportation of Oil"* Ibid.

The 1954 Convention, which was subsequently amended in 1962, dealt with deliberate or operational discharge of oil from ships, especially tankers, with the principal aim of protecting amenities, such as beaches, from tank washing and balasting operations. The Convention did not deal with accidental pollution.

The 1954/1962 Convention had serious shortcomings : although the discharge of oil mixtures from a new ship of 20,000 tons gross tonnage or more is banned outside the prohibited zone, the master of the ship is allowed to discharge such oily mixtures if special circumstances make it neither reasonable nor practicable to retain them on board. The lack of shore reception facilities has given the ship masters justification for such discharges. The special circumstances have thus virtually become the normal circumstances and oily mixtures have been discharged outside the prohibited zones almost without restriction.

In view of this unsatisfactory situation, the tanker industry considered various alternatives for improving tanker operations. This has resulted in the development of the load-on-top, LOT, system. This system was designed to obviate the need to rely on shore reception facilities for treatment and disposal of oil wastes generated on board. However, although the system was very effective, some difficulties were encountered in complying strictly with the requirements of the Convention during certain phases of its operation.

The 1969 Amendments to the 1954 Convention adopted by the IMCO Assembly were designed to overcome these difficulties by specifying new criteria which could be met in practice by the LOT system. The Amendment prohibits the discharge of oily mixtures from a tanker except under the following conditions :

(i) the tanker is proceeding en route ;

(ii) the instantaneous rate of discharge of oil content does not exceed 60 litres per mile ;

(iii) the total quantity of oil discharged on a ballast voyage does not exceed 1/15,000 of the total cargo carrying capacity ;

(iv) the tanker is more than 50 miles from the nearest land.

The 1969 Amendments were accepted by the required number of Contracting States and came into force on 20 January 1978. In order to ensure satisfactory implementation of the 1969 Amendments, it is necessary for tankers to follow proper operational procedures. The Oil Companies International Marine Forum and the International Chamber of Shipping have published the "Clean Seas Guide for Oil Tankers – the Operation of load-on-top" and "Monitoring of load-on-top". The former publication is intended for the guidance of masters and crews in following the LOT procedure and in complying with the requirements of the 1969 Amendments. Whereas the latter publication is for guidance to check this compliance at tanker terminals. Implementation of the 1969 Amendments will eliminate a very large portion of oil discharges from tankers.

The 1967 Torrey Canyon accident gave rise to two broad questions of legal character.

a/ The extent to which a State directly threatened or affected by a casualty which takes place outside its territorial sea can, or should be enabled to, take measures to protect its coastline, harbours, territorial sea or amenities even though such measures may affect the interest of shipowners, salvage companies or even of a flag government ;

b/ the nature, extent and amount of liability of the owners or operator of a ship for damage caused to third parties by oil which has escaped or been discharged from a ship as a result of an incident.

As a result of these issues, three Conventions were adopted in Brussels in 1969 and 1971.

– International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (1969).

– International Convention on Civil Liability for Oil Pollution Damage (1969)

– International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1971).

In 1973, IMCO convened the International Conference on Marine Pollution and concluded the following instruments :

– International Convention for the Prevention of Pollution from Ships.

– Protocol relating to Intervention on the High Seas in Cases of Marine Pollution by Substances other than Oil.

Implementation of the 1973 Convention which will supersede the 1954 Convention and Amendments would substantially achieve the complete elimination of intentional pollution by oil and other noxious substances and the minimization of accidental spills. The 1973 Convention consists of five technical Annexes and two Protocols, one relating to procedures for reporting incidents involving harmful substances and the other relating to the settlement of disputes. The Convention applies to any ship of any type operating in the marine environment including submersibles, floating craft and fixed or floating platforms. It does not however, apply to exploration and exploitation of seabed mineral resources, nor the disposal of shore-generated waste by dumping from ships.

With respect to the discharge of oil, Annex 1 of the Convention can be summarized as follows :

a/ The definition of "oil" has been broadened to mean petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than petrochemicals) ;

b/ For new tankers, the total quantity of oil which may be discharged into the sea must not exceed 1/30,000 of the total quantity of the particular cargo of which the residue formed a part ;

c/ When discharging oil, tankers and other vessels must have in operation an oil discharge monitoring and control system ;

d/ Certain regions, including the Mediterranean Sea, the Black Sea, the Baltic Sea, the Red Sea and the Gulf Areas have been designated as "special areas" in which any discharge of oil or oily mixture into the sea is prohibited except in cases of "force majeure" ;

e/ Parties to the Convention are obliged to ensure the provision of adequate reception facilities for residues and oily mixtures at oil loading terminals, repair ports and in other ports in which ships have such residues to discharge ; in certain special areas these facilities must be provided by 1 January 1977 and must be adequate for the reception and treatment of all the dirty ballast and tank washings from tankers.

In addition the 1973 Convention introduces certain requirements for the construction and equipment of ships to prevent operational discharges and to reduce the risk of uncontrolled release of oil should accidents of tankers occur, and these are :

a/ Oil tankers must be fitted with oil discharge and monitoring equipment, with a recording device to provide a continuous record of the discharge ;

b/ Any ship of 400 tons gross tonnage and above must be fitted with an oily-water separating equipment or filtering system ;

c/ Oil tankers must be provided with suitable slop tank arrangements with the capacity necessary to retain the slops generated by tank washing, oil residues and dirty ballast residues ;

d/ New oil tankers of 70,000 tons deadweight and above must be provided with segregated ballast tanks of sufficient capacity to enable them to operate safely on ballast voyages without recourse to the use of oil tanks for water ballast except in very severe weather conditions ;

e/ Requirements for tank arrangements and limitation of tank size adopted as the 1971 Amendments to the 1954 Convention have been retained ;

f/ New subdivision and damage stability requirements have been introduced to ensure that tankers can survive assumed side or bottom damage to a degree specified on the basis of their length.

The enforcement of conventions by contracting parties involves legal and technical aspects, namely :

a/ The establishment of a legal regime whereby flag States, port States and/or coastal States can exercise control in respect of breaches of the convention ;

b/ The establishment of a system of survey, certification and inspection of ships in respect of design, construction and equipment ;

c/ Establishment of a system for the control of operational procedures of ships, including the inspection of oil record books ;

d/ The development of procedures and arrangements for the surveillance and detection of discharges in contravention of the convention.

The 1973 Convention will enter into force twelve months after acceptance by at least 15 States, representing at least 50 percent of the world's merchant fleets. There are, however, certain aspects which call for considerable study before they can be effectively implemented, and it could be several years before the Convention enters into force. For this reason emphasis has been laid on the desirability of implementing the 1969 Amendments to the 1954 Convention without waiting for the entry into force of the 1973 Convention.

To give impetus to the ratification of the 1973 Convention IMCO convened the International Conference on Tanker Safety and Pollution Prevention in February 1978.

The conference, in its final session on 17th February, adopted, without a dissenting voice, Protocols to the Convention for the Safety of Life at Sea (SOLAS 74) and the Convention for the Prevention of Pollution from Ships (MARPOL 73) as well as eighteen resolutions covering a large number of mainly technical subjects. Some of the conclusions of the Conference are, from the date of entry into force of the Protocols :

a/ All new crude oil tankers over 20,000 deadweight tons will have segregated ballast and crude oil washing equipment;

b/ All new product tankers over 30,000 d.w.t. will have segregated ballast;

c/ All existing crude oil tankers over 40,000 d.w.t. will have either segregated ballast or crude oil washing equipment, or, for a limited time, dedicated clean ballast;

d/ All existing product tankers over 40,000 d.w.t. will have either segregated ballast or dedicated clean ballast, without time limitation;

e/ All existing and new tankers over 10,000 g.r.t. will have improved emergency steering gear, dual radar and inert gas equipment (for tankers over 20,000 d.w.t.) with certain exceptions;

f/ All tankers will be subject to more strict and frequent certification and inspection procedures, including unscheduled inspections and mandatory annual surveys ;

g/ A resolution adopted by the Conference, inter alia, "invites all Governments concerned to put these requirements into effect to the maximum extent, without waiting for the entry into force of the MARPOL Protocol, by June 1981 or as soon as possible thereafter", and a similar resolution was adopted for the SOLAS Protocol.

New oil tanker means an oil tanker :

(a) for which the building contract is placed after 1 June 1979 ; or

(b) in the absence of a building contract, the keel of which is laid, or which is at a similar stage of construction after 1 January 1980 ; or

(c) the delivery of which is after 1 June 1982 ; or

(d) which has undergone a major conversion :

(i) for which the contract is placed after 1 June 1979 ; or

(ii) in the absence of a contract, the construction work of which is begun after 1 January 1980 ; or

(iii) which is completed after 1 June 1982.

Although either segregated ballast or dedicated clean ballast systems are required for existing ships, the acceptance for crude carriers of the "crude oil washing" process as another option makes it very unlikely that a significant part of the world fleet will adopt the other two systems since they would place them at a competitive disadvantage because of reduced cargo capacity. Hence, the Protocols as adopted, while making a major contribution, if effectively enforced, to reducing pollution and increasing vessel safety, will have only a very limited effect upon ameliorating the world shipping and shipbuilding surplus situation.

The International Chamber of Shipping has developed a Pollution Prevention Code (Oil Tankers) whereby the shipping industry may voluntarily put into practice those aspects of the 1973 Convention that are amenable to immediate or easy adoption. This interim measure initiated by the oil industry will contribute towards filling the gap until the 1973 Convention enters into force.

A problem of crude oil washing is that it causes an increase in the level of hydrocarbons found in the ship's cargo tanks. Consequently if during any subsequent ballasting operation the procedures for the control of emissions detailed in the IMCO Specification for crude oil washing are not followed, an emission to the atmosphere might occur. This may be of significance in areas where levels of photochemical oxidants are already high.

Technical assistance is needed to augment the adoption and implementation of Conventions to prevent oil pollution from ships. Some of these are :

– provision of reception facilities for treatment and disposal of residues and oily mixtures which remain on board and for which discharge is prohibited (1) ;

- contingency planning for combating spillages, including regional or subregional arrangements ;
- availabity of equipment and material and methods for dealing with spillages ;
- training of personnel ;
- prevention of maritime accidents, including traffic separation schemes and provisions of aids to navigation.

3.2. Liability and Compensation of Oil Pollution Damage

There are two voluntary industry agreements relating to liability of oil pollution clean up and damage. The TOVALOP (Tanker Owners Voluntary Agreement concerning Liability for Oil Pollution) which came into effect on October 6, 1969, is based on fault liability with the burden of proof reversed. It requires each tanker owner who becomes a party to the agreement to establish and maintain financial capability to reimburse a national government for removal costs incurred by it up to a maximum US$ 100 per gross registered ton of the tanker or US$ 10 million whichever is less. At present 99.5 percent of the world tanker tonnage is entered in TOVALOP.

CRISTAL (Contrat Regarding an Interim Supplement to Tanker Liability for Oil Pollution) also a voluntary agreement among the oil companies came into effect on April 1, 1971. This agreement supplements TOVALOP and increases the overall total to US$ 30 million per incident. Liability for removal costs, with limited exceptions, is strict or absolute. However, three basic conditions must be met before a claim will be considered.

