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UNITED NATIONS

THE VITAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

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GUNNAR KULLENBERG

THE VITAL SEAS

Questions and Answers about the Health of the Oceans

PREFACE

There are many questions about the health of the oceans for which we do not have answers at the moment. But for perhaps a surprising number we do have at least tentative answers, and some idea of how we might go about solving the problems created by our use of the seas.

That is one reason it seemed a good idea to present GESAMP's findings on the health of the oceans as a series of questions and answers.

In fact, this was how the booklet took shape: as an attempt to answer the questions an ordinary person might ask about the marine environment and GESAMP's efforts to provide a scientific assessment of the problems of pollution.

Fuller replies can be found in GESAMP's Review of the Health of the Oceans (published as GESAMP Reports and Studies No. 15 by UNESCO and as UNEP Regional Seas Reports and Studies No. 16) and in the Technical Annexes which are still appearing. For easy reference, the text indicates the pages where subjects are treated in the Regional Seas edition of GESAMP's Review*.

My thanks go to Dr. Stjepan Keckes of the Regional Seas Programme Activity Centre for suggesting the project and to Peter Hulm for preparing and editing the text.

GESAMP scientists all have their own strong opinions about the health of the ocean and how to safeguard its vital resources. They may not agree with all that is said here. But so far as is possible, this booklet sets out the scientific consensus of the GESAMP Working Group over which I presided. Our findings show that much can be done to ensure the oceans stay healthy and their resources can be exploited on a rational and sustained basis. GESAMP has set out the options. Action is now a question for governments. But we see no reason why, with proper care, the patient should not be restored to health and stay that way.

Gunnar Kullenberg

Chairman, GESAMP Working Group
on the Review of the Health of the Oceans

Geneva, 10 April 1984

* GESAMP (IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution): The Health of the Oceans. UNEP Regional Seas Reports and Studies No. 16. UNEP, 1982.

CONTENTS

		Page
I	WARNING SIGNALS FROM BEYOND OUR SHORES	1
II	THE OCEAN DOCTORS	5
III	PASSENGERS IN THE PLANETARY LIFEBOAT	7
IV	THE THREAT TO THE OCEANS	9
V	THE TAINTED BEACH	13
VI	THE RISKS WE RUN	15
VII	BIOCIDES AND SUICIDE	19
VIII	OIL AND ENERGY	22
IX	A PRESCRIPTION FOR THE OCEANS	26
X	SIGHTS ON THE FUTURE	29

I WARNING SIGNALS FROM BEYOND OUR SHORES

Roll on, thou deep and dark blue ocean - roll !
Ten thousand fleets sweep over thee in vain;
Man marks the earth with ruin - his control
Stops with the shore.

George Gordon, Lord Byron

Why should we worry at all about the health of the oceans?

The short and simple answer is that the oceans play a fundamental role in maintaining present conditions for life on earth (10)*. A deterioration in the condition of the oceans could result in the end of life on our planet.

Why should we be particularly concerned now?

We have plenty of evidence that human activities today dump unprecedented amounts of material, including poisonous substances, into the heart of this gigantic life support system (1) by direct discharge, run-off from land, via rivers or through the atmosphere.

What are the effects?

I should imagine we have nearly all seen examples of coastal pollution in the form of sewage sludge, industrial wastes, litter, oil spills, or contaminated shellfish (2). Today we know many contaminants get as far as the deep sea floor where they have caused serious damage to life, though so far this has been restricted to very small areas (1). Over the past few years there has been further cause for concern. Scientists have found traces of the insecticide DDT in the Arctic seal and the Antarctic penguin, thousands of kilometres distant from anywhere the pesticide is likely to

* Numbers refer to pages where the subjects are treated in GESAMP's review of the Health of the Oceans.

be used. With the advent of the nuclear era, we have begun to discover "man-made" radioactive material in the open ocean, in places as far apart as the Bahamas and the Arctic (1). For one reason or another - and partly because we have now developed sensitive detection techniques - we can find the tracks of contaminating substances a long way from their sources (1).

