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Environmental pollution in offshore operations

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The oil industry has made contingency plans from the earliest operations to clean up any spills due to accidents during exploration and production. The Oil Industry International Exploration and Production Forum (E & P Forum) was established in 1974 to coordinate oil industry opinion with governments and intergovernmental agencies. The United Nations Environment Programme and the Intergovernmental Maritime Consultative Organization are working together to organize regional oil spill clean-up arrangements both on the apparatus and on the financial side.

The E & P Forum member companies have formulated a computer program to estimate the cost of clean-up following any hypothetical blow-out in the North Sea. This program is applicable, provided the appropriate meteorological data are available, to other areas of the world such as the Mediterranean, the Persian/Arabian Gulf, the Gulf of Mexico, the Malacca Straits, etc., where U.N.E.P./I.M.C.O. are proposing to set up multi-national conventions.

In places such as the North Sea, the oil companies have mutual aid organizations which maintain stocks of dispersant, suitable vessels and spreaders, skimmers and booms to minimize any oil that may be driven to the shore.

Looking to the future, there may be some problems associated with harvesting manganese nodules or mining the Red Sea mineral-rich lands. However, conservation is today part of any general planning of an operation and new processes that are developed will take into consideration adequate anti-pollution measures.

Introduction

The record of the offshore oil production industry in environmental pollution is in general a good one. The most active area in the world has been the Gulf of Mexico, where offshore oil production started in earnest in the 1940s, and where, for example, in 1972, 17 % of the U.S.A.'s domestic crude oil originated. Although some mistakes have been made and accidental blow-outs have occurred, there is no obvious ecological damage along the Louisiana and Texas coasts. Offshore exploration and production is now taking place in many of the continental shelves of the world and the lessons learned from the earlier activities are being applied, with suitable climatic and political modifications to new areas.

The volume of the oceans is 300 million cubic miles (*ca.* 1250×10^6 km^3); the total world oil production is one cubic mile (*ca.* 4.2 km^3) per year so that, provided sufficient mixing takes place, the small percentage of oil that is spilt becomes sufficiently diluted for it to get lost by natural processes. Since oil is formed in a marine environment from the decay of animal and plant matter, there are always hydrocarbons of a petroleum-like nature associated with recent sediments on the sea bed, and there do not appear to be any animal or plant chains of life that concentrate hydrocarbons as is the case in some instances with heavy metals.

In looking ahead at offshore mineral production, there should not be any oil problems that have not already been experienced. The possibilities for minerals such as manganese or

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phosphatic nodules causing deleterious effects in the vast volume of the oceans are unlikely, since they already exist in contact with the sea and the ocean floor and they are therefore in as strong a concentration locally as they would be in any extraction process.

Oil spill statistics

Several surveys of the main sources of oil in the sea that have been made during the past few years (National Academy of Sciences 1974) agree that the offshore oil drilling and production side of the industry is responsible for only a comparatively small amount of oil pollution that is less than 2% or 30000 tons per year in a total of about 2 million tons a year. The accepted make-up of oil in the sea is shown in table 1.

Table 1

	quantity/(t/a)
ballast and wash water from tankers:	
(*a*) non load-on-top	670000
(*b*) load-on-top	120000
machinery space bilges	24000
accidents to ships:	
(*a*) tankers	135000
(*b*) other vessels	23000
effluents from shore	500000
offshore oil drilling and production	34000
natural sources (seepages underwater)	500000

Although incidents such as the *Torrey Canyon* wreck which spilt over 100000 t of crude oil near shore are notorious and heard of world-wide, only one such accident (or an equal tonnage of smaller ones) occurs on average each year. Four times as much waste oil goes down with the untreated sewage from hundreds of large coastal cities who cannot afford modern plant to clear their effluent, and who prefer to put it straight into the sea.

The offshore oil contribution to total oil spill is less than a quarter of that from tanker accidents, and although more wells are coming into production each year, the accident rate does not appear to be increasing. This is because each accident provides lessons learned and consequent changes in codes of practice and improvements in safety and fail-safe devices.

The figure for oil introduced into the sea from natural seepage is possibly much greater than given above since only those seepages on or close to the shore have been identified. In cases where seepages have existed throughout historical times there is no observable bad effect on the fauna and flora. Oil spills in the sea are probably more a nuisance value to human beings than a harmful agent to other animals.