- the oil carried by the vessel must have been "owned" by a party to CRISTAL at the time of the incident;
- the tanker from which the oil escaped must be a signatory to TOVALOP at the time of the incident, and
- CRISTAL will compensate persons sustaining pollution damages (other than owner's clean-up) only to the extent if recovery of the damage is not available from other sources.

Oil company participation in CRISTAL represents over 90 percent of the crude oil and fuel oil moved by sea.

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(1) – IMCO "*Guidelines on Means for Ensuring the Provision and Maintenance of Adequate Reception Facilities in Ports*" Inter-Governmental Maritime Consultative Organization, London, 1977.

It is envisaged that the TOVALOP and CRISTAL agreements will be gradually taken over by the 1969 Civil Liability Convention (which came into force on June 19, 1975) and the 1971 Fund Convention which supplemented it. By the 1971 Convention, compensation payable to the victims of a pollution incident is given a new overall limit of approximately US$ 36 million. Furthermore, compensation is payable for a natural phenomenon of an exceptional, inevitable and irresistable character, which is not covered in the 1969 Convention. The fund for the 1971 Convention is financed through contributions made in respect of each contracting state, by persons who have received in that state oil carried by sea in large quantities. This feature assures that the oil industry as well as the shipping industry share responsibility for pollution damage. The 1971 Fund Convention is, however, not in force and is still in the process of ratification.

3.3. Inland Transportation

Although a considerable quantity of oil is transported overland by pipelines, only a comparatively small amount is carried by other modes such as inland waterways, road or rail. Spillage of oil products rather than crude oil are the major cause of oil pollution from inland transportation. Since consignments by these modes are small, the problems are usually localized. However, if there is a spillage, steps should be taken to avoid the spilled product being washed down into drains, which may contaminate a river or seep into surface and or ground water used for human consumption.

Transportation of liquids, such as crude oil, through steel pipelines has been practiced for over 100 years. The technique has developed continuously so that modern pipelining methods ensure an efficient and safe method of moving large volumes of crude oil, petroleum products and gas.

The total length of crude oil trunk and gathering lines in the world is presently estimated to be about 800,000 Km. The longest pipeline is the Comecon pipeline carrying crude oil from the Volga-Ural fields in the USSR to Hungary, German Democratic Republic, Poland and Czechoslovakia.

The pipeline is about 5,200 Km long with pipe diameters ranging between 50 cm to 100 cm. The capacity is 20 m.t.p.a. The largest capacity pipeline is the Trans Alaska pipeline. It is about 19 cm in diameter and 1,300 Km long capable of carrying 100 m.t.p.a.

Recent technical developments with regard to material used and main pipeline strength design as well as deepwater offshore pipelining have been reviewed (1). The environmental aspects of the Trans Alaska Pipeline, and the

(1) – Watkins R.E. "*Crude Oil Pipelines*" Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry, Paris, 29 March - 1 April 1977.

Transalpine Pipeline were also reviewed. The environmental problems encountered and the solutions for preventing and minimizing the impacts caused are specific to the terrain through which the pipeline passes, whether it be sea-bed, agricultural land or arctic tundra. Statistics of spillage from pipelines in Europe show a very low spillage rate, of less than one part per million transported. The most significant cause of pipeline incidents is third party damage either by interference or exceptionally by sabotage. Although regular patrol by line walkers and low flying aircraft would identify construction activities liable to cause damage, there is no simple answer to sabotage. Inevitably the conflict lies between the need to identify pipeline locations clearly to avoid damage by legitimate operations with the desirability of making it difficult to locate the pipeline for security reasons. Suitably framed legislations to protect pipelines could be of assistance and where legislation exists, better coordination in relation to third party activities within the vicinity of a pipeline shoud be strengthened.

Present technology can enable a leak to be located, from the control monitoring system, to within about 1 Km. However, not all pipelines are so equipped. Modern pipeline systems can detect instantly loss by means of line mass balance, which constantly compare the flow into with the flow out of the pipeline as well as by monitoring sudden fall off in pipeline pressure from predicted values. Minute leaks can be detected by periodic pressure tests, or preferably by the use of intelligent "pigs", such as the sonic leak detection pig, which can be passed through the pipeline without causing loss of throughput.

Pipeline corrosion on land can be adequately prevented by provision of a good reinforced bitumen or tape pipe coating, supplemented by cathodic protection, either by sacrificial anodes or an impressed current system.

With proper design, construction and operation, pipelines could provide satisfactory performance in the foreseeable future.

4. REFINING

Refining of crude oil to manufacture a variety of marketable products is a complex technical operation. In accordance with crude oil supply and market requirements, refineries can differ significantly in size, complexity and flexibility. It is therefore difficult to describe a "typical" refinery, since each plant is characterised by unique features, such as processing equipment, range and quantity of products manufactured. The severity of the environmental impact of a refinery depends also upon its location. Despite the differences general similarities exist in the operation of a petroleum refinery and its pollution abatement and control practices.

For the purpose of this overview the impact of a refinery on the environment is reviewed under five distinct aspects, viz :

– Atmospheric emissions, including odour ;

– Waste-water effluent ;

– Solid waste ;

– Noise ;

– Other, especially visual and aesthetic effects.

A review of the source, cause and potential remedies of these impacts has been undertaken (1).

4.1. Atmospheric Emissions

Major air pollutants emitted by a "typical" refinery are hydrocarbons, oxides of nitrogen, sulphur oxides, carbon monoxides and particulates. In addition, minor quantities of pollutants such as ammonia and aldehydes may emanate from catalyst regeneration units. In common with high temperature combustion processes, polynuclear aromatics including benzo-a-pyrene are found in the flue gases. Under normal conditions very few process units emit pollutants directly into the atmosphere. Major processing units that do so are catalytic cracking units and sulphur recovery plants. Other sources of significant emissions are combustion processes – e.g. process heaters – and storage and loading facilities. The quantity of the emitted sulphur oxides is to a certain degree dependent upon the properties of the fuel used.

Hydrocarbons :

Major sources of hydrocarbon emissions are storage tanks, loading facilities and fugitive sources including seals of compressors and pumps, valves including relief valves, flanges, oil/water separators, barometric condensers etc. Depending upon original design, maintenance and good housekeeping standards, fugitive emission could be a substantial source of hydrocarbon emission in a refinery.

Oxides of nitrogen (NO_x)

All combustion processes will generate NO_x, i.e. heaters, boilers, some catalyst regenerators, flares etc.

(1) – Mofidi C.M.H. "*Environmental Conservation in the Petroleum Industry with Particular Reference to Refining*" Paper prepared for and presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry. UNEP/ISS. 5/4, Paris, 29 March - 1 April 1977.

Sulphur oxides (SO_x)

Major sources are again combustion processes, such as heaters and boilers, but also sulphur recovery units, and catalyst regenerators.

Carbon monoxide and particulates

CO and/or particulate matter may be emitted from combustion processes, especially FCC catalyst regeneration units etc.

Suggestions (1) for source control measures to reduce air contaminants from petroleum refining are :

Source	Control Method
Storage vessels	Vapor recovery systems, floating-roof tanks, pressure tanks, vapor balance, painting tanks white
Refinery Process Gas	Ethanolamine absorption
Catalyst regenerators	Cyclones-precipitator-in situ CO combustion-CO boiler, cyclones-water scrubber, multiple cyclones
Accumulator vents	Vapour recovery, vapour incineration
Blowdown systems	Smokeless flares-gas recovery
Pumps and compressors	Mechanical seals, vapor recovery, sealing glands by oil pressure, maintenance
Vacuum jets	Vapour incineration
Equipment valves	Inspection and maintenance
Pressure relief valves	Vapour recovery, vapour incineration, rupture discs, inspection and maintenance
Effluent-waste-disposal	Enclosure of separators, covering of sewer boxes and use of liquid seal, liquid seals on drains
Bulk-loading facilities	Vapour collection with recovery or incineration, submerged or bottom loading
Acid treating	Continuous-type agitators with mechanical mixing, replacement with catalytic hydrogenation units, incineration on all vented cases, cessation of sludge burning
Acid sludge storage and shipping	Caustic scrubbing, incineration, return system

(1) – Mallat R. C. *"Refinery Emissions and Effluents Control in the U.S. Petroleum Industry"* Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry, Paris, 29 March - 1 April, 1977.

Source	Control Method
Spent-caustic handling	Incineration, scrubbing, neutralization
Sweetening processes	Steam stripping of spent doctor solution to hydrocarbon recovery before air regeneration, replacement of treating unit with other less objectionable units
Sour-water treating	Use of sour-water oxidizers and gas incineration, conversion to ammonium sulfate
Mercaptan disposal	Conversion to disulfides, adding to catalytic cracking charge stock ; incineration, use of material in organic synthesis
Asphalt blowing	Incineration, water scrubbing (non recirculating type)
Shutdowns, turnarounds	Depressuring and purging to vapor recovery.

In addition to these control methods, sulphur recovery plants and sulphur plant tail gas systems can also be considered to be part of a refinery process gas control system.

With regard to major specific gaseous pollutants emitted from refineries, abatement and control methods for hydrocarbons, nitrogen oxides and sulphur oxides, are :

Hydrocarbons : These may be reduced at distribution points by discontinuing splash loading and following the practice of bottom loading rail and road tankers. There appear to be problems with safety and cost effectiveness of various recovery systems. For bulk storage of products in the 0.1 to 0.76 bars absolute range in tank farms, hydrocarbon losses are minimized by tanks with floating roofs. Hydrocarbon losses to the atmosphere could be an environmental problem in areas affected by photochemical smog. To reduce energy losses, cost effective techniques should be used.

Nitrogen oxides : Japan as well as a number of other countries, have regulations limiting nitrogen oxide emissions. In the United States, new source performance standards exist for controlling NO_x emissions from steam generators of more than 264×10^6 KJ/h heat input. Nitrogen oxides, however, are not presently considered to be a serious emission problem for refineries, except where they contribute to photochemical oxidant air pollution. Theoretically, it is possible to reduce NO_x concentrations in combustion process flue gases by 1) modifying the burners or firebox or both; 2) decomposing nitric oxide and possible nitrogen dioxide back to the elements oxygen and nitrogen; 3) or scrubbing the effluent gases. Of the three possibilities, modifications of the combustion equipment have been shown to be the most effective and probably offer the most promise of further NO_x reduction at combustion sources.

Sulphur Oxides : The main emissions of sulphur oxides, primarily sulphur dioxide, are from burning organic sulphur compounds contained in the fuels. Desulphurisation of refinery gas and fuel oil reduces SO_2 emissions, but also results in large quantities of solid elemental sulphur which must be disposed of. Sulphur recovery plants may not be cost-effective when recovery efficiencies are increased over the 96 per cent capability of a basic sulphur recovery plant, since the incremental cost of recovery by tail gas treatment exceeds considerably the value of the recovered sulphur.

Odour : The degree of nuisance caused by the emission of malodorous substances is usually very difficult to assess since individual reaction to odour is highly subjective. Threshold concentrations at which specific substances can be detected vary substantially from person to person and even with a given individual long time exposure to a particular odour can increase the threshold concentration.

