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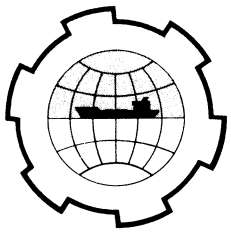

MARINE POLLUTION, ITS IMPACT AND CONTROL AT HIGHER LATITUDES.

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Man wishes to make use of the sea in various ways, one of which is the disposal of waste of various description. The sea has an enormous capacity to receive waste. Domestic waste, both solid and liquid, need not cause any concern if only properly handled and transported. Discharge or disposal of industrial waste can lead to pollution, i.e. to deleterious effects on navigation, on the living resources of the sea, and on the amenities. Biological accumulation of toxic components in the food chains and smothering of the beaches by mineral oil are the types of pollution which cause the greatest concern. An international convention for prevention of marine pollution is urgently needed.

Environmental pollution is a front-page topic nowadays. Almost every day newspapers, radio, and television tell us how the natural environment is violated again and again by deliberate or accidental introduction of dangerous waste of various description. In many of these cases it is the sea which is the unvoluntary recipient of such waste and the public concern is now so much aroused about it, that diplomatic activities are a logical consequence. This, because the sea is common property of mankind. It is this common property aspect which still makes it extremely difficult to stop and to control marine pollution. Beyond the territorial waters the legal basis for reglementation and prosecution is extremely weak, indeed. Hugo de Groot's "Mare Librum" still reigns in this domain.

A few weeks ago, the "Stella Maris", heading for a site at 65° N.Lat. and 0° W.Long., to discharge 600 tons of tars and "heavy ends", containing short-chained chlorinated hydrocarbons, was called back to its home port Rotterdam.

Diplomatic pressure from several sides, backed by a general public concern, made it virtually impossible for the "Stella Maris" to carry through its dumping programme. Strictly speaking nobody could prohibit, based on any law or convention, the discharge of the cargo of waste at the given site. But even if one would have had an international convention to reglement disposal of waste in the sea, it would still be questionable whether this special cargo would be refused for dumping. The site chosen is so deep (over 2000 m) that no fisherman's gear would ever be smothered by the tar-like waste lying on the sea bottom and the toxicity of the material is not very great, whereas the natural chemical decomposition of the more volatile and soluble components will not take very much time. Therefore, there are no indications that any deleterious effects on the living resources of the sea would sooner or later ensue from dumping this material.

Evidently, marine pollution is a phenomenon so much loaded with public sentiment that it is increasingly difficult to give a sound advice in this matter on a purely scientific basis. What exactly should be called "marine pollution"? It is not so easy to define this, and a working group of the Intergovernmental Oceanographic Commission of UNESCO, of which I had the honour to be the Chairman, took quite a long time to reach agreement on the following wording, now internationally adopted:

> "Introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairing the quality for use of sea water, and reduction of amenities".

The salient terms in this definition are the "introduction by man" and the "deleterious effects". The point is, that along other pathways than man's activities, the sea receives a considerable amount of material from the continents. The main cause of this is the perpetual cycle the chemical component called "water" performs. Evaporation means that water molecules escape from the sea to enter the atmosphere. During the vertical migration in the atmosphere they may congregate into droplets, or, when the temperature is low, into ice-crystals. This leads to formation of clouds, which are easily transported by the wind. As rain or snow the water may descend again in due course, partly falling back into the sea, partly on the continents, when driven thither by the wind. Rivers and glaciers bring most of it back to the sea again, loaded with particulate and dissolved erosion products of the earth's solid crust. The particulate matter carried down to the sea varies in size from big boulders, via sand, to the finest clay particles. Most of this sinks to the bottom of the sea, the smaller the particles, the further they may travel in the sea. Virtually all of this is

deposited on the continental shelf, locally at a rate of several cm per year. One should, however, not forget that the wind too sees to transportation of erosion products from the continents to the seas. A dustlike material is blown to the sea from deserts and montainous areas. This aeolian material finally reaches the bottom of the sea and is found there as the "red clay", covering about 40% of the floor of the oceans. Its rate of sedimentation is of the order of 1 mm in 1000 years.