Louisiana experience

Evidence concerning the limited environmental effect of oil operations has been provided by a recent comprehensive study by the Gulf Universities Research Consortium. The objective study, known as the Offshore Ecology Investigation or O.E.I., was to determine the effect of petroleum operations in the 'Louisiana oil patch', the continental shelf area which has experienced about 25 years of intensive petroleum exploration and production operations. If, indeed, exploration and production operations have an adverse effect on the ecosystem, here is where one might expect the evidence of such effects. This is particularly true with regard to

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long-range effects which might be hidden by natural phenomena over the short term. That study indicated the following:

1. Natural phenomena completely dominate the characteristics, productivity and general health of the ecosystem. These include seasonal changes in water quality, water mass movement, and the turbid layer arising from the Mississippi River, which contributes far more to silting and sedimentation than does production and drilling activity.

2. The presence of offshore producing platforms and pipelines has an insignificant effect which, if anything, appears beneficial, owing to the reef effect of the structures increasing the productivity of basic nutrients in the vicinity.

3. Petroleum operations have not resulted in any significant accumulation of potentially toxic materials in either the sediment or water column in the vicinity of such operations.

4. No accumulation of hydrocarbons was found in the animal life in the area and the accumulation of organic materials in the sediments and beach sand was found to be of a low order and not ecologically significant.

The report also emphasized that in so far as environmental protection is concerned, there was little comparison between the exploration and production operations of the late 1940s and 1950s in shallow waters (which would presumably be more susceptible to ecological damage) and operations today with advanced technology in deeper waters more remote from the coast.

The E & P Forum subcommittees

The Oil Industry International Exploration and Production Forum (E & P Forum) was established in 1974 as an association of oil explorers and producers in order that the industry may speak with a united voice to international agencies who are interested in formulating regulations to control oil activities. The membership is of three types: oil companies engaged in finding and producing oil, national oil companies, and regional groups such as the U.K. Offshore Operators Association, the American Petroleum Institute, the North Sea Operators Committee in Norway. The E & P Forum has its office in London, since this is where the Intergovernmental Maritime Consultative Organization (I.M.C.O.) of the United Nations is situated. I.M.C.O. has in the past dealt with international aspects of safety and oil spillage from tankers and have now turned their attention to offshore oil operations. The E & P Forum has been awarded non-governmental observer status with I.M.C.O. and assists with technical advice on relevant drilling and production matters.

The E & P Forum is a member of the International Petroleum Industry Environmental Conservation Association (I.P.I.E.C.A.) and has assisted on the exploration and production side of the oil business in meetings in Tehran (1975) and Paris (1977) to discuss with the United Nations Environment Programme (U.N.E.P.) the impact of petroleum on the environment.

Subcommittee A of the Forum deals with pipelines and a yearly survey is made of any accidents to pipelines in the North Sea and the Persian/Arabian Gulf. This survey will be extended to new production areas of the world with a view to continual improvement of techniques from lessons learnt in practical operations.

Subcommittee B deals with I.M.C.O. affairs and arranges for appropriate experts to attend I.M.C.O. meetings to advise on technical matters, after gathering the concerted opinion of the industry through working groups drawn from E & P membership.

Subcommittee C, on oceanography and meteorology, helps to coordinate the information

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on climate and weather which is needed for successful operations at sea. In the first instance, accurate forecasting of waves and wind is needed for critical operations such as pipe-laying or moving large equipment from shore to operational site. An extension of this day-to-day forecasting is the average weather picture needed in order to plan ahead and cost the effect of unavoidable delays. In addition to forecasts, the long-term wave current and tidal data are needed to allow adequate and economic design of offshore structures which will stand up safely to the prevailing conditions. The exchange of information, for example, between Norway and Britain, on conditions and guidelines produced by governments is important where design criteria are laid down by national regulations. The experience gained in one region of the world enables subcommittee C to advise operators in new places on the type of measurements that will be needed for both design and operational purposes.

Subcommittee E looks after the long-term design of offshore structures, and maintains liaison with the I.M.C.O. committees on stability, etc., and also with subcommittee C on matters pertaining to wave and wind forces on structures at sea.