What about life in the sea?

Well, just to speak of the living resources we exploit: salmon and oysters, now rare and expensive delicacies in many regions, were once so common they were considered food only for the poor. Several whale species have been hunted close to extinction, fisheries have collapsed, and in some regions species of seal and birds have been endangered by pollution. Exploitation, gradually turning into overexploitation, of resources, combined with a gradual deterioration of the environment, unavoidably takes its toll.

Are these effects to be considered as symptoms, local accidents, freak results, or products of the sea's normal processes?

They are indications that the sea's capacity to absorb wastes has its limits (7), that the ocean system cannot be regarded as an isolated entity (10), and that we cannot treat its living riches as inexhaustible. These are all ideas that not so long ago were uncommon outside a small community of scientists, conservationists and explorers.

And are the oceans sick?

After making our study, the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) concluded that increasing contamination and the effects of pollution could be found mainly in the areas that humanity uses most intensively - the coastal zones. However, we noted that the effects of pollution had not yet reached the open oceans on a global scale.

It very much depends on how you assess health and sickness. GESAMP pointed out that these trends are strong warning signals (6). We sounded a clear alarm that the combined effects of many local disturbances could become serious on a regional and perhaps gradually on a global scale (4).

What, then, is GESAMP's prescription?

Improved management of the seas. That means controlling more closely what we put into the seas and what we take out of them, together with careful monitoring of contaminant levels. Our understanding of the fate and effects of pollutants in the oceans must be improved (7). A re-examination of sewage disposal practices is necessary, along with proper management (4). The open sea is the main body of the ocean system and must be kept in good health. But that does not mean the extremities - the estuaries, lagoons and shallow waters - can be neglected. Our warning was that deterioration there, if allowed to progress, might affect the whole body (9).

Weathering of rocks, discharges from deep sea vents and winds all put material into the sea. Why do you say human actions are so important for the health of the oceans?

Because we introduce disturbances to the natural system at exactly those points where many of the ocean's life-supporting processes take place: where land meets the sea, at the air-sea interface, and in the sea-floor sediments. Human activities now put into the ocean loads which rival the natural sources for arsenic, mercury, lead, cadmium - even something as basic as carbon dioxide, the gas all animals exhale (1). The 20th century has also seen the development of chemical compounds never found in nature such as DDT and the industrial synthetics known as polychlorinated biphenyls or PCBs. These man-made products are completely outside the natural system and so persist for a very long time in the environment.

What, then, are the prospects for the future?

Certainly, we can expect world developments to produce even more sewage, industrial wastes and other effluents for the seas to absorb in the future (4). Growing energy demands are likely to add to marine pollution - whether from oil exploration or radioactive discharges resulting from nuclear power (5).

And your recommendation?

If we are going to use the oceans properly, we need to understand the ocean system and the marine environment, just as physicians need to understand how the body works to keep us in good human health and prevent sickness. In several major respects, much about the body of the sea remains a mystery. Increased understanding can only come from research, which should be paralleled by proper decisions and actions on control and management.