Apart from particulate erosion products the sea receives via the rivers large quantities of dissolved matter, often in ionised form. The remarkably high salinity of the ocean should at least partly be ascribed to contribution from the land. It may seem surprising that the chemical composition of river water differs quite a bit from that of sea water, but that can be explained in terms of a different residence time of various elements in the sea. The remarkably constant chemical composition of sea water should not be considered as a given static phenomenon, but rather as a dynamic equilibrium. Some elements, introduced into the sea, are sooner or later absorbed on bottom material, e.g. in the well-known manganese nodules, whereas other elements are taken up by living organisms for the building up of their soft body tissues or of their skeletons. Diatoms take up silicum, foraminifera calcium, and their microscopic frustules and shells cover large areas of the sea bottom. After consolidation orogenic processes may bring such marine deposits above sea level some day, and in fact most of the calcareous rocks now found on the continents have once been deposited on the bottom of the sea as skeletons of marine organisms. Just as water, calcium performs a cycle, be it at a somewhat slower rate. The same holds good for various other elements playing part in biological processes.

Though these phenomena may adversely affect the living organisms in the sea, especially where rivers discharge large quantities of fresh water, or are locally heavily loaded with silt, all this should not be called marine pollution. Pollution refers to introduction of various substances by man, leading to deleterious effects of various nature. As the definition shows, deleterious effects can, among other things, be observed on the living resources, on man's health or on the amenities, i.e. the areas used for recreation.

Whether dumping of certain waste substances in sea should be considered as "marine pollution" does therefore first of all depend on the type of use one wishes to make of the section of the sea under consideration, or of the area to which the dumped material can be transported by the sea currents. Man wishes to use the sea to various ends : for navigation, requiring absence of obstacles ; for fishery and mariculture, requiring a high oxygen level and a given fertility level leading to a high production of food organisms, to which in the case of mariculture the factors shelter and cleanliness should be added ; for recreation on the beaches and in the coastal strip of water, requiring clean sandy beaches and clear water by preference poor in organisms such as diatoms, crabs,

jelly-fishes, sea-urchins, weevers, sharks and sting-rays ; for industrial use such as manufacture of drinking water and magnesium, requiring water free of chemical contamination ; and, last but not least, as recipient of waste of various nature. The quality requirements differ from case to case, and if one is faced with a clash of various interests, priorities should be set after a careful study.

In studying the effect of waste disposal in the sea we should clearly distinguish domestic waste from industrial waste. Domestic waste concerns organic products such as droppings and urine, dead organisms, both plants and animals, to which should be added in our time also waste products of the industrial working up of animal and vegetable matter. All these products have in common that they are non-toxic as such, and are easily degraded by micro-organisms. This means that bacteria and other heterotrophic organisms of microscopic dimensions use them as food to build up their own body tissues, and mineralize a fair part of it down to carbon-dioxide and nutrient salts, which can be used again by the green organisms of the phyto-plankton as basic material. This process is called biodegradation. It requires a given amount of oxygen and leads to increasing fertility of the water. When domestic waste is discharged in a large body of water, e.g. 10 or 20 miles offshore in the sea, no deleterious effects will be observed, which means that such an introduction into the marine environment should not be counted among the cases of marine pollution. When, on the other hand, the domestic waste, transported by a sewer, is discharged into an estuary or in the shallow water bathing a beach, marine pollution often is a reality : swimming and bathing will become dangerous in that area, since not all the people at the other end of the sewer are healthy ; shellfish such as oysters and mussels, filtering the water in search of food, may ingest pathogenic germs and viruses and become dangerous to eat without prior cooking ; oxygen may become depleted, especially in the deeper water layers, which makes life impossible for most of the denizens of the sea, fishes included ; the fertility of the water may become so much increased that a special type of organisms, adapted to such conditions, oust the normal type of phytoplankton. In the latter case one often observes the development of a poisonous type of plankton, rendering shellfish unfit for consumption, even after thorough cooking or frying, and in serious cases even killing fish and other denizens of the sea. Increased fertilization of the water is generally called eutrophication. Various inshore areas, especially estuaries and inlets, have thereby lost their original flora and fauna and their importance for the production of fish and shellfish. The Oslo fjord is a notorious case.