Subcommittee D looks after the legal aspects of offshore operations and was formed to keep liaison with the Offshore Pollution Liability Association Ltd (Opol) and to help to extend this arrangement from the U.K. sector of the North Sea to other parts of the world. The Opol argument has been extended to cover most of the active area of the North Sea, but may be superseded by the Nine Nations Convention on Civil Liability in the North Sea. This convention at their meeting in London appointed the E & P Forum to be their technical advisers, and the Forum members have produced a computer program to simulate the movements and quantities of spills consequent on accidents in present North Sea oilfields, together with the cost of clean-up operations and awards for damages. Although in the early stages some astronomical costs for single incidents were proposed by some nations, the technical aspects were considered and some form of general limit of about $30 M per incident were agreed for civil liability, although this agreement was to some extent vitiated by a loophole clause which allowed individual nations to assess the industry with unlimited liability. It was hoped that the nine nation convention would provide a workable pattern for other regions of the world where offshore production may take place, but it appears to have confused the issue rather than to have provided a universal workable arrangement between governments, oil producers and the insurance world.

Subcommittee F was formed to provide technical advice to subcommittee D on all aspects of oil pollution prevention in offshore operations.

The sliktrak computer program

During discussions on civil liability it became apparent that there was a need to illustrate effectively and realistically the combined efforts of clean-up activities and natural spill-reducing phenomena, and so predict the quantities of oil that could reach the shore. Estimates were made of the amount of oil that might be emitted in a platform blow-out and the duration of the emission before the wells were brought under control. The known rate of evaporation from the surface film of oil and estimated amounts of oil that could be contained and picked up by booms, skimmers, etc., were fed into the analysis. The rate of speed of the oil slick is determined by the wind speed and for this purpose the computer selected random weather from determined meteorological data over the past three years. The weather conditions which, if severe, could

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hamper containment operations, would increase the loss of oil slick by natural mixing with the sea water. The removal of oil from the surface in this way was included in the program based on rates of mixing determined by the U.K. Government research station at Warren Springs. The cost of breaking up oil slicks with dispersant was included in the cost of the operation, and the remaining slick, driven mainly by the wind, was followed until it disappeared completely or reached the shore. The effect of currents was included, but is very small compared with wind effect in the North Sea, especially as most North Sea water movement is caused by tidal streams and reverses with the tidal cycle. The computer assessed the cost to fishermen of temporary loss of livelihood, and to hotel and boarding house keepers of diminishing of tourist trade as well as the local authorities and government bills for cleaning beaches. Five thousand random incidents were analysed by the computer on this basis. The simulation showed that the average total spill cost is expected to be \$6 M, that the probability is 90 % that the spill cost will not exceed \$15.8 M and that the worst case would amount to less than \$25 M in civil liability.

Although the SLIKTRAK program (Blaikley *et al.* 1977) is designed for random accidents to production wells in the North Sea U.K. sector, it can be readily adapted to other areas, and with small modification to replaying real incidents with actual weather data.

The recent *Ekofisk Bravo* incident in the North Sea, where the total oil spilt was less than a quarter of the *Torrey Canyon* spill, and where the point of spill was more than 100 miles from shore, shows that the SLIKTRAK prognostications are on the right lines and if anything overrate the civil liability costs. The *Bravo* spill was, like accidents in the airline industry, due to a combination of human errors and fallibilities, and was put right by the opposite facet of human abilities: bravery, ingenuity and experience in adversity.

The computer program provides not only a useful yardstick for legislation in other parts of the world, where extensive offshore oil production may develop, but also shows on what beaches spills are likely to arrive, and the size of the clean-up problem that may be posed. It is probable that more experimental figures for evaporation and mixing of oil with water will be required for different climates, but, provided the meteorological data are available, the general lines of thought of the SLIKTRAK program are applicable.

North Sea contingency plan

The U.K. offshore operators have for many years had contingency plans for coping with accidental oil spills during exploration and production operations. Stocks of dispersant are maintained at strategic points and the supply lines to the manufacturing sources are arranged. The devices needed to spread the dispersant are held ready for fitting to vessels which are on call from their normal duties when an emergency arises. The locations of company-owned booms and oil collectors are known to all operators and a chain of command and liaison with government authorities is laid down.

It was notable in the *Ekofisk Bravo* spill that the contingency plans worked well; all the other producing wells on the platform shut down automatically; the 120 man crew of the platform were evacuated without injury; rigs for drilling relief wells were made available; and fire fighting vessels were soon on the scene.

Similar mutual self-help arrangements have been made for the Gulf of Mexico and the Persian/Arabian Gulf, and there is no doubt that the oil offshore production industry is

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prepared for emergency. Recently I.M.C.O. and the Intergovernmental Oceanic Commission (I.O.C.) have, with the financial support of U.N.E.P., formulated regional clean-up schemes for various areas of the world. A monitoring centre has been set up in Malta to determine the size of the pollution problem in the Mediterranean. One of the substances being monitored is oil. Similar regional schemes are proposed for West Africa, the Persian/Arabian Gulf, the Malacca Straits and Southeast Asian waters, and the Caribbean. In those places where oil production is well established, oil industry arrangements will be available as a basis for inter-governmental cooperation.

