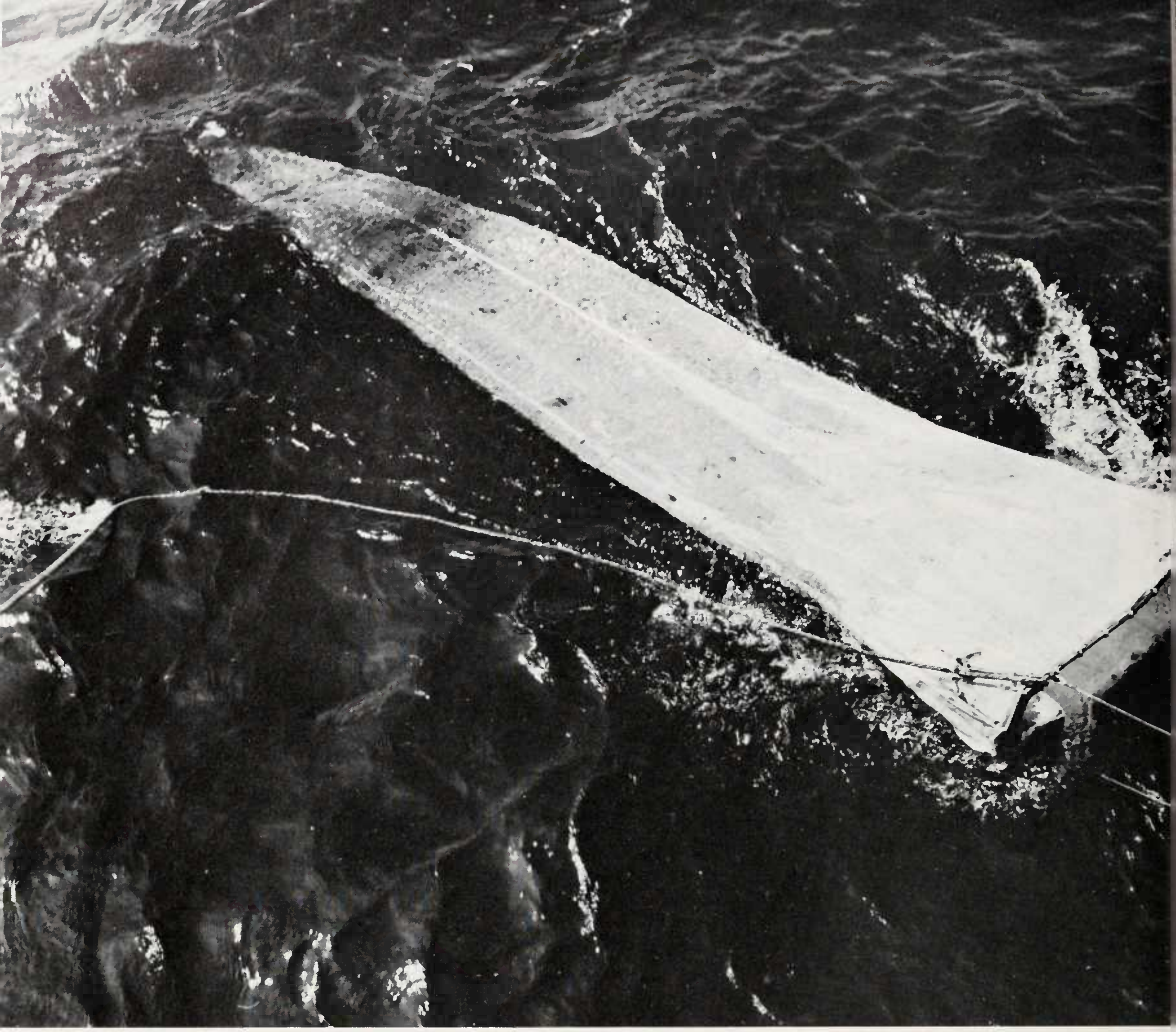

A neuston net being towed alongside the R.V. 'Atlantis II' in July 1969 shows a blackened cod-end and other black spots due to oil particles. The mouth of the net skims the upper few centimeters of the water to collect plant and animal life of the sea surface.