Industrial waste is a phenomenon of more recent nature than domestic waste. The mushrooming of the chemical industry and the greatly increased demand for mineral oil are at its basis.

Industrial waste contains products of divergent nature, among which mineral

oils, pesticides and heavy metals are the more notorious elements causing marine pollution. The general public is above all concerned about oil pollution. One vividly remembers the frightening case of the "Torrey Canyon", front page news for weeks in succession, and almost everyone knows the vexation caused by oil polluted beaches, spoiling so much of the pleasure of marine recreation. Not all oil floating on the surface of the sea should, however, be called a case of marine pollution. Where marine recreation does not take place because of the climate or somewhere far away from any beach, the floating oil is rather harmless. Crude oil is a natural product, with marine plankton at its basis, not very toxic as such for most of the denizens of the sea. It is, moreover, liable to biodegradation by micro-organisms, especially where the water temperature is rather high. Its more volatile components evaporate readily and move into the atmosphere, where they are liable to physico-chemical degradation, in which ultraviolet rays play an important part. When Thor Heyerdahl reported floating oil fields in the midst of the tropical Atlantic, this can hardly be called marine pollution according to our definition. Apart from marine recreation at the fringe of the sea, organisms like sea-birds, whales and seals may suffer from floating oil fields, because the oil may smother their feathers and skin, leading to leaks in their plumage and in the marine mammals to cancerous sores on their skins, perhaps also to inflictions of their respiratory systems.

As long as the oil fields float, fishes have little to fear, but since the floating oil may reach beaches used as amenities, the authorities concerned wish to do something to prevent such ill effects. In such a case one uses emulgators, turning the floating oil into very small droplets, dispersed in the water, and certain products to be sprayed on the oil to make it sink to the bottom. In both cases one does not really destroy the oil, but only displaces it. Since the oil is out of sight after such treatment one feels to have achieved something, but in reality it is nothing else than having swept the dust under the carpet. For fishes and shellfish such treatment may cause havoc : the emulsifiers are often considerably more toxic than the oil itself ; fish and shellfish may become tainted when ingesting too many small oil droplets or passing too many through their gills, and thus become unpalatable ; spawning beds and feeding grounds for demersal fish may receive such a coating of oil that they loose their quality as such. Therefore, considerable caution is required in case one wishes to proceed to attack a floating oil field. The damage caused may be of greater economical importance than the advantages one hopes to achieve.

Biodegradation of oil is in many cases the best way to get rid of it : in a moist mixture of oil and sand biodegradation proceeds quite rapidly where temperature is not too low. One considers also to attack floating oil fields with a preparation containing oil-consuming bacteria and some kind of compound releasing phosphates, since the latter often are the limiting factor in bacterial development in superficial water layers in the warmer sections of the

ocean. In principle this might yield satisfactory results, provided one can culture an adequate strain of bacteria and keep them in storage for a long time, awaiting the need for action. Under arctic conditions floating oil will not easily be degraded by micro-organisms, but on the other hand, amenities do often not occur there, and fishes have nothing to fear as long as the oil is floating. Evaporation will take away the more volatile compounds, and only where seals or whales are a resource of economical importance, damage may be feared.

By far the best way to control oil pollution is, however, to prevent it. It must be possible to organize obligatory tanker cleaning in ports and to frame more effective regulations for tanker navigation. It has been said before that when aviation would be performed with the same accuracy as navigation that air crashes would be daily news!