Compounds such as H_2S, mercaptans and hydrocarbons can give rise to odour nuisance. Hydrocarbons that cause most complaints are due to unsaturated C_5/C_6 and aromatic compounds. Generally, steps taken to achieve safe working conditions within a refinery will alleviate odour problems in the vicinity of the refinery and so protect the general public.

4.2. Waste Water Effluents

Refinery waste waters may be divided into the following categories (1).

Water free of oil and organic material – boiler blowdown, boiler feed water make-up units, cooling water, rainwater from oil free areas.
Water accidentally contaminated with oil - rainwater from tank farms, pipe tracks and oil free processing areas.
Water continuously contaminated with oil but not contaminated with soluble organic material – rainwater from oil processing areas, tank drain water, deballasting water, cooling water blowdown, flushing and cleaning water.
Process water – water that has been in intimate contact with processing streams, originating from steam stripping, crude oil washing, some chemical oil treatment processes. It contains variable amounts of oil and soluble material such as ammonium sulphide, phenols, thiophenols, organic acids and inorganic salts such as sodium chloride.

These categories of water need different treatment and are often kept segregated in a modern refinery to reduce the cost of water treatment

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(1) – Cadron E.C. and Klein J.P. "*Emissions and Effluents from European Refineries*" Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry, Paris, 29 March - 1 April 1977.

facilities. In addition, water recirculation is practised extensively in modern refineries in contrast to older refineries where much less segregation and recirculation has been built into the design. Older refineries are thus not able to meet the same water quality standards as modern refineries and waste-water treatment costs are more expensive, because of the large and unsegregated streams.

The pollutant parameters considered as significant for petroleum refining are BOD_5, COD, TOC, Oil and grease, NH_3-N, Phenolic compounds, sulphides and chromium.

Wherever possible the first undertaking in dealing with refinery effluents should be to reduce and abate the formation of waste-water effluents by reducing water use, in-plant improvements and by good house-keeping.

Waste water treatment technology can be divided into three categories.

Primary treatment : main techniques are sedimentation for suspended solids, gravity separation for separating undissolved oil present as small droplets in waste water and steam strippers for removing volatile malodorous compounds particularly hydrogen sulphide.

Secondary treatment : for the removal of non-dissolved oil and/or the removal of dissolved organic material. Oil which is not separated in the gravity separators can be removed by filtration, flocculation and/or flotation, sometimes with the addition of chemicals. The dissolved organic material is generally removed by biological oxidation in systems such as oxidation ponds, activated sludge and trickling filters. Secondary treatment is applied after optimum results are achieved by primary treatment.

Tertiary treatment : is to safeguard against a failure in primary and secondary treatment and to remove the remaining contaminants which could interfere with immediate re-use. Holding basins are widely used and additional biodegradation takes place in the basin owing to long residence time. Filtration can also be used as a tertiary treatment to remove mainly entrained biomass from the biological oxidation process.

With the exception of holding basins, tertiary treatment is not generally used in European refineries. With primary and secondary treatment facilities, and with adequate segregation and recirculation, a waste water output of less than 0.4 ton per ton of crude processed can be achieved. Also, the following criteria can be met.

Suspended solids	30 mg/l or 0.012 Kg/t crude processed
Oil	10 mg/l or 0.004 Kg/t " "
BOD_5	30 mg/l or 0.012 Kg/t " "

In countries where land is cheap and climatic conditions favourable, aerated lagoons and oxidation ditches are preferable to activated sludge and trickling filter systems.

Effluent standards should be related to volume throughput of a refinery water system, rather than specified as parts per million of pollutant in water, which may be achieved by dilution. Standards for refinery effluent should as far as possible be set on a local basis, taking into account the nature of the receiving waters, the uses to which they are put (amenity, recreation, fishing, wild life preservation etc.), the technology available for treating wastes and the benefits to be derived from the expenditure involved.

4.3. Solid Wastes

A variety of solid wastes is produced in a refinery and these include catalyst fines from cracking units, coke fines, iron sulphide, filtering media, and sludges from tank cleaning operations, oil-water separators and biological oxidation processes.

Handling and disposing of solid wastes can be major cost items in a refinery. However, much can be done to alter the nature and quantity of sludges.

Two major options are available for "ultimate" disposal of solid wastes : incineration, land farming and land filling. Incineration technology is well established, with fluid-bed incinerators being the most prevalent type of installation. Sludges, emulsion and caustic wastes are stored in separate tanks and pumped to the incinerator where they are burned in the fluid-bed at about 700° C.

Spent calatysts that are not worth processing for recovery of valuable components, are generally disposed of by means of landfill.

4.4. Noise

Noise, defined as unwanted sound, is an annoyance. Excessive exposure can lead to physical and psychological disorders, which may have an adverse effect on work quality and productivity. Refinery noise affects two general groups of people, the inplant workers and the surrounding community.

Sources that generate noise in a refinery are, motors, high speed compressors, control valves, piping systems, gas turbines, flares, aircooled heat exchangers, cooling towers and steam leaks and vents.

Noise reduction can be accomplished by containment and absorption of the sound waves by silencers, plenum-chambers, lagging with acoustic materials, barriers and special enclosures or by redesigning equipment to reduce gas velocity or mechanical noise. Noise attenuation can also be achieved by locating noise sources away from areas where its impact would be objectionable. Generally sound pressures have an inverse square relationship with distance.

Typical noise sources in a refinery, their approximate sound pressure levels, as well as some of the common methods for noise reduction have been reported (1).

4.5. Visual and Aesthetic Effects

These are to a large extent subjective. Factors such as cleanliness, good house-keeping, landscaping, architectural style and colour scheme can be helpful. However, some degree of objectivity can also be achieved in assessing visual impacts by such parameters as smoke and particulate emissions, flares and oil spills, since these are possible to quantify and hence regulate. Smoke emissions, water vapour from stacks, exhaust steam, evaporation from cooling towers, and atmospheric haze caused by particulates, all create adverse visual effects and are identified as pollution by the general public. Photochemical smog resulting from the reaction of NO_2 and hydrocarbons in the presence of sunlight also cause adverse visual effects as well as health hazards.

In summary, where appropriate legislation for control of refinery discharge does not exist, regulations relevant to local conditions should be considered and implemented for :

- emissions to the atmosphere of sulphur oxides, hydrocarbons, particulate matter and odours ; additionally, where necessary, nitrogen oxides and carbon monoxide ;
- effluents containing hydrocarbons (free, emulsified and water soluble), sulphur compounds, ammonia, phenols, cyanides, inorganic particulate matter and trace toxic metals ;
- disposal of solid wastes, sludges, sediments and product treatment wastes, taking care not to create problems of air or water pollution ;
- noise.

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(1) – Hall R.H. and Krawciw W. "***Sensory Pollution and the Petroleum Industry***" Proceedings of the IPIECA Symposium on Petroleum and Environmental Conservation. Tehran, April 7-9, 1975.

5. OIL SPILLS

5.1. Methods for Dealing with Oil Spillages

Tides, currents, wind and waves, amount of oil spilt, the gravity, temperature viscosity and emulsibility of the oil, as well as the location where it was spilt will influence the decision regarding what actions need or need not to be taken. Generally four basic steps are involved.

Limitation : Thorough training of personnel is an effective way to prevent and minimize spills. They should be aware of the risk of oil spills and be prepared to take immediate and effective action, for example, the closing of an accidentally opened valve, the ceasing of pumping through a ruptured line or the plugging of a leak. After a tanker accident every effort should be made to salvage a cargo to prevent more spillage. The oil which has escaped must be dealt with, preferably while still afloat, to minimize pollution of coastal areas and harm to wildlife.

Containment : When crude oil is poured on pure water, and the quantity is small, the oil quickly spreads out to a very thin film of 0.3 μm and less. The spreading is aided by the surface active agents which crude oils contain. When large quantities are spilled and the water surface is heavily contaminated, then the thickness near the source may be 1 mm or more. The spreading of oil on a surface of water can be computed. For example, 1 m^3 of Middle East crude will spread in 10 minutes to a circle 48 m in diameter with an average thickness of 0.5 mm. In 100 minutes, this will have grown to 100 m in diameter with an average thickness of 100 μm. While spreading, the fate of the oil at sea depends on the degrading factors, such as evaporation, emulsification and bio-degradation.

When oil is spilt, it is important to contain the spill, so that it will not spread over a large area and render subsequent need for recovery costly and time consuming.

The choice of containment equipment will depend on availability, possibility of transporting and launching it as well as its effectiveness.

The state of the sea has a decisive influence on the effectiveness and the applicability of equipment. The different types are :

- mechanical booms, which, depending on the circumstances, can be used in a static or sweeping mode, towed or anchored,
- pneumatic barriers,
- chemical barriers.

Each type has its advantages and disadvantages, but they are not effective with wave heights of more than 2 m. or under heavy surf. In most seas of north west Europe, containment measures can be used only in protected harbours, fiords, and lochs.

Removal : The next step in combating an oil spill is the removal of the oil from the surface and this can be achieved by one of the following methods or a combination of them :
– mechanical,
– chemico-mechanical,
– chemical.

As much oil as possible should be quickly removed before it is deposited on to beaches, estuaries, harbours, fishing grounds, wild life habitats and near water in-takes. Once deposited, not only are the environmental impacts compounded, but the problems encountered and expenditure involved in final removal and clean-up increased.
With the **mechanical method**, devices such as skimmers, rotating drums and discs or endless belt pick-up devices have been used. The "weir" type involves the separation of the oil film from the surface of the water by passing the film over a "weir" into a collecting area. Such skimmers are very sensitive to wave motion and normally unsuitable for use at sea. Recovery rates from calm water range between 1 and 30 tonnes per hour, according to the thickness of the oil film and the size of the device. Another type of mechanical device involves the use of moving belts or ropes or revolving discs. These belts, ropes or discs pass through the oil film and the oil which adheres to them is scraped or squeezed off and collected. Wave action does not have as much affect on this type, therefore it has more potential for use at sea. Typical collection rate is between 25 and 100 tonnes an hour depending on conditions. Yet another type of mechanical device relies on centrifugal force to separate oil from water. The oil which has a lower density than water, collects in the center of the vortex from where it is pumped to storage tanks. The vortex motion is induced either by a powered impeller or by the forward motion of the collection vessel. At present, their suitability has not yet been demonstrated under spill conditions.

The advantages of mechanical methods are that the oil is physically separated and removed from the water, thus preventing ecological effects. Furthermore, the spilled oil that is recovered can be reused. The major drawback of mechanical methods is that in rough seas the removal efficiency is low to zero.

Chemico-mechanical methods include, sinking, gellation, combustion and sorption.

Several materials such as sand, flyash, chalk, gypsum, have been used to sink an oil slick from the water surface. There are two basic principles underlying the sinking method.

- adding a sinking agent that will make the density of the oil greater than that of water;
- adding a high density sinking agent that will absorb the oil as it sinks through the slick to the bottom.

Although some of the oil will return to the surface in the first few minutes, the remainder stays down, and in some cases for at least a period of months, promoting biodegradation. Dutch and UK trails however, show sunken oil to be unstable. Nor is the ecological effect on the benthic population well understood. Indeed, fouling of fish and gear is a major economic reason why sinking can be used only in areas where non fishing takes place at any time of year. In the United States of America and Canada, the use of sinking agents is now prohibited.