WATER DISCHARGE OR OTHER PROCESS OF ACTIVITY POTENTIALLY CAUSING CONTAMINATION	BALTIC SEA	NORTH SEA	MEDITERRANEAN SEA	PERSIAN GULF	WEST AFRICAN AREAS	SOUTH AFRICAN AREAS	INDIAN OCEAN REGION	SOUTH-EAST ASIAN REGION	JAPANESE COASTAL WATERS	NORTH AMERICAN AREAS	CARIBBEAN SEA	SOUTH-WEST ATLANTIC REGION	SOUTH-EAST PACIFIC REGION	AUSTRALIAN AREAS	NEW ZEALAND COASTAL WATERS
SEWAGE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PETROLEUM HYDROCARBONS (MARITIME TRANSPORT)	X	X	X	X	X	X	X	X	X	X	X	X			
PETROLEUM HYDROCARBONS (EXPLORATION AND EXPLOITATION)		X		X	X			X		X	X	X	X	X	
PETROCHEMICAL INDUSTRY		X	X	X					X	X	X				
MINING			X					X		X			X	X	
RADIOACTIVE WASTES	X	X	X				X		X	X		X			
FOOD AND BEVERAGE PROCESSING	X	X	X			X				X	X	X	X	X	X
METAL INDUSTRIES		X	X		X				X	X		X			X
CHEMICAL INDUSTRIES	X	X	X						X	X					
PULP AND PAPER MANUFACTURE	X				X					X			X	X	X
AGRICULTURAL RUNOFF (PESTICIDES AND FERTILIZER)			X		X		X	X		X					X
SILTATION FROM AGRICULTURE AND COASTAL DEVELOPMENT						X	X	X			X				
SEA-SALT EXTRACTION							X				X				
THERMAL EFFLUENTS						X	X		X	X	X	X			
DUMPING OF SEWAGE SLUDGE AND DREDGE SPOILS		X							X	X					

Table: Sources of marine pollution around the world (from GESAMP, The Health of the Oceans) first published in The World Environment, 1972-1982 , UNEP 1982.

II THE OCEAN DOCTORS

> With science as a basis and law as a rational instrument of rational men, we can ensure that the great riches of the world are used with conscious moderation in the interests of all nations.
>
> Manfred Lachs, Member, International Court of Justice

The Review of the Health of the Oceans was a study prepared by a GESAMP Working Group under your chairmanship. What exactly is GESAMP?

The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) was set up in 1969.* It is sponsored by eight United Nations agencies, which each nominate a number of members. The members then act as individual experts serving GESAMP as a whole. Special care is taken to ensure that GESAMP expertise covers all relevant scientific disciplines and includes representatives from many regions. Perhaps what makes GESAMP unique is that it is interdisciplinary and independent.

What is its function?

As the name indicates, the GESAMP Members' task is to provide scientific evaluation of the problems of pollution. They carry out this voluntary job through Working Groups on specific issues, in which other experts are normally invited to take part on an equal basis with the Group experts to ensure we obtain the best scientific opinions. My Working Group had 51 members and corresponding members, for example.

* For a brief history see: V. Pravdic: GESAMP, The First Dozen Years, UNEP 1981.

How did GESAMP come to produce this review of the health of the oceans?

Periodic reviews of the marine environment and pollution became one of GESAMP's main responsibilities in 1977, after several years of preparatory work including assembly of the available data.

Then early in 1978, GESAMP's Tenth session in Paris set up the Working Group on a Review of the Health of the Oceans. We were asked to provide succinct critical reviews and scientific evaluation of the influence of pollutants on the marine environment. The Working Group was instructed to advise on pollution's overall impact on the oceans and our uses of the marine environment. We are also asked to advise which issues require further study.

Your Review of the Health of the Oceans has been described as the first integrated report aiming at a global assessment of the pollution of the marine environment. Will there be others?