About one million tons of oil
are lost annually at sea
which is the equivalent of one tenth of one percent
of all oil transported across the ocean.

Oil Pollution of the Ocean

by M. BLUMER

OIL Pollution is the almost inevitable consequence of the dependence on a largely oil-based technology. The oil reserves which have accumulated in the earth during the last 500 million years will be exhausted within a few hundred years. The use of oil without loss is impossible; losses occur in production, transportation, refining and use. The immediate effects of large scale spills in coastal areas are well known, but only through the recent introduction of skimming nets have we become aware of the degree of oil pollution of the open ocean. Thus, during a recent cruise of our R/V 'Chain' to the Sargasso Sea, many surface "Neuston" net hauls were made to collect surface marine organisms. These tows were made between 32°N – 23°N latitude (corresponding to a distance of 540 miles) at longitude 67°W. During each tow, quantities of oil-tar lumps, up to 6 cm in diameter were caught in the nets. After 2–4 hours of towing the mesh became so encrusted with oil that it was necessary to clean the nets with a strong solvent. On the evening of 5 December 1968, at 25°40'N, 67°30'W, the nets were so fouled with oil and tar material that towing had to be discontinued. It was estimated that there was 3 times as much tar-like material as Sargasso weed in the nets. Similar occurrences have been reported worldwide.

Much of the oil transport is concentrated in restricted lanes, as shown by this tanker in the busy traffic of the Straits of Gibraltar. Of the world's total oil production, some 25% passes through the English Channel.

The Extent of Oil Pollution

To find out how much oil enters the ocean from various sources we need figures for the total amount of oil produced, shipped, and for the fraction lost in shipping and handling. The world oil production is about 1800 million metric tons a year. Of this amount at least 60% or 1000 million metric tons per year is transported across the ocean. Much of the transport is concentrated in restricted shipping lanes; for instance, 25% of the world production passes through the English Channel!

A minimum estimate of the fraction of lost oil can be calculated from the extent of single large accidents and from operating records of oil ports. The tanker 'Torrey Canyon' alone carried and lost 100,000 tons or 0.01% of the annual sea transport. The recent accident at Santa Barbara has introduced into the ocean some 10,000 tons of crude oil. Reliable figures about oil losses in port are available from Milford Haven, a relatively new British oil port, adjacent to a national park. There, great efforts have been made to control and prevent oil pollution and to keep a record of the size of any spills. In 1966 the annual turnover at Milford Haven was 30 million tons. The losses in the same time period amounted to 2900 tons or 0.01% of the total amount handled. A single accident (the tanker 'Chrissi P. Goulandris') contributed between 10 and 20% of this total; the other losses are attributed to design faults, breakages, and mechanical failures, losses in transfer, and human error. This figure does not include losses outside the port due to accidents in shipping, (e.g. the 'Torrey Canyon') and from numerous other sources such as ballasting and flushing of the bilges, etc. With the less stringent operation of many other ports and the additional losses on the high seas, the loss in transport alone may amount to 0.1% of the total oil shipped, or 1 million metric tons! The actual oil spread on the ocean is higher, since these figures do not include accidents in production (Santa Barbara) return to the ocean of petroleum products (fuels and spent lubricants) in untreated municipal wastes and incomplete combustion of marine fuels.

Therefore, the oil influx to the ocean is at least 1 million tons per year (shipping losses only) and is likely to be ten to one hundred times higher.