Gelling agents have been applied onto oil slicks to cause it to coagulate, concentrate, fix and simplify collection. This method is however expensive with the presently used gelling products, because the application ratio is, at best, one to one. Generally a good deal of mixing energy is required to ensure gellation takes place and furthermore, more efficient harvesting methods must be developed to make the method viable. The use of such agents under improper conditions or in excessive quantities can actually complicate the removal operation and have undesirable environmental effects.

A large number of natural sorbents have been proposed and used. For example, natural materials such as coconut husk, straw, hay, reeds, bagasse etc. have been succesfully used for treating oil spills. They function by virtue of their having an oleophilic surface so that the oil is trapped in the natural criss-cross strands. Some oil is trapped through capillary action. Under ideal conditions, these materials pick up about 5 times their weight of oil, but under actual spill conditions, the sorption capacity is approximatively 1 g/g. With the exception of coconut husks, the other materials tend to absorb water and sink after a prolonged period. Sawdust and wood chips have also been used but they also tend to sink.

A number of natural or treated minerals which have a porous structure such as volanic ash, pumice, mineral and rock wools have been tried. Of particular interest is pulverized fuel ash. This waste material from coal burning power stations is available in vast tonnages for example, in the U.K., and it can be easily surface treated to absorb oil.

Many man-made polymers are suitable for use as sorbents, most of them are strongly oleophilic and when used as foams or fibres will retain oil. These synthetic materials generally have sorption capacities of about 30 g/g but the efficiency decreases, with weathered crude.

The criteria for considering the best material to use for sorbing an oil spill, must be considered with regard to availability and cost. A technically less satisfactory material may under some circumstances have a much higher cost effective ratio than the technically more satisfactory, but higher priced material.

The use of chemical dispersants as an option for oil spill control in those instances where oil cannot be left to evaporate and degrade naturally because it is causing or threatening damage, is one which many countries are now considering. Yet anxieties exist in some states on the question of ecotoxicological effects, and research is now being carried out on the fate and ecotoxicological effects of hydrocarbons in the marine environment (see following section). Uncertainties also exist concerning the distribution of oil/dispersant mixtures as well as the rates of application and mixing energy requirements for the dispersant.

Most toxicity data for dispersants have been derived from controlled laboratory biological experiments commonly referred to as bioassays. Although there are many types of laboratory bioassays, only two are in general use, the static and flow-through bioassays.

Bioassay results are generally reported as the median tolerance limit (TL_m or TL_{50}) or median lethal concentration (LC_{50}). These symbols indicate the concentration of a substance that kills 50 percent of the test organisms within a specified time period. As the TL_m is a lethal threshold concentration it is for this reason that the term toxicity has been generally accepted in giving bioassay data.

The TL_m is a convenient reference point for expressing the acute lethal toxicity of a dispersant but it is not the safe level or safe concentration of a dispersant for all aquatic organisms. The safe level is not known, but it is less than the TL_m.

There are at present no international standards that define toxicity.

GESAMP in 1969 proposed grades of toxicity for pollutants in the aquatic environment. As a result of a recommendation of the U.S. National Academy of Science – National Academy Engineering Committee on Water Quality Criteria, an application factor of 0.01 of the LC_{50} values for dispersants, was derived for discussion purposes (1), and these are shown below. A dispersant to oil ratio of 1:10 was also suggested, based on current information on new dispersants.

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(1) – McCarthy Jr. L.T. "*Considerations for Field use of Dispersants*" Proceedings, 1977 Oil Spill Conference (Prevention, Behaviour, Control, Clean-up) Sponsored by American Petroleum Institute, Environmental Protection Agency and the United States Coast Guard. New Orleans, Louisiana, March, 1977.

Grades of Toxicity and Dispersant Concentration

Grades	TL_m mg/l	Application factor	Dispersant Concentration (mg/l)
Practically non toxic	10,000	0.01	100
Slightly toxic	1,000-10,000	0.01	10
Moderately toxic	100-1,000	0.01	1
Toxic	1-100	0.01	0.1
Very toxic	1	0.01	0.01

With the recent trials at sea in the United Kingdom however, a ratio of 2:5 was used and the study of a number of incidents suggest that the ratio between dispersants and oil has been in practice 1:3, although under some operating conditions the ratio may be as high as 1:1 or even greater (1).

The most important parameter with regard to dispersant effectiveness is the oil slick thickness. For a given quantity of dispersant the degree of oil dispersion is indirectly related to slick thickness, i.e. the thinner the slick the more extensive is the dispersion.

In the United States of America, the use of chemicals for cleaning up oil spills is regulated by the National Contingency Plan, Annex X. Dispersing agents, defined as chemical agents which emulsify, disperse, or solubilize oil into the water column or act to further the surface spreading of oil slicks in order to facilitate the dispersal of oil in the water column, are included in the schedule of chemicals and other additives for removing oil and other hazardous substances discharged.

Approval for the use of dispersants is given when their use will (2) :

- reduce hazards to human life or limb or reduce explosion or fire hazard to property;
- prevent or reduce hazard to a major segment of populations or vulnerable species of water fowl, and
- result in the least overall environmental damage or interference with designated use.

(1) – Department of the Environment "*Accidental Oil Pollution of the Sea*". Pollution Paper No. 8 Her Majesty's Stationery Office, London (1976).

(2) – Snyder H.A. Jr. "*Federal Regulatory Control of Oil Spill Removal Methods*" Proceedings of the 1975 Conference on Prevention and Control of Oil Pollution. American Petroleum Institute, Washington D.C., (1975).

The U.S. Environmental Protection Agency has requested 17 items of technical product data from manufactures or suppliers of dispersing agents. The information will be used to maintain an effective reference file to advise on-scene coordinators and EPA regional response team members.

In the United Kingdom, in recognition of different conditions of use of dispersants at sea and on beaches, two different testing procedures have been developed. These are the "sea test" and the "beach test" (1).

The "sea test" is based on the premise that where dispersants are properly applied at sea, marine organisms are exposed, not to a suspension or solution of a dispersant alone, but to a mixture of oil and dispersant. The test compares the toxicity of oil dispersed under standard conditions of mechanical agitation, with that of the same amount of oil dispersed with an equal quantity of dispersant under the same condition of mechanical agitation.

The "beach test" takes into account that when dispersants are used to clean oil from beaches, animals are exposed to very different conditions than those at sea. Both oiled and unoiled animals may be exposed to undiluted dispersant and left in the air until the incoming tide, or the use of water hoses, washes off the contaminants. The toxicity test of dispersants for beach use has, therefore, been based on these exposure conditions.

Final Clean-up : Oil should always be removed from lagoons, land-locked seas, from coastal areas where the tidal differences are slight and consequently the exchange of water small, and from beaches and coast-lines. Where a coast-line is threatened by oil, contamination can be minimized by pegging down organic sorbent bales such as coconut husk, straws etc. at the low water mark, disposing the sorbed material when the tide has gone out and replacing it with fresh sorbent material for the next tide. Oil can also be removed by burning, provided that damage to structures can be avoided and air pollution tolerated. However, oil, especially weathered crude, when it is spread out in a thin layer on a cold surface, is very difficult to ignite, and even when ignited, is difficult to burn off completely, despite the use of an efficient flame gun. Ignition and combustion can be accelerated by treating the polluted areas with chemical oxidizing agents or by using absorbent materials for wicks. Combustion, however, is never complete, even in calm weather and a black mass of sooty

(1) – Blackman R.A.A., Franklin, F.L. , Norton M.G. and Wilson K.M., *"New Procedures for the Toxicity Testing of Oil Slick Dispersants"* Fisheries Research Technical Report No. 39. Ministry of Agriculture Fisheries and Food. Directorate of Fishery Research. Lowestoft U.K. (1977).

residue tends to be left. Experiments with water-in-oil emulsion and tar lumps shows that when burning, the oil becomes thinner, and seeps down into the beach material, so that although a relatively innocuous carbon mass is left on top, some of the oil remains almost unchanged underneath. If the oil can be collected, burning becomes more feasible as the oil can then be ignited more readily and combustion sustained.

With solid or semi-solid tarry deposits on beaches and with lumps of sand/oil mixture, **mechanical removal** is one of the most practical methods. Mechanical raking with agricultural implements may be possible, but if the deposits are scattered or if the beach is inaccessible to vehicles, removal will have to be done manually. If the beach is sandy and contamination heavy, then the upper layer of sand can be bulldozed away.

6. EFFECTS OF PETROLEUM

6.1. Effects of Petroleum in the Marine Environment

Tanker accidents, such as that of the Amoco Cadiz, and increased off-shore exploration and production of petroleum with the associated risks of blow outs, have heightened the concern over the possible effects of petroleum hydrocarbons in the marine environment. Petroleum hydrocarbons also enter the environment from other sources and estimates of the annual input are (1):

Comparison of Estimates for Petroleum Hydrocarbons Annually Entering the Ocean, circa 1969-1971

	Authority (Millions of Tons per Annum)		
Source	MIT SCEP Report (1970)	USCG Impact Statement (1973)	NAS Workshop (1973)
Marine transportation	1.13	1.72	2.133
Offshore oil production	0.20	0.12	0.08
Coastal oil refineries	0.30	–	0.2
Industrial waste	–	1.98	0.3
Municipal waste	0.45	–	0.3
Urban runoff	–	–	0.3
River runoff[a]	–	–	1.6
SUBTOTAL	2.08	3.82	4.913
Natural seeps	?	?	0.6
Atmospheric rainout	9.0[b]	?	0.6
TOTAL	11.08	?	6.113

[a] PHC input from recreational boating assumed to be incorporated in the river runoff value.
[b] Based upon assumed 10 percent return from the atmosphere.

(1) – National Academy of Sciences "*Petroleum in the Marine Environment*" National Academy of Sciences, Washington D.C., 1975.

Evaluation of the effects of hydrocarbons in the ocean requires reliable analytical techniques. The methods must be capable of differentiating hydrocarbons into various classes and categories as well as sensitive enough to measure accurately minute concentrations, in the range of parts per trillion (10^{12}), of individual low molecular weight hydrocarbons that may be present. No one analytical technique can solve all types of problems encountered in the determination of hydrocarbons in the marine environment. For the lower molecular weight hydrocarbons, ($C_1 - C_{10}$) gas equilibrium, gas stripping and vacuum degassing techniques have been used. For C_{11} plus hydrocarbons, gravimetric, UV absorption spectrometry, UV fluorescence spectrometry, infra red spectrometry, gas chromatography and mass spectrometry have been used. The advantages and disadvantages of each of these methods as well as the importance of sample collection, handling and preservation have been reviewed by the National Academy of Science (1975) workshop.

The ultimate fate of spilled petroleum hydrocarbons in the ocean is one of the following :

- loss of the lower molecular weight components by evaporation and dissolution
- oxidation by physico-chemical or biological means to carbon dioxide
- dispersal in the water column
- incorporation into sediments.

Oil slicks and tar balls are transient conditions and do not represent the ultimate fate of petroleum spilled on the sea.