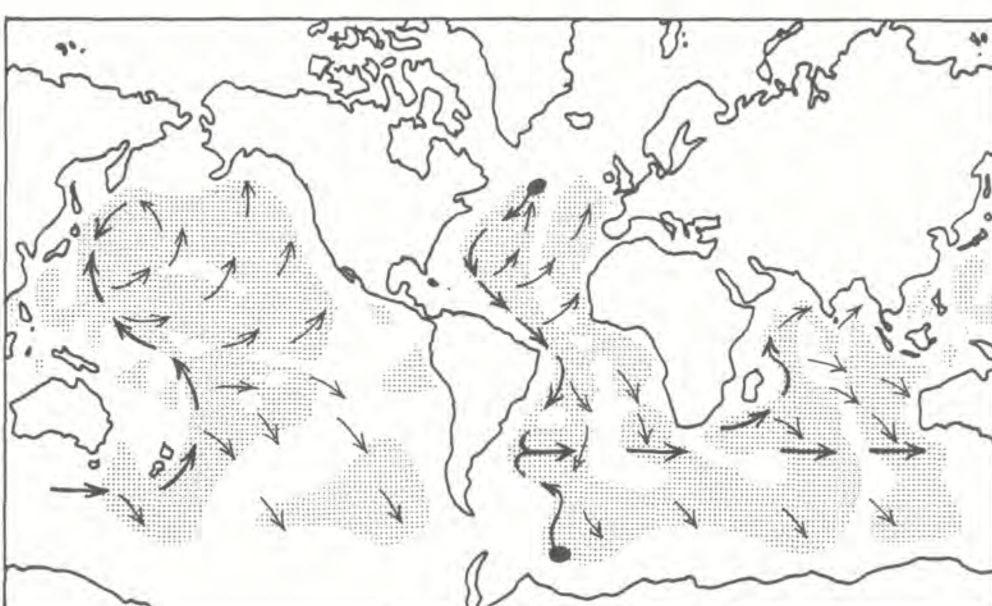
According to our terms of reference, these reviews are to be produced every three or four years. Our report on the health of the oceans was published in 1982 as our response to the recommendation by the United Nations Conference on the Human Environment (Stockholm, 1972), which suggested that we should assemble data and provide scientific advice on marine pollution. The Review appeared for the UNEP Governing Council which commemorated the 10th anniversary of the Stockholm Conference.

III PASSENGERS IN THE PLANETARY LIFEBOAT

> One who is in a boat at sea does not quarrel with the boatman.
>
> African song

In what way are the oceans essential for life?

All life on our planet depends on the global circulation of water -- the cycle that draws water from the ocean to become clouds and vapour in the atmosphere, which then fall as rain over land and return via rivers eventually to the sea. We rely on the hydrological cycle not only for our fresh water. The water transports and cycles vital nutrients through the soil and under the ground, along



Deep ocean currents, modelled after Henry Stommel rivers and into lakes, and thus supports the rich variety of terrestrial life. From this precise balance of chemicals and water, the plants on land and in the sea use sunlight to produce the oxygen all animals need to live. It has been calculated that the sea's microscopic plants produce something like a quarter of the world's oxygen.

Physically as well as biologically, the oceans are a major stabilising force for life on Earth, aren't they?

Yes. The seas act as a giant reservoir for heat from the sun and help even out temperatures around the globe as well as shape our climate. Without the fluid envelope around the Earth provided by the oceans and the atmosphere, it has been calculated, the effective surface temperature on our planet would be minus 25^{o}C instead of the present 15^{o}C.

Apart from providing us with water, the hydrological cycle helps meet our equally vital needs -

Oh yes. The circulating water takes with it our wastes, which would otherwise build up, gradually poisoning the land and air. Since time immemorial the seas have been humanity's main garbage dump.

As well as a major source of our food?

Right. Fish and other aquatic animals account for an average of 17 per cent of the animal protein in human diets. Over 30 countries get more than a third of their animal protein from seafood. More important, they include many developing states of West Africa and Asia, for example, as well as major commercial fishing nations. It has been calculated that fish provide about 55 per cent of all the animal protein consumed in Asia.

How does this marvellously productive system operate?

The complex web of life in the sea continuously recycles the chemicals essential for living organisms to survive. The marine plants transform inorganic nutrients into organic matter. Animals convert organic matter back into carbon dioxide when they breathe. The plants serve as food for vegetarian forms of life. These in turn are eaten by the carnivores. At the bottom of the sea, scavenging forms of marine life and bacteria which decompose organic debris help regenerate the nutrients which are gradually carried back to the surface. This takes place particularly in the so-called upwelling regions near coasts, where over 90 per cent of fish production occurs.