Oil Composition and Biological Effects

To assess the biological effects of oil pollution we should discuss the composition of crude oil and the relative toxicity of its fractions. Crude oil is one of the most complex mixtures of natural products, extending over a wide range of molecular weights and structures. The low boiling* saturated hydrocarbons (gasoline range) have, until recently, been considered harmless to the marine environment. However, it has now been demonstrated that these hydrocarbons at low concentrations produce anesthesia and narcosis and, at greater concentration, cell damage and death in a wide variety of lower animals, and that they may be especially damaging to the larval and other young forms of marine life. Higher boiling* saturated hydrocarbons (kerosene and lube oil range) occur naturally in many marine organisms and are, probably, not directly toxic though they may interfere with nutrition and possibly with the reception of the chemical clues which are necessary for communication between many marine animals. Olefinic hydrocarbons probably are absent from crude oil, but they are abundant in oil products, e.g. in gasoline and in cracking products. These hydrocarbons also are produced by many marine organisms, and may serve biological functions, e.g. in communication. However, their biological role is poorly understood. Aromatic hydrocarbons are abundant in petroleum; they represent its most dangerous fraction. Low boiling aromatics (benzene, toluene, xylenes, etc.) are acute poisons for man as well as for all other organisms. It was the great tragedy of the 'Torrey Canyon' accident that the detergents which were used to disperse the oil spill had been dissolved in low boiling aromatics. Their application multiplied the damage to coastal life. It should be pointed out, however, that poisoning of marine life will occur even with non-toxic detergents or dispersants which are applied in non-toxic solvents, because they disperse the toxic materials of crude oil. This exposes organisms to these poisons through contact and ingestion. The high boiling aromatic hydrocarbons are suspected as long term poisons. Current research on the cancer producing hydrocarbons in tobacco smoke has demonstrated that the carcinogenic activity is not—as was previously thought—limited to the well know 3.4 benzopyrene. A wider range of related hydrocarbons can act as potent tumor initiators. While the direct causation of cancer by crude oil and crude oil residues has not yet been demonstrated conclusively, it should be pointed out that oil and residues contain hydrocarbons similar to those in tobacco tar. In their behavior and toxicity, the non-hydrocarbons of crude oil (nitrogen, oxygen, sulfur, and metal compounds) closely resemble the corresponding aromatic compounds.

*Different components of petroleum have different boiling points. This is the basis of refining, by heating crude oil to increasingly high temperatures and collecting the portions that boil off. (Ed.)

Oil Analysis and Law Enforcement

The great complexity of crude oil has an interesting consequence: The variety in the composition of different crude oils and oil products is so great that every oil has its own compositions which are typical and as permanent as fingerprints. Great efforts have been expended by many oil companies in utilizing this characteristic to determine the relationships or differences between oils produced from different oil bearing horizons or discovering a mutual relationship between oils and the sediments from which they originate. This fingerprinting technique is becoming available to the public and will lead to an improved and often conclusive way to tie an oil spill to oil from a particular oil field or from a particular vessel. The analytical techniques are simple and should be a great aid to law enforcement.

Long Term Effects of Oil Pollution

The immediate, short term effects of oil pollution are obvious and well understood in kind if not in extent. The oil pollution damage to coast lines and to bird populations is well known. As mentioned, oil pollution on the high seas is just being recognized, even though the amount of tar already exceeds the amount of plant life floating at the sea surface. We have discussed the short term toxicity for individual petroleum fractions. In contrast, we are rather ignorant about long term and low level effects of crude pollution. I fear that these may well be far more serious and longer lasting than the more obvious short term effects.