Although it is known that petroleum contains small amounts of carcinogens and possibly small amounts of other harmful materials, the quantities that could be ingested by eating contaminated marine organisms is estimated to be no greater than that acquired from eating other foods. Recent published reports (1) indicate marine organisms rapidly purge themselves in oil-free waters and they suggest that it is unlikely that oil contamination would become more and more concentrated by transfer from one trophic level to the next up the food chain.

The report (2) of the Joint Group of Experts in the Scientific Aspects of Marine Pollution, GESAMP has concluded that no direct correlation has

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(1) – Mertens E.W. and Allred R.C. *"Impact of Oil Operations on the Aquatic Environment"* Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry, Paris, 29 March - 1 April 1977.
Mertens E.W. and Gould J.R. *"The Effects of Oil on Marine Life : An Overview of Research Sponsored by the American Petroleum Institute"*. Paper prepared for the American Petroleum Institute Tanker Conference. Houston. Texas, June (1977).

(2) – Joint Group of Experts on the Scientific Aspects of Marine Pollution *"Impact of Oil on the Marine Environment"*, Reports and Studies No.b., FAO, Rome, 1977.

been found to exist between the presence in the sea or in the sea food of petroleum carcinogens and carcinomas in marine ecosystems or cancer in man. Nonetheless, to reduce potentially harmful effects to man, all sources of carcinogens should be investigated, and if possible, eliminated.

Documented studies exist on the biological, chemical and physical acute and long-term effects of petroleum in the marine environment. A majority of these studies however, have been conducted in estuaries, on limited target species and by different sampling procedures and analytical techniques which are not comparable. Hence an accurate evaluation and comparison of the fate and longterm effects of hydrocarbons cannot be made. Nevertheless the National Academy of Science (1975) reports that :

- Concentration of petroleum hydrocarbons dissolved in water is generally low (< 10 ppb). Whilst that in sediments ranges from 1,500 to 5,700 ppm in polluted coastal sediments and from 26 to 130 ppm in nearby unpolluted areas. On the outer coastal shelf, concentration in sediments might be as high as 20 ppm and in the deep ocean 1 to 4 ppm is the usual concentration.
- Different petroleum products were found to have different effects, with toxicity being most pronounced for refined distillates and physical smothering most severe with viscous crudes or fuel oils.
- The amount of oil and the type of organism afflicted was also found to be important. For example, a single coating of fresh or weathered crude oil or its derivatives on certain bird species or on seeds of plants caused death, whereas marsh plants (1) were killed only after several coatings. In general, emergent plant life was less likely to be affected than marine boita, unless the spill occured in tropical waters where mangroves were present.
- The extent of mortality depends on local conditions and is greatest when the release of oil is confined to inshore areas where natural marine resources are abundant. Intertidal organisms tend to be more resistant to stress than subtidal species.
- The rate of reproduction and growth of organisms comprising an ecological community is important. If the rate is very low, then even if oil spills are widely spaced in time, some species may never recover.
- In marshes or estuaries which are well isolated from one another, almost all organisms spring from the resident population. If this population is completely destroyed, recolonization by chance immigration from a distant estuary will probably take a very long time. Moreover the resident population of estuaries provides shelter and food for the young stages of many commercially important marine organisms such as shrimp and fish.

(1) – Unpublished studies at Chedabucto Bay, Nova Scotia in years following grounding of tanker Arrow, show that marsh plants can die on the second year after oiling as a result of delayed mortality. Private communication from Environment Canada.

– Recovery of oil polluted areas varies greatly, depending on the flushing of the polluted area, the type of the sediments on the substrata, and the degree of isolation of its ecosystems and the kinds of organism that form them. The time-periods of recovery may vary from a few months to several years. In general, the initial stages of recovery are characterized by opportunistic species that are often very productive, with a much longer time required to restore the community to one that supports more long-life species.
– Very little is known about the effect of oil on pelagic species, and without more research, it is premature to conclude anything about the effects of oil on the open ocean.

One way to minimize the effects of petroleum in the marine environment is to reduce the input of oil to the sea. The capability to achieve that reduction exists, but is dependant on a much wider adoption of known control measures by all countries. International operation of tankers, their control and surveillance must be improved as must land based shipping/operations to minimize oil spills and discharge. Reducing inputs to coastal waters from coastal refineries and river run-off is much more difficult, since that requires improved control of petroleum hydrocarbon sources in municipal and industrial waste water. Hydrocarbons from atmospheric fallout may be reduced by controlling automobile emissions.

6.2. Ecotoxicological Effects

The ecotoxicological impacts, which are the appraisal of the toxic effects of chemical compounds on natural populations in various ecosystems, caused by the petroleum industry have been reviewed (1). The total quantity of pollutants released into the environment in 1974, as a result of oil and gas combustion is estimated to be :

Pollutant	Oil firing (10^6 tons)	Gas firing (10^6 tons)
Aldehydes	0.3	0.02
Carbon monoxide	0.2	0.007
Hydrocarbons	0.6	negligible
Nitrogen oxides as NO_2	20	6
Sulphur dioxide	60	0.01
Particulates	2	0.4
Benzo-a-pyrene	10^{-5}	3×10^{-6}

Based on the combustion of 1736×10^6 tons of liquid fuels and 1549×10^6 tons of oil equivalent gas and does not include the release from coal, wood, industrial processes as well as other anthropogenic emissions.

(1) – Korte F. "*Potential Impact of Petroleum Products on the Environment*" Paper prepared for and presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry. UNEP/ISS 5/5, Paris, 29 March - 1 April, 1977.

Particulates include metals from residual fractions of the crude oil as well as additives, most notably lead, used in fuel products. The metal fractions released, consisting mainly of vanadium and nickel are estimated to be about 0.06×10^6 tons and those of lead to be about 380,000 tons per year from the combustion of gasoline.

The whole issue of atmospheric lead resulting from the use of petroleum products has been and continues to be extensively assessed. Recent publications on this topic are by WHO (1) and UNEP (2).

Carbon dioxide is the main product of combustion and is released in quantities of approximately $1 - 2 \times 10^{10}$ tons per annum which is estimated to be about 10 - 20 percent of that released from natural sources. The increase in global concentrations due to combustion is estimated to be 0.7 to 1.3 ppm/year. However, the meteorological or climatic effects of this increase are still not known.

The ecological effects of carbon monoxide are equally uncertain. Until recently fuel combustion was assumed to account for almost all of the total quantity emitted. However, it is now estimated that at least five times more CO is produced through natural reactions such as methane oxidation, release from algae and volcano eruptions. Removal sinks for CO are not well known, but the gas does not seem to accumulate in the troposphere.

Nitrogen dioxide and nitric oxide are of current concern with regard to pollution of the stratosphere. Nitric oxide is thought to result from oxidation of nitrous oxide and the concentration of nitrogen dioxide in the stratosphere has been estimated at 0.20 ppm. Among the various atmospheric oxides of nitrogen, nitric oxide and nitrogen dioxide are the most important in relation to photochemical reactions and their known effects on materials, vegetation, and health. In a study on the medical and biological effects of nitrogen oxides the U.S. National Academy of Sciences (3) concludes that at present "no specific information is available on the effects of nitrogen oxides on animals in ecosystems. Research on crop plants indicates that NO_X should have effects similar to other air pollutants on some plant communities." The same report also states "experimental fumigations have shown that nitric oxide is less injurious to vegetation than nitrogen dioxide, and both are less phytotoxic than sulphur dioxide, gaseous fluoride or photochemical oxidants. Nitrogen dioxide induced injury in the field has usually been associated with

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(1) – World Health Organization *"Environmental Health Criteria 3 - Lead"* WHO, 1977.

(2) – UNEP *"Lead Evaluation Technique for one of the Priority Pollutants"* Report of the Executive Director. Sixth Session of the Governing Council. UNEP/GC/Info/8, January, 1978.

(3) – National Academy of Sciences *"Medical and Biological Effects of Environmental Pollutants. Nitrogen Oxides"*. National Academy of Sciences, Washington, 1977.

accidental acute exposures near industries that manufacture or use nitric acid. There have been no confirmed reports for nitric oxide injury to vegetation in the field".

Sulphur dioxide is produced by natural sources as well as by man-made activities. Hydrogen sulphide is the major biosphere source of sulphur compounds. The conversion of hydrogen sulphide to sulphur dioxide over land appears to be so rapid that the detection of any hydrogen sulphide over the oceans or polar regions is unlikely. Of man-made processes, the combustion of sulphur containing fuels as well as smelting give rise to most of the oxides of sulphur in the environment. The oxides of sulphur are in turn partially converted to sulphuric acid aerosol or to particulate sulphate. The sulphur compounds in particulate form may be contributing to the increase in atmospheric turbidity as well as to plant damage, now being observed in many local and regional areas around the world.

The ecotoxicological impact of anthropogenic sulphur compounds released to the environment is of major concern, although monitoring results show ground level concentration of SO_2 to have decreased in European cities in recent years (1). A detailed analysis of air pollution and human health (2) has shown sulphates and sulphur dioxide to exhibit satistically significant associations with mortality. The study which was based on 69 Standard Metropolitan Statistical Areas, (SMSAs), in the United States of America, showed that the mean and maximum biweekly sulphur dioxide readings for these areas were 33 $\mu g/m^3$ and 116 $\mu g/m^3$ respectively. Although, the corresponding primary standard based on the annual arithmetic mean and on the maximum twenty-four hour values were 80 $\mu g/m^3$ and 365 $\mu g/m^3$ respectively, (see chapter 7), sulphur dioxide was still significantly related to mortality rates across the SMSAs.

Most hydrocarbons have been found biodegradable. Nevertheless polynuclear aromatic compounds (PNA's), including those with heteroatoms (N, S, O) present in petroleum as well as in the combustion products, benzo-a-pyrene and benzene, are considered to be carcinogenic and consequently are causing concern.

Degradation mechanisms as well as toxicity studies are derived from laboratory experiments, where conditions are controlled or even optimized. In practice, environmental conditions are changing, more numerous and not quantifiable. Synergistic effects should also be considered ; pure benzo-a-pyrene for instance, has been reported not to cause lung cancer when inhaled, whereas it does exhibit carcinogenic properties in the presence of other compounds such as SO_2.

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(1) – WHO "*Air Quality in Selected Urban Areas 1973-1974*" WHO, Geneva (1976).

(2) – Lave. L. and Seskin. E.P. "*Air Pollution and Human Health*". Published for Resources for the Future. The John Hopkins University Press, Baltimore and London, 1977.

On a global basis PNA's although not so readily metabolized when compared with other hydrocarbons, do not present an ecotoxicological threat, because of the small absolute quantity that is discharged.

The great majority of these hydrocarbon products are eventually degraded, both under biotic and abiotic conditions. Thus despite the natural release of hydrocarbons and the vast amounts of petroleum products involved in human activity over the past century, no hydrocarbons appear to have accumulated in the global environment. Nevertheless precautions must be taken to prevent undue accumulation of hydrocarbons in the working environment.

Because of their exposure to petroleum and its products, refinery workers are likely to indicate before the general population any deleterious effects on health. Hence they make the best subjects for epidemiological research.

Studies of disability, absenteeism and specific disease experience are useful indicators of morbidity in a work force. Mortality studies in refinery employees are also informative with regard to death and survival patterns, when compared with other worker groups and the general population. Studies have been reported (1) which support the concept that the health status of refinery workers is good, with relative freedom from disorders which lead to premature death.