It's almost a perpetual motion machine for life, isn't it?

Certainly some of these elements are essential to life - for example, the four major chemical building blocks for living matter: carbon, oxygen, hydrogen and nitrogen. Other substances - such as phosphorus, magnesium and sulphur - are nutrients which living things need in small but significant amounts. Tiny quantities of other elements perform essential functions. Examples are chromium, cobalt, copper and iodine.

But it is a delicate balance. Oxygen is poisonous for micro-organisms such as yeasts, which do not need air to survive. At high concentrations it is even toxic to mammals, human beings included. Ammonia, poisonous for humans, is an important source of nitrogen for many plants. Hydrogen sulfide, extremely toxic for mammals, is a necessary nutrient for certain bacteria.

IV THE THREAT TO THE OCEANS

I have a feeling that we are sweeping the floor and throwing it all underneath the carpet - and this carpet is the most important part of this planet.

Thor Heyerdahl, marine explorer

One question we ought to tackle first here - what do we mean by the term "pollution"?

GESAMP's working definition of marine pollution is: "The 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, impairment of quality for use of sea-water, and

reduction of amenities."

This definition implies that we need to see a definite change for the worse in the environment before we cry pollution. Obviously, not all substances that enter the sea are pollutants according to this definition. Often the amounts are critical. The decisive factor in our deliberations was the effect of substances, not just their presence.

The oceans and seas are so huge - covering 70 per cent of the Earth's surface - why can't they swallow up all our wastes?

First one has to say that the oceans are capable of absorbing huge quantities and as such represent an important resource (7). But this capacity is certainly not infinite.

To understand what happens to wastes we need to look at the basic processes in the World Ocean, for that is what the seas are: seen from the Antarctic, the seas clearly form one main ocean with three branches into the Atlantic, Pacific and Indian Ocean regions.

Changes generally take place very slowly in the open seas. The huge size of the ocean enables it to disperse and dilute enormous amounts of material. But the deeper ocean waters interact with the surface and coastal waters extremely slowly since they move to the surface at an ocean-wide average rate of only a few metres a year (18). Winds, eddies and currents complicate this simple picture. But one implication is that any persistent contaminant which reaches the deep ocean layer could circulate there for hundreds, maybe thousands, of years.

How does this affect life in the ocean?

This situation carries with it the potential risk of a long-term build-up of toxic substances in the ocean. It also means that huge amounts of substances added to the seas near the surface will remain there, and that only the top 1 to 2 per cent of the upper ocean, the part where the waters are well-mixed, is available for diluting this material. This part of the open ocean, where the sun's rays penetrate, is where we find much of sea life, and especially its primary biological production (photosynthesis, the system by which plankton use sunlight to turn chemicals into food). A similar situation prevails for the coastal zone. Much of the material reaching coastal waters from land stays there because of physical, chemical and biological processes.

The GESAMP Report also devotes a special section to part of the ocean which is no thicker than a sheet of paper: the uppermost layer. What makes it so important?

> The top millimetre of the ocean is a micro-environment in itself, the home of many species important to us economically and ecologically at various stages in their lives. They include the eggs, larvae and adults of tiny mollusks, minute crustaceans, starfish and marine worms.
>
> But this micro-layer where air and water meet is burdened with a much higher level of pollution than the waters directly beneath (16). We have now discovered that more than half the zinc, cadmium, lead, mercury and selenium carried from land to the ocean comes through the air (15). Substantial amounts of substances synthesized by human activities, including radioactive material such as plutonium, also reach the ocean through the atmosphere.
>
> This air-sea interface plays a fundamental part in the exchange of gases and materials between the sea and the atmosphere (16). Life in the micro-layer has a principal role in maintaining the balance between oxygen and carbon dioxide in the sea (16).

How serious is the threat to this micro-layer?