Deeper water problems: oil

In most parts of the world, moving into deeper water means that production will be farther from the shore. The chance of oil spills reaching land will therefore be reduced, so that there is no reason why the movement of the oil industry into deeper water should provide any greater problem of pollution (Blaikley 1977). There may be greater difficulty in reaching the source of spill for relief vessels, but this effect will be marginal, especially when unforeseen delays can occur in any case due to bad weather.

There will of course be a much greater opportunity for the oil to mix with the ocean water, except in the case of some crude oils, which seem to form 'tar-balls' which can persist with an outer coating of weathered oil for many months. However, these persistent blobs of oil are generally formed from the heavy sludge from the bottom of fuel oil tanks rather than from crude oil with its usual mixture of a wide range of hydrocarbons.

Deeper water problems: minerals

Any extraction of mineral wealth from the seabed, either by mining manganese nodules or sucking up mineral rich brines from the Red Sea, will take place in deep water, which means that there will be ample opportunity for dilution of any waste products. These may be clouds of dust particles produced when manganese nodules are washed or when unwanted mud and sand are put back into the sea. These clouds of dust may be carried for miles before they gradually descend to the seabed. This process takes place all the time when rivers bring down sediments derived from the land, and there is no conceivable way in which this material can pollute the varigated seabed picture that nature produces. There may be some confusion in the meaning of the geological evidence from cores taken in the seabed in years to come, but it will be a similar trouble for the marine geologist as has been provided by the carriage of erratic materials by icebergs.

New industry is fortunate compared with old established extraction processes such as those for coal and oil, which grew up in a small way before human beings became conscious of the nuisance and danger of pollution in the seas. New processors are well aware of the need to make impact surveys to forecast what effect their operations will have on the environment, and they can include necessary precautions in their planning. The older industries have had to face the more expensive problem of making modifications to their previously accepted techniques. In all cases, however, industry realizes what has to be done and has engineers and scientists as well qualified as those in other walks of life to study the problems and their solutions.

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Addendum (21 April 1978)

It is interesting to add a footnote concerning the tanker accident from the ground of the *Amoco Cadiz* on 17 March 1978. This was a very large tanker containing 200 000 t of oil, but the result of the accident will be seen eventually to bear out what has been stated above. The tanker, of course, had nothing to do with exploration and production which are the subject of this paper. The spill accounted for less than twice the annual average for tanker accidents, which as all those versed in probability studies will agree is hardly out of the ordinary. The long-term effect on marine life will be found to be negligible. It is already reported that most of the oysters were not killed, and it is thoroughly well demonstrated by marine biological experiments that oil assimilated by marine life is cleaned out in two weeks sojourn in clear water. It is probable that a small criticism could have been made of the authorities because they did not start where the *Torrey Canyon* experience of 10 years ago left off, but there were extenuating political conditions of a current election. A great deal is known about the best way to cope with accidental oil spillages and how to clean up oil covered beaches and it is time the academic world and the media applied their normal commonsense to what is necessarily an emotive problem, that is, to use past experience to guide them into the best solution. In the long run, of course, that is in about a year, it will be rough weather and the pounding of beaches by waves that clears up the mess. Meanwhile, it should be appreciated that oil in the proper place brings benefit to man.

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Discussion

B. White (*Department of Mineral Resources Engineering, Royal School of Mines, Prince Consort Road, London S.W.*7). I should like to congratulate Dr Gaskell on his paper. It is good to hear such a reasoned and pragmatic discussion of the problems associated with the exploitation of the mineral wealth of the oceans rather than the more usual emotional outbursts of the more vociferous of the 'environmentalist' lobby.

I concur with his comments about the awareness of the potential exploiters of the deep ocean mineral resources. All the consortia involved report that work is being done to evaluate the possible environmental pollution hazards and to determine remedial measures; notable is the joint Industry/U.S. Government work on the Domes Project (Deep Ocean Mining Environmental Study). We at the Royal School of Mines are undertaking sponsored research work on the disposal of tailings following shipboard processing as part of the studies into the feasibility of exploiting the metalliferous muds of the Atlantis II Deep in the Red Sea.