7. STANDARDS AND REGULATIONS OF SOME COUNTRIES

The major if not main purpose of environmental standards and regulations is to protect people, whether in their work place or in the environment at large, from hazards to health or safety that could result from products and substances consumed internally or released directly or indirectly into the environment. Measures to protect the environment by limiting or preventing the release of pollutants fall into a number of categories. They may be statutory or voluntary, regulations or guidelines, enforced by different agencies, sometimes set up by central governments, sometimes national and sometimes local.

Of the different types of standards, three are of particular relevance to this overview. They are :
Products Standards – which set levels of pollutants or nuisances not to be exceeded in the composition of the product, for its intended use (eg. the

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(1) – Weaver N.K. *"Morbidity and Mortality in Refinery Employees"* Paper presented at the UNEP Industry Sector Seminar on Environmental Conservation in the Petroleum Industry. Paris, 29 March - 1 April, 1977.

sulphur content of fuel oil, lead additives in gasoline) or specify properties or design characteristics (as for motor vehicle design) in order to limit the levels of pollutants emitted.

Emission/Effluent Standards – which set levels of pollutants or nuisances not to be exceeded in discharges. Restrictions on the disposal of solid wastes, occupational noise emissions and radioactivity are a similar type of control.

Environmental Quality Standards – which prescribe, usually but not necessarily with legal force, the levels of pollution not to be exceeded in a given geographical area of medium, however many the sources of emissions.

To protect the environment, different countries have used different approaches as well as standards, based on the availability and interpretation of scientific data, subjective judgemental values and socio-economic considerations. Two main approaches are in operation. One is the "best practicable means" typified by the system used in the United Kingdom, and the other is the setting of national discharge and/or environmental quality standards.

In the **United Kingdom**, the Alkali Act of 1874 established many of the principles and basis for pollution control used up to the present time (1). As well as setting emission standards for hydrochloric acid gases from alkali works, that Act and its successors developed the concept of reducing pollution by the "best practicable means", in the light of local circumstances – a principle since extended to other forms of air pollution. The Royal Commission on Environmental Pollution in its Fifth Report endorsed the concept and proposed that it should be extended to cover industrial pollution affecting water and land as well as air.

In the UK approach, the toxicity of pollutants, the circumstances of their release, the likelihood that they will reach a "target" (human or otherwise) and the impact they may have on the target whether immediate or long term and thus their bio-accumulative quality, are considered. Once substances are identified as potentially harmful and provided that sufficient data is available the hazards can be evaluated, quality objectives can be recommended for specific environmental circumstances and individual discharges can then be controlled to meet these objectives. Since each case varies, each hazard is treated separately, pollutant by pollutant and disposal situation by disposal situation, but using the general knowledge gained through similar cases elsewhere.

To date no air quality objectives or standards have been defined in the United Kingdom but some are now under consideration.

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(1) – Department of Environment. "*Environmental Standards, a Description of United Kingdom Practice*". Pollution Paper No. 11. Her Majesty's Stationery Office, London (1977).

With marine pollution from ships, the UK supports a global approach to the problem, involving generally applicable discharge standards which depend on the distance of a discharge from land, whilst realizing that more stringent standards may sometimes need to be applied in certain specially sensitive areas of the world's seas, provided this is done by international agreement. With regard to marine pollution from the offshore oil industry, the philosophy of "best practicable means" is extended, for present production areas which are well out to sea.

National discharge standards and regulations have been promulgated by a number of countries. Some examples of these are given in this section for illustration only and they must not be construed as proposed values by UNEP nor recommended for adoption. As this section is not intended to be a comprehensive survey, omission of a country does not imply that standards and regulations do not exist in that country.

7.1. Effluent Discharge Standards

In a number of countries, there are regulations relating to water quality standards and to the discharge of effluents into surface water. Furthermore, authorities responsible for issuing discharge permits may fix special conditions depending on local circumstances. These special conditions may be more severe than the general conditions, in order to achieve certain quality objectives, or temporarily they may be less severe if there are technical or economic reasons for not being able to meet the general regulations.

Canada :

The Petroleum Refinery Liquid Effluent Regulations, P.C. 1973-3440 of 30 October 1973 authorized deposits of deleterious substances in water frequented by fish, as follow :

SCHEDULE I

Authorized deposits of Deleterious Substances

	Column I	Column II	Column III	Column IV
Item	Deleterious Substance	Monthly amount in pounds per 1,000 barrels of crude oil	One day amount in pounds per 1,000 barrels of crude oil	Maximum daily amount in pounds per 1,000 barrels of crude oil
1.	Oil and Grease	3.0	5.5	7.5
2.	Phenols	0.3	0.55	0.75
3.	Sulfide	0.1	0.3	0.5
4.	Ammonia Nitrogen	3.6	5.7	7.2
5.	Total Suspended Matter	7.2	12.0	15.0

If the daily and monthly arithmetic mean of the actual deposits for each substance does not exceed the respective daily and monthly authorized deposits and if the pH of the waste water effluent or once-through cooling water is within the limits of 6.0 and 9.5.

These regulations apply to new refineries. For existing refineries, a guideline in similar but different limits (generally twice that of new refineries) applies but is not yet a legal requirement.

When storm water is deposited by a refinery on any day, the authorized deposit of a deleterious substance may be increased on that day by an amount shown below in schedule II.

SCHEDULE II

Additional Authorized Deposits of Deleterious Substances When Storm Water is Being Discharged and Limits of Deposits Authorized

	Column I	Column II	Column III
Item	Deleterious Substance	Pounds per 10,000 Canadian Gallons of Storm Water	Pounds per month per 1,000 barrels of crude oil per day
1.	Oil and Grease	1.0	25.0
2.	Phenols	0.1	2.5
3.	Total Suspended Matter	3.0	75.0

These regulations, methods for calculating authorized maximum deposits, guidelines for acute toxicity of liquid effluents from petroleum refineries and bioassay procedures are given in Canada Gazette, Part II, vol. 107. No 21 of 14 November 1973.

France :

The regulations on effluents of new refineries are (1) :

refinery type	max. volume effluent discharged per ton of crude oil processed (excluding rain and ballast water)
a – skimming plant with distillation, reforming and desulphurization	0.4 m^3
b – as "a" plus cat. cracking	0.8 m^3
c – same as "b" plus steamcracking and/or lube oil manufacture	1.2 m^3

(1) – CONCAWE *"Published Regulatory Guidelines of Environmental Concern to the Oil Industry in Western Europe"* CONCAWE, Report No 2/77, June, 1977.

Specifications for treated effluents on daily representative basis

items		AFNOR methods*	refinery type a	refinery type b, c
temperature	°C		30	30
P_H			5.5 to 8.5	5.5 to 8.5
BOD_5	mg/l	T.90103	30	40
COD	mg/l	T.90101 K. bichromate	120	150
suspended matter	mg/l		30	30
hydrocarbons	ppm	T.90202 hexane extraction	5	5
hydrocarbons	ppm	T.90203 infrared	20	20
phenols	mg/l	T.90204 4 amino-antipyrine	0.5	1
lead	mg/l		0.1	0.1
chromium $^{+6}$	mg/l		0.05	0.05

* AFNOR : Association Française de Normalisation.

Federal Republic of Germany :

The standards for oil refinery effluent water quality established by the Länder-Arbeitsgemeinschaft Wasser, LAWA, are :

After mechanical treatment	
a – settleable solids	0.3 ml/l
b – suspended solids	nil
c – extractable matter (diethylether)	20 ml/l
After chemical treatment	
a – settleable solids	0.3 ml/l
b – suspended solids	nil
c – pH	6.0 to 9.0
d – extractable matter (diethylether)	10 mg/l
After biological treatment	
a – settleable solids	0.3 ml/l
b – suspended solids	nil
c – oil sheen	no
d – BOD_5	30 mg/l
e – extractable matter (diethylether)	5 ml/l
f – sulphides	not detectable
g – phenols (volatile)	0.5 mg/l

(from CONCAWE, 1977)

Japan :

Effluent standards were promulgated on 21 June 1971 and they are (1):

1. Substances related to the Protection of Human Health

Toxic Substances	Permissible Limits
Cadmium and its compounds	0.1 mg/l
Cyanide compounds	1 mg/l
Organic phosphorus compounds (parathion, methyl parathion, methyl demeton and EPN only)	1 mg/l
Lead and its compounds	1 mg/l
Hexavalent chrome compounds	0.5 mg/l
Arsenic and its compounds	0.5 mg/l
Total mercury	0.005 mg/l
Alkyl mercury compounds	Not detectable[1]
PCB	0.003 mg/l

[1] By the term "not detectable" is meant that the substance is below the level detectable by the method designated by the Director-General of The Environment Agency.

2. Items related to the Protection of the Living Environment

Item	Permissible Limits
pH	5.8 ≈ 8.6 for effluent discharged into public water bodies other than coastal waters 5.0 ≈ 9.0 for effluent discharged into coastal waters
BOD, COD	160 mg/l (daily average 120 mg/l)
SS	200 mg/l (daily average 150 mg/l)
N-hexane extracts	5 mg/l (mineral oil) 30 mg/l (animal and vegetable fats)
Phenols	5 mg/l
Copper	3 mg/l
Zinc	5 mg/l
Dissolved iron	10 mg/l
Dissolved manganese	10 mg/l
Chrome	2 mg/l
Fluorine	15 mg/l
Number of coliform groups (per cc)	3,000 (daily average)

(1) The discharge standards in this table are applied to the effluents from industrial plants and other places of business whose volume of effluents per day is not less than 50 m^3.

(2) The discharge standards for BOD are applied to public waters other than coastal waters and lakes, while the discharge standards for COD are applied only to effluents discharged into coastal waters and lakes.

(1) – Japan Environment Agency "Quality of the Environment in Japan", 1977.

Also, the discharge of oil into the marine environment is regulated and this has been summarized and reported (1) to be :

Kind of oil to be regulated		Crude oil, heavy oils decided by the Ministry of Transportation, lubricating oils.
Ship to be regulated		All tankers and other vessels more than 300 G.T. (Excluding Whaling Vessels)
Regulation Standards	Discharge of oil or oily mixture from tanker	(1) Over 50 nautical miles from shore (2) During sailing (3) Below 60 1/nautical mile of oil discharged (4) Not exceeding the total quantity of oil discharged 1/15,000 of the total cargo carrying capacity.
	Discharge of bilge water from tanker and discharge of oil or oily mixture from vessels more than 300 G/T	(1) As far as possible from ashore (2) During sailing (3) Below 100 ppm oil content in discharged fluid (4) Below 60 1/nautical mile of oil discharged

Switzerland :

Comprehensive water quality objectives and effluent standards exist and these are :

Parameters	Water quality objectives of surface waters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public sewers
	The values in this col. disregarding naturally existing values, apply to a flow measured during 347 days/years.	The limit values must be met at all times during dry periods. Under certain conditions derogations are permitted.	The limit values are applicable to artisanal and industrial waste water and must be met always. In justified cases derogations can be permitted.
Temp.	Max. Δt = 3° C Max.temp. = 25° C	Max. 30° C	Max. 60° C In sewer max. 40° C
Transparance Method Snellen	No turbidity	30 cm	No limit
Colour	No colouration	May not cause colouration of receiving water	Dyes may be discharged if they are eliminated in the municipal treatment plant
Odour and taste	No odour and taste	May not cause alteration of odour and taste of receiving water	Odour may not cause nuisance

(1) – Yamaguchi, T. "*The situation in Japan*" Paper presented at the Regional Marine Oil Pollution Conference, Brisbane, Australia, 1977.