> We know three types of organic contaminants that could modify the chemical and physical properties of the air-sea interface. These are detergents, organic wastes and petroleum hydrocarbons (17). There is no documentation of cases where detergents in the open ocean have significantly influenced the properties of the sea surface (17). But marine dump sites for municipal wastes have blocked the exchange of chemicals across the air-sea interface, and the U. S. National Research Council has identified the potential for pollutants to build up in the surface film of such dump sites (17).
>
> As for petroleum hydrocarbons, recent analyses indicate that at the present time, oil films do not modify the global exchange of matter or energy significantly. But GESAMP in 1980 pointed out that they could have local effects in certain coastal areas and seas, especially along shipping routes (17).

But surely the gigantic life support system represented by the World Ocean has operated for billions of years without any significant disruption of the environment?

We do not know this. We do know that over the past two centuries world industry and population have grown at phenomenal rates. For every square kilometre of land our planet had an average of 33 people in 1980. Historians estimate this rate at over 50 times as high as in 1750, on the eve of the Industrial Revolution. The world's population is also becoming predominantly urban, whereas even at the beginning of this century, it was mainly rural. Around the globe we are becoming industrial town dwellers rather than, as in centuries past, agricultural villagers.

What does this mean for the health of the oceans?

Once our main activities directly exploited the productivity of local ecosystems: farming, forestry work and fishing. Our organic wastes returned to the soil. Industrialization and urbanization have broken the links in this chain. Factories, industrial plants, farms and city drains pour unprecedented loads of chemicals into the environment. In towns, bodily wastes are often not returned to the soil but are dumped into fresh surface waters, where they can overwhelm the system's capacity for self-adjustment.

One result is that human, agricultural and industrial wastes from inland all make their way gradually to the coasts. For example, on a world scale the Rhine is a relatively small river. But it flows through the industrial heartland of several countries. The United Nations Educational, Scientific and Cultural Organization (UNESCO) reported in 1981 that the Rhine transported to the sea 10 times more chloride than at the beginning of this century. The amount now equals that of the Amazon, the world's largest river (15).

This is why coastal zones are among the most contaminated parts of the sea?

Yes, and they are under pressure from more than pollution. In fact, coastal regions, shallow waters and the tide-washed river mouths we call estuaries are worth looking at separately.

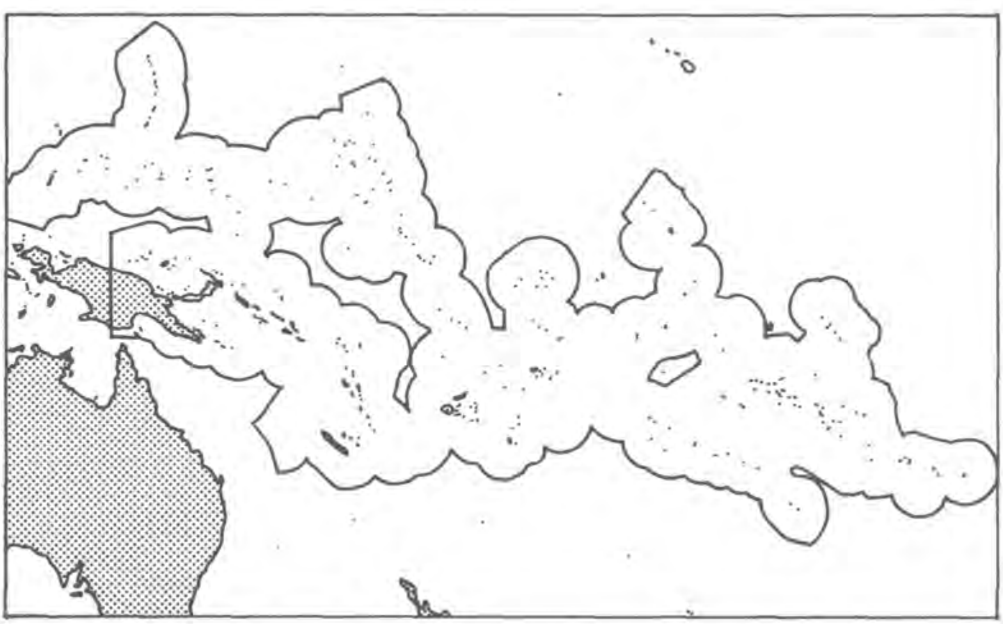
V THE TAINTED BEACH

Deep in the sea are riches beyond compare
But if you seek safety, it is on the shore.