Quite a different category of industrial waste is formed by metal ions, acids, lyes, and other inorganic constituents. The sea can accept large quantities of various inorganic compounds, provided one closely follows the official prescriptions and reglementations, even though the latter still lack a solid legal background beyond the territorial waters. In discharging inorganic constituents, one should compare their chemical composition with that of natural sea water. When the extra concentration after initial dilution (this to be understood as the concentration measured one hour after discharge in the wake of a rapidly sailing ship) is less than 50% of the concentration of the ions under consideration in natural sea water, no ill effects whatsoever are to be anticipated, which means that the discharge under consideration should not be called marine pollution. Inorganic acids are readily neutralized in sea water when properly distributed and even lyes can be taken up in this well-buffered medium. When one does not obey this 50% rule in discharging inorganic waste deleterious effects are to be expected. The organisms living in sea water are since aeons adapted to a very constant chemical compositions of their environment, and therefore have never felt the need to develop mechanisms to defend themselves against fluctuations in the chemistry of their milieu. Certain elements are liable to biological accumulation, which means that some organisms, faced with a too high concentration of it, take it up in such quantities that it either leads to their death or to the death of predators feeding on them, man included. Heavy metals such as mercury, cadmium and copper are notorious in this. Therefore, the greatest care is required in discharging into the marine environment elements which occur only sporadically in natural sea water and are at the same time liable to biological accumulation.

A third category of industrial pollution concerns man-made compounds not occurring at all in natural sea water. When such compounds are persistent, which means that they are not liable to chemical and microbiological degradation in sea water, deleterious effects of various description are to be feared. Notorious examples are persistent pesticides such as chlorinated hydrocarbons

(e.g. DDT) and also compounds like the PCB's (polychlorbiphenyls) used for various industrial purposes. Such products show a very great difference in solubility in water and in fats, which means that every bit of it discharged into the sea finds its way sooner or later to the oil droplets in diatoms and copepods. Once arrived there, they will follow the food chain from predator to predator in ever increasing concentration. At the end of the food chain, which may be a bird, a seal, a whale or man for marine organisms, death may strike. This occurs especially when oil and fat containing the toxic products is digested, setting the poisons free, or when the natural fat reserves are used up rapidly, which can be the case during migration or during sitting on the eggs in birds, or during periods of food shortage. A product like methylmercury, so easily formed from inorganic mercury by micro-organisms, belongs in the same category by its extremely toxic nature and its great fat solubility.

Every effort should be made to avoid introduction of such compounds in the sea. Some of it finds its way to the sea via their agricultural application, either by leaching out to rivers or by co-destillation processes immediately after spraying, which make them air-borne and liable to rapid transportation over long distances. Thus even the penguins in the Antarctic got some DDT in their body fat.

It seems wise to replace the persistent pesticides as soon as feasible by degradable pesticides and to incinerate waste of this nature rather than to dump it in the sea.

The sea can take up large quantities of waste without any deleterious effects, therefore without causing pollution. One should, however, discriminate carefully the products one wishes to dispose of. There is an urgent need for an international convention to reglement waste disposal in the sea. One should make strict prescriptions indicating which type of waste can be safely discharged in the coastal area, which type should be brought further offshore, taking care of a good initial dilution, which type should be brought to the area beyond the continental shelf to safeguard the natural resources and the fishery. Where the depth exceeds 2000 meters one can deposit non-poisonous waste heavier than water (such as old cars) and products safely packed in drums or concrete without causing marine pollution, for no fishing operations will ever take place at such depths. Some extremely dangerous chemical products should never be dumped in the sea, but should be disposed of in another way. Technically marine pollution can be prevented to a very high degree, even taking into account nautical calamities, but one will only reach that goal on the basis of a good international convention, backed by an excellent system of international control. The recent arsenic scandal in Germany demonstrates that one should not only order a given material to be dumped in a given site, but should also use a good system of control. Dumping or incinerating dangerous material at sea requires a foolproof

registration system to control the course, the distances covered, the rate of discharge, and the temperature during incineration. With our modern instrumentation such a system of control is very well feasible, especially when bona fide companies are charged with the disposal. One should realize, however, that all this requires financial sacrifice from all of us.