Parameters	Water quality objectives of surface waters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public waters
Toxicity	No toxicity	No toxicity towards fish after 24 hours for undiluted to 5 x diluted effluent, depending on dilution ratio in receiving water	Effluent may not affect negatively the efficiency of the biological waste water treatment plant
Salts	Water quality may not be deterioriated	Quality of the receiving water may not be deterioriated	The sewer system and treatment plant, as well as the efficiency may not be deterioriated
Total unsoluble matter	No sludge formation	4 out of 5 composite samples must be lower than 20 mg/l (24 hr average)	To be set case by case
Settleable solids	No sludge formation	Max. 0.3 mg/l after 2 hr settling time.	To be set case by case
pH	Natural pH.	6.5 - 8.5 Up to 9.0 may be permitted if river flow is high enough	6.5 - 9.0 6.5 - 9.5 if prevailing conditions permit
Oxygen	Min. 6 mg O_2/l	In receiving water : min. 6 mg O_2/l	No lower limit.
Surface tension	>65 dyn/cm at 20° C	In receiving water : >65 dyn/cm at 20° C	To be set case by case
Al	0.1 mg Al/l	10 mg/Al/l	20 mg Al/l in influent to municipal treatment plant.
As	0.01 mg/As/1	0.1 mg As/l	0.1 mg As/l
Ba	0.5 mg Ba/l	5 mg Ba/l (dissolved)	To be set case by case
Total P	- As low as possible in lake basins - Limiting proliferation of algea and weeds outside lake basins	- In lake basins : max. 1 mg P/l (4 out of 5-24 hr composite samples) min. P elimination : 85 % - Outside lake basins : see column 1	As low as possible
SO_4^{--}	100 mg SO_4^{--}/l	As low as possible	300 mg SO_4^{--}/l
S^{--}	No toxicity	0.1 mg S^{--}/l	1 mg S^{--}/l
SO_3^{--}	No toxicity	1 mg SO_3^{--}/l	10 mg SO_3^{--}/l
Dissolved organic carbon	2 mg C/l	10 to 15 mg/l	To be set case by case
Total organic carbon (TOC)	Not specified	17 to 22 mg C/l. Higher values may be specified if intake water has high TOC content	To be set case by case

Parameters	Water quality objectives of surface waters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public waters
COD	Not specified	To be set case by case	To be set case by case
$KMnO_4$ Value	Not specified	To be set case by case	To be set case by case
BOD_5	4 mg O_2/l	20 mg O_2/l (4 out of 5 24 hr composite samples)	To be set case by case
Aromatic amines (as dichloro-aniline)	0.005 mg/l	To be set case by case	To be set case by case
Oil and fatty acids	Not specified	20 mg.l	Oil separator required
Total hydrocarbons	0.05 mg/l	10 mg/l	20 mg/l
Chlorinated solvents	0.005 mg/l (as Cl)	0.1 mg/l (as Cl)	0.1 mg/l (as Cl)
Non-volatile lipophilic chlorinated compounds	0.005 mg Cl/l	To be set case by case	To be set case by case
Total organochloro-pesticides	0.0005 mg Cl/l	To be set case by case	To be set case by case
Phenols : – volatile	0.005 mg/l	0.05 mg/l (up to 0.2 mg/l may be admitted as an exception)	5 mg/l
– non-volatile	0.005 mg/l	0.05 mg/l	1 mg/l
Pb	0.05 mg Pb/l	0.5 mg Pb/l	0.5 mg Pb/l
B	1 mg B/l	To be set case by case	To be set case by case
Cd	0.005 mg Cd/l	0.1 mg Cd/l	0.1 mg Cd/l
Cr^{+3}	0.05 mg Cr^{+3}/l	2 mg Cr^{+3}/l	2 mg Cr^{+3}/l
Cr^{+6}	0.01 mg Cr^{+6}/l	0.1 mg Cr^{+6}/l	0.5 mg Cr^{+6}/l
Fe	1 mg Fe/l	2 mg Fe/l (4 out of 5 composite samples, average time 24 hr)	20 mg Fe/l in influent to municipal treatment plant
Co	0.05 mg Co/l	0.5 mg Co/l	0.5 mg Co/l
Cu	0.01 mg Cu/l	0.5 mg Cu/l	1 mg Cu/l
Ni	0.05 mg Ni/l	2 mg Ni/g	2 mg Ni/l
Hg	0.001 mg Hg/l	0.01 mg Hg/l	0.01 Hg/l
Ag	0.01 mg Ag/l	0.1 mg Ag/l	0.1 mg Ag/l
Zn	0.2 mg Zn/l	2 mg Zn/l	2 mg Zn/l
Sn	0.5 mg Sn/l	2 mg Sn/l (except when organotin fungicides are present)	2 mg Sn/l (except when organotin fungicides are present)

Parameters	Water quality objectives of surface waters	Quality standards for effluents discharged into surface waters	Quality standards for effluents discharged in public waters
Active Cl	No toxicity	0.05 mg Cl_2/l	3 mg Cl_2/l
Active Br	No toxicity	0.1 mg Br_2/l	3 mg Br_2/l
NH_3/NH_4^+	0.5 mg N/l ($NH_3 + NH_4^+$) Higher values may be set if not used for drinkwater supply	To be set case by case	To be set case by case
ClO_2	No toxicity	0.02 mg ClO_2/l	3 mg ClO_2/l
Cl^-	100 mg Cl^-/l	To be set case by case	To be set case by case
CN^-	0.01 mg CN^-/l	0.1 mg CN^-/l	0.5 mg CN^-/l
F^-	1 mg F^-/l	10 mg F^-/l	10 mg F^-/l
NO_3^-	25 mg NO_3^-/l Higher values may be set if water not used for supply of drinkwater	To be set case by case	To be set case by case
NO_2^-	No toxicity	1 mg NO_2^-/l	10 mg NO_2^-/l

(from CONCAWE 1977)

United States of America :

The Federal Water Pollution Control Act specifically sets as a goal that by 1983 all water bodies in the U.S. be "swimable and fishable" and that by 1985 all pollutant discharges into navigable waters be eliminated. Under the Act, the Administrator of the Environmental Protection Agency must require what is, in his judgement, the "best practicable control technology currently available" (BPCTCA) by 1977 and the "best available technology economically achievable" (BATEA) for non-municipal discharge sources, including refineries.

BPCTCA for refineries has been construed as the best demonstrated end-of-pipe treatment, in conjuction with good house-keeping and in-plant control measures. Suggested in-plant controls include.

- installation of sour water strippers to reduce the sulphide and ammonia concentrations entering the treatment plant;
- elimination of once-through barometic condenser water by using surface condensers or recycle systems with oily water cooling towers;
- segregation of sewers, so that uncontaminated storm run off and once-through cooling waters are not normally treated with the process or other contaminated waters;
- elimination of once-through cooling water by the monitoring and repair of surface condensers or by the use of wet and dry recycle systems.

BATEA has been construed as including changes in basic in-plant processes to reduce the generation of waste loads.

The EPA has defined significant pollutant parameters for the petroleum refining industry as consisting of BOD_5, COD, Total Suspended Solids, Oil and Grease, Phenolics, Ammonia, Sulphides, Chromium (total and hexavalent) and pH. The EPA is also in the process of developing guidelines regulating the discharge of 65 compounds or classes of compounds considered potentially toxic.

7.2. Air Quality Standards

Canada :

Three levels of ambient air quality objectives have been formulated, namely Desirable, Acceptable and Tolerable. The Tolerable levels (1) are as follows :

SCHEDULE I

Column I	Column II	Column III
Air Contaminants	Concentrations	Range of Quality
1. Sulphur dioxide	300 to 800 micrograms per cubic metre average concentration over a continuous 24 hour period	Tolerable
2. Suspended particulate matter	120 to 400 micrograms per cubic metre average concentration over a continuous 24 hour period	Tolerable
3. Carbon monoxide	15 to 20 milligrams per cubic metre average concentration over a continuous 8 hour period	Tolerable
4. Oxidants (ozone)	160 to 300 micrograms per cubic metre average concentration over a continuous one hour period	Tolerable
5. Nitrogen dioxide	400 to 1,000 micrograms per cubic metre average concentration over a continuous one hour period	Tolerable

The concentration of air contaminant is measured and corrected to a reference temperature and pressure of 25° C and 760 mm of mercury respectively.

(1) – Canada Gazette, Part II, Vol 112, No 3, 25 January, 1978.

The Desirable and Acceptable levels are :

SCHEDULE 1 (1)

Column I Air Contaminants	Column II Concentrations	Column III Range of Quality
1. Sulphur dioxide	*(a)* 0 to 30 micrograms per cubic metre annual arithmetic mean *(b)* 0 to 150 micrograms per cubic metre average concentration over a 24 hour period *(c)* 0 to 450 micrograms per cubic metre average concentration over a one hour period	Desirable
2. Sulphur dioxide	*(a)* 30 to 60 micrograms per cubic metre annual arithmetic mean *(b)* 150 to 300 micrograms per cubic metre average concentration over a 24 hour period *(c)* 450 to 900 micrograms per cubic metre average concentration over a one hour period	Acceptable
3. Suspended particulate matter	0 to 60 micrograms per cubic metre annual geometric mean	Desirable
4. Suspended particulate matter	*(a)* 60 to 70 micrograms per cubic metre annual geometric mean *(b)* 0 to 120 micrograms per cubic metre average concentration over a 24 hour period	Acceptable
5. Carbon monoxide	*(a)* 0 to 6 milligrams per cubic metre average concentration over an 8 hour period *(b)* 0 to 15 milligrams per cubic metre average concentration over a one hour period	Desirable
6. Carbon monoxide	*(a)* 6 to 15 milligrams per cubic metre average concentration over an 8 hour period *(b)* 15 to 35 milligrams per cubic metre average concentration over a one hour period	Acceptable
7. Oxidants (ozone)	*(a)* 0 to 30 micrograms per cubic metre average concentration over a 24 hour period *(b)* 0 to 100 micrograms per cubic metre average concentration over a one hour period	Desirable
8. Oxidants (ozone)	*(a)* 0 to 30 micrograms per cubic metre annual arithmetic mean *(b)* 30 to 50 micrograms per cubic metre average concentration over a 24 hour period *(c)* 100 to 160 micrograms per cubic metre average concentration over a one hour period	Acceptable

(1) – P.C. 1974 - 1153 14 May 1974.