The Food Chain

The great complexity of the marine food chain and the stability of the hydrocarbons in marine organisms, lead to a potentially dangerous situation. The food chain of those terrestrial organisms, which are important for human nutrition, is simple. Man either eats plant material or meat products from animals that have been raised on plant food. Human food derived from the sea is much more remote from its origin in plants. Few marine plants are used directly for human nutrition. Except for shellfish, we consume few marine animals that have fed directly on marine plants. Most larger marine animals derive their food from other marine animals already remote from the original plant source. We have studied the fate of organic compounds in the marine food chain and have found that hydrocarbons, once they are incorporated into a particular marine organism are stable, regardless of their structure, and that they may pass through many members of the marine food chain without alteration. In fact, the stability of the hydrocarbons in marine life is so great that hydrocarbon analysis serves as a tool for the study of food sources. In the marine food chain, hydrocarbons may not only be retained but they can actually be concentrated. This is a situation akin to that of the chlorinated pesticides which are as refractory as the hydrocarbons. These pesticides are concentrated in the marine food chain to the point where toxic levels mays be reached. It is likely that the treatment of oil spills with detergents or dispersants, or the natural dispersion of oil in storms, produces oil droplets of such small sizes that they can be eaten and consequently taken up in the body of many sea animals. Once assimilated, this oil passes through the food chain and eventually reaches marine products that are harvested for human consumption. The incorporated oil particles may produce an undesirable flavor. A far more serious effect is the potential accumulation in human food of long term poisons derived from crude oil, for instance of cancer causing compounds.

Another concern is the possible long term damage by pollution to the marine ecology. Many biological processes important to the survival of marine life are affected by extremely low concentrations of chemical messengers in the sea water. Marine predators are attracted to their prey by organic compounds which are present at less than one part per billion. Such chemical attraction—and in a similar way repulsion—plays a role in the finding of food, the escape from predators, in the homing of many commercially important species of fishes, in the selection of habitats, and in sex attraction. There is good reason to believe that pollution interferes with these processes in two ways: by blocking the taste receptors and by mimicking natural stimuli; the latter leads to false responses. Those crude oil fractions likely to interfere with such processes are the high boiling saturated and aromatic hydrocarbons and the full range of the olefinic hydrocarbons. It is obvious that a simple —and seemingly innocuous—interference at extremely low concentration level may have a disastrous effect on the survival of any marine species and on many other species to which it is tied by the marine food chain.

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Countermeasures Against Large Oil Spills

It must be clear from this discussion that I do not consider the use of detergents or dispersants, toxic or nontoxic, as a solution for pollution problems. The introduction by dispersants of toxic components of crude oil into the sea and the marine food chain constitutes a risk that should not be taken lightly.

Sinking of an oil spill by treatment with hydrophobic minerals, (e.g. chalk treated with stearic acid or refractories treated with silicones) may be preferred; however, we do not know whether the oil remains on the sea floor or whether it will return to intermediate or shallow waters where it can enter the food chain. Also, we do not know enough about the effect of oil on bottom communities.* Sedimentation rates in the open ocean are quite low, and oil that has been sunk will remain exposed on the bottom for long periods of time.

*See page 8 of this issue.

In my opinion, burning of the oil where possible or containment and rapid recovery are the only acceptable solutions for managing large spills.

The Long-Term Outlook

Mankind is depleting the natural oil reserves rapidly. Therefore, it is unlikely that oceanic oil transport will increase by several orders of magnitude. In spite of this, there are several good reasons to anticipate an increase in the seriousness of the marine oil pollution. Marine oil transport through more hazardous waters will increase, (e.g. transport of the Alaskan oil through the Bering Straits). Oil production will shift increasingly to the continental shelves and to oil reserves in deep water; for instance, the Sigsbee Deep in the Gulf of Mexico may be tapped. This will lead to an increasing risk of accidents. Oil products and synthetic oil, (coal hydrogenation products, shale oil) which are more toxic than crude oil, will make up a larger fraction of the oil transported, used, and spilled.

We are convinced of the great value of oceanic food production for mankind. In the future, a larger fraction of human nutrition must be derived from the sea. Farming of the sea (aquaculture) will become an important pursuit for man. If we do not take care of the present biological resources in the sea, we may do irreversible damage to many marine organisms, to the marine food chain and thus eventually may destroy the yield and the value of the food which we hope to recover from the sea.

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DARE I GO IN . . . ?