SCHEDULE I (1)

Column I	Column II	Column III
Air Contaminants	Concentrations	Range of Quality
Nitrogen Dioxide	0 to 60 micrograms per cubic meter annual arithmetic mean	Desirable
	0 to 100 micrograms per cubic meter annual arithmetic mean 0 to 200 micrograms per cubic meter average concentration over a 24 hour period 0 to 400 micrograms per cubic meter average concentration over a one hour period	Acceptable

Japan :

Pollutant	Measurement method	Ambient Air Quality Standard	Date Promulgated
SO_2	Conductometry	- 0.04 ppm daily average of hourly values - Hourly values shall not exceed 0.1 ppm	8 may 1973
CO		- Average hourly values in 8 consecutive hours shall not exceed 20 ppm - Average hourly values in 24 consecutive hours shall not exceed 10 ppm	20 February 1970
Nitrogen Dioxide	Colorimetry using Saltzman reagent (with Saltzman's coefficient being 0.72 or other methods which produce equivalent results).	Daily average of hourly values shall not exceed 0.02 ppm.	
Photochemical Oxidants	Colorimetry with neutral potassium iodide solution	Hourly average valves shall not exceed 0.06 ppm	8 may 1973
Suspended Particulate Matter	Sampled at a height of 3-10 meters above ground with measuring device calibrated by standard particulates	- Average of hourly values of suspended particulate matter, with diameter of 10 μ or less, should be 0.10 mg/m^3 or less measured in 24 consecutive hours. - Any hourly value should be 0.20 mg/m^3 or less.	8 may 1973

(1) – P.C. 1975 - 10 16 January 1975.

United States of America :

The Clean Air Amendments of 1970, (PL91-604) require that the Environmental Protection Agency establish primary and secondary national ambient air quality standards for each air pollutant for which criteria had been issued under the 1967 Clean Air Act.

The primary standard is that level of ambient air quality which in the judgement of the administrator of the EPA is "requisite to protect the public health".

In establishing the secondary ambient air quality standard, the administrator is directed to establish parameters of air quality which are necessary to protect "public welfare", defined as "any effects on soils, waters, crops, vegetation, man made materials, animal wildlife, weather, visibility and climate, damage to or deterioration of property and hazards to transportation, as well as effects on economic values and on personal comfort and well being". Thus, its purpose is to establish the level of ambient air quality that in no way will affect adversely man or the environment. These air quality standards are :

National Primary and Secondary Ambient Air Quality Standards

	Federal standard	
Air pollutant	*Primary*	*Secondary*
Sulfur dioxide	80 μg per cubic meter (0.03 ppm) annual arithmetic mean	60 μg per cubic meter (0.02 ppm) annual arithmetic mean*
	365 μg per cubic meter (0.14 ppm) maximum in twenty-four hours	260 μg per cubic meter (0.1 ppm) maximum in twenty-four hours*
		1,300 μg per cubic meter (0.5 ppm) maximum in three hours
Suspended particulates	75 μg per cubic meter annual geometric mean	60 μg per cubic meter annual geometric mean
	260 μg per cubic meter maximum in twenty-four hours	150 μg per cubic meter maximum in twenty-four hours
Carbon monoxide	10 mg per cubic meter (9 ppm) maximum in eight hours	10 mg per cubic meter (9 ppm) maximum in eight hours
	40 mg per cubic meter (35 ppm) maximum in one hour	40 mg per cubic meter (35 ppm) maximum in one hour

Air pollutant	Federal standard	
	Primary	*Secondary*
Photochemical oxidants	160 μg per cubic meter (0.08 ppm) maximum in one hour	160 μg per cubic meter (0.08 ppm) maximum in one hour
Hydrocarbons (corrected for methane)	160 μg per cubic meter (0.08 ppm) maximum in three hours, 6 A.M. to 9 A.M.	160 μg per cubic meter (0.08 ppm) maximum in three hours, 6 A.M. to 9 A.M.
Nitrogen dioxide	100 μg per cubic meter (0.05 ppm) annual arithmetic mean	100 μg per cubic meter (0.05 ppm) annual arithmetic mean

Note : Maximum concentrations are not to be exceeded more than once per year.
* In 1973 EPA relaxed the secondary standard for sulphur dioxide by withdrawing the requirement of annual mean measurement and contining the secondary standard to a three-hour measurement.

8. CONCLUSIONS

Energy is a pivotal factor in industrial development and this has been evident since the industrial revolution. With a higher expectation of material standards and convenience, the dependence upon energy also increases. At first, energy needs were supplied by coal and then, since the end of the nineteenth century, oil began to make major inroads into coals's share as the main primary fuel, because of its greater versatility in industry, agriculture, transportation, commerce and the home. In 1975, the world consumption of oil excluding planned economy countries, was about 6 million tonnes par day. Depending upon the rate of growth of demand and prices, which have some correlation, the consumption according to some forecasts could increase to between 10 and 13 million tonnes per day, remain at the same level or decline between the years 1978 and 2000. Whatever the scenario, proven reserves are being depleted and exploration and drilling for new hydrocarbon sources, especially off-shore, continue to be made in regions around the world, to supplement the existing resource base.

Knowledge and experience are available to abate and control pollution caused by drilling muds, produced waters, oil and lubricants as well as the more subjective environmental issues such as noise and aesthetics, that are caused by exploration and production activities on land and off-shore. Accidents and mishaps can also be significantly minimized by a sound well-control programme and blow-out plan.

In addition there should also be regulations to deal with the qualifications of personnel ; with working hours including working periods in relationship to rest periods for all personnel working and supervising on the drilling platforms ; and with an adequate manning plan with proper supervision especially on workover operations.

Successful development leads inevitably to the need for supporting facilities. These include storage tanks, pipelines, terminals and ports to serve oil related vessels. Also, other industries and development activities may be attracted to the region owing to symbiotic effects. Before drilling and production take place offshore, and onshore supporting facilities along the coastal region are built up, their impact should be assessed. With careful environmental impact assessments, assessing not only the ecological effects, but also the effect on traditional coastal activities such as fishing, tourism and recreation, an effective and pragmatic environmental management plan can be prepared and implemented.

The major centres for hydrocarbons consumption are and will continue to be considerably away from the main sources of production, with the exception of the North Sea fields. Althouth offshore exploration and drilling continues in all regions, the chances of finding large concentrated deposits such as those in the Middle East are remote. Hence, hydrocarbons will continue to be transported over long distances to the major regions of consumption and use.

Marine transportation has been and will continue to be the major mode of transporting oil. Petroleum hydrocarbons enter the marine environment by operational discharges and accidents. With an estimated yearly input of between 6 to 11 million tons of hydrocarbons into the marine environment, highlighted by oil spills resulting from tanker accidents, efforts are being made to control and prevent hydrocarbons from entering the oceans. Amongst the major international measures are the IMCO Conventions and Protocols.

The coming into force of the 1969 Amendments to the 1954 IMCO Conventions on January 20, 1978 will reduce the discharge of oily mixtures into the oceans. When the 1973 Convention is implemented, it will substantially achieve the complete elimination of intentional discharge of oil and other noxious substances and the minimization of accidental spills. The February 1978 IMCO Conference also adopted Protocols and Resolutions for safety and prevention of pollution from ships. When these are ratified, all existing crude oil tankers over 40,000 d.w.t. will have to have either segregated ballast or crude oil washing equipment, or for a limited time, dedicated clean ballast ; while all new crude oil tankers over 20,000 d.w.t. will have to have segregated ballast and crude oil washing equipment.

Without international Conventions, Protocols and Resolutions to control and prevent intentional and accidental oil spills, as well as to improve maritime safety, spills would be more likely and more serious. Concerted efforts by governments, industries and institutions on a world-wide basis are also necessary to minimize accidents and mitigate marine pollution. Furthermore, technical assistance programmes, through relevant international organizations, should be extended to developing countries for implementing the conventions.

One area in which technical assistance may be of use is for measures dealing with oil spill emergencies, arising from exploration and production or tanker accidents. Countries that are likely to be affected should have adequate contingency plans including personnel, equipment and materials available in readiness. The administrative mechanism for dealing with an emergency should be established with a responsible national and/or regional oil spill control executive.

Impacts by an oil refinery on the natural environment can be categorized under five major types : gaseous emissions, including odour ; waste-water effluents ; solid wastes ; noise ; and visual or aesthetic effects. Technologies are available to treat emission and effluents to meet acceptable and permissible air and water quality standards. Where appropriate legislation for the control of refinery discharge does not exist, regulations relevant to local conditions should be considered and implemented for (i) gaseous emissions of sulphur dioxides, hydrocarbons, particulate matter and odour ; additionally where necessary nitrogen oxides and carbon monoxide ; (*ii*) effluents containing hydrocarbons (free emulsified and water soluble), sulphur compounds, ammonia, phenols, cyanides, inorganic particulate matter and trace toxic metals ; (iii) disposal of solid wastes, sludges, sediments and product treatment wastes, taking care not to create problems of air or water pollution ; and (iv) noise control.

When an oil spill occurs, the decision regarding what action can best be taken is influenced by tides, currents, wind, amount of oil spilt, type of oil, as well as the location of the spill. Generally, four basic steps can be taken and these are : limitation, containment removal and final clean-up of the spilled oil.

The use of chemical dispersants as an option for oil spill control in situations where oil cannot be left to evaporate and degrade naturally, because of the likelihood of ecological and resource damage or because of it being a fire hazard, is one which more countries are now considering. One of the issues with chemical dispersants is the correlation, transfer and application of laboratory data to actual field application. In many countries the use of chemical dispersants is regulated and approval is given only when their use will result in the least overall environmental damage. Such approval is especially necessry before use in estuaries and coastal areas which serve as marine breeding grounds, because of their vulnerability.

A great number of factors, acting both individually and in combination, govern the effects that an oil discharge may have on marine life. In general, the ecological damage is more severe if the discharge occurs in a coastal or estuary environment, especially if the intertidal zone is affected, than if it occurs in the open ocean. Effects may be lethal, or sublethal, acute or chronic with different organisms reacting in different ways and different petroleum products giving rise to different effects.

Recovery of oil polluted areas varies greatly from a few months to several years. This depends on the flushing of the polluted area, the type of sediments on the substrata, the degree of isolation of its ecosystem and the kinds of organism that form them. Long term effects of sublethal concentrations of hydrocarbons in the marine environment, not only on particular species that have economic values, but also on pelagic species as well as the marine ecosystem, are still not adequately known. Also, reliable and comparable base line data is not available to enable an objective assessment of the changes that may be taking place.

At present there is no evidence that any link exists between the presence in the sea of carcinogens found in the oil and carcinomas in marine organisms, or between the presence in sea food of carcinogens from oil and cancer in man.

The most damaging and adverse effects of oil spills are the tarring of beaches, the endangering of seabird species, and the modification of benthic communities along affected coastlines where petroleum is heavily incorporated in the sediments.

The environmental impacts of the petroleum industry which are currently of major concern are primarily those on the marine environment. Although emissions of hydrocarbons, oxides of sulphur and particulates are of concern, these are mainly released from the use of petroleum products.

There are many possible sources of oil pollution in the marine environment and some of these are : offshore production, tanker accidents, deballasting operations, tank washings, coastal refineries as well as natural seepages and direct discharge of untreated municipal and industrial wastes. Technical and legislative means to prevent, control and mitigate oil discharge from these sources will be effective, if they are identified, so that appropriate measures can then be taken. Internationally, Protocols and Conventions are also available to minimize accidents and prevent oil pollution of the marine environment. The faster these are ratified and implemented the faster the objectives will be reached.

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