Saadi Shiraz, 13th century poet

What makes marine life in the coastal zone so special?

Most of the life produced in the World Ocean occurs in the coastal zone. At the bottom of the food chain we find the microscopic plants (phytoplankton) and the small animals (zooplankton) which feed on them. Their populations tend to bloom in coastal regions, because of the abundance of nutrients. As a result, coastal zones also serve as hatching, nursery and feeding grounds for important fish species, and provide homes for shellfish and clams. They are



The islands of the South Pacific and the approximate boundaries of the 200-mile exclusive economic zone becoming more and more important for the fast-growing mariculture (sea-ranching) industry. In the open ocean, the relatively constant physical and chemical conditions mean that most life there is not adapted to sudden changes. Marine organisms lack a built-in flexibility to deal with substances not usually present in sea water or to handle unusually high concentrations of substances normally found in small amounts.

In coastal areas, organisms must be able to tolerate a wide range of salt-water conditions and sometimes they are able to live in a wide range of temperatures, too. Though river water on average has less than half a per cent of the salts found in sea water, it has been calculated that roughly 20,000 million tonnes of suspended matter and dissolved salts enter the oceans each year from rivers.

But it has also been estimated that only 10 per cent of all the substances which enter estuaries and bays along with fresh water reach the deep ocean (14). The rest accumulates in the coastal sediments - and the coastal zones account for 90 per cent of the world's fishing catch.

Doesn't this mean that coastal organisms are more resistant to pollution?

They are more able to tolerate a variety of nutrient conditions. But they also bear the brunt of almost undiluted contaminants from land. This adaptation by marine organisms to coastal life can put them - and human beings - at particular risk from pollution, if the substance is something they cannot use or excrete. Oysters feed by constantly filtering the water in the shallow coastal zones where they live and where contaminants are most common. DDT has been found in oysters at concentrations 70,000 times greater than in the water around. Birds that feed on the coast can be found with levels of toxic substances in their tissues which are several hundred times that recorded further down the food chain, because the birds normally consume a large number of the animals and plants below them in the pyramid.

What are some other pressures on coastal life?

In coastal regions, human settlements compete with many birds and species of wildlife which depend on coasts and estuaries for food and shelter. Tourism development and tourists can exact a high toll from the very amenities that attract the visitors - by increasing sewage loads, turning wildlife refuges into bathing beaches and burying marine habitats under brick and concrete. Irrigation works on the Nile and Indus have led to erosion of the coastal zone and a drastic decrease in regional fishing harvests (15).

In the intertidal zone, sewage can encourage species which are adapted to high nutrient levels, but it can also greatly reduce the diversity of species there. The impact on coral reefs, which contain an easily disturbed balance of a wide range of marine life, can be devastating. A large number of other human activities are also concentrated in the coastal zone simply because the resources we use are most commonly found or most easily exploited there: sand and gravel, metal mining, oil and gas exploitation, shipping and fishing. Much of the infrastructure - buildings, communications and construction works we need for these activities - is installed on the coast or offshore on the continental shelf, often leading to changes in transport patterns and erosion. All in all, the coastal zone is generally subject to a great deal of human interference, which at present is increasing globally.

VI THE RISKS WE RUN

We read the world wrong and say that it deceives us.

Rabindranath Tagore

You say the way we dispose of our wastes can affect our fishing resources. How does this come about, if much of the sewage includes nutrients?

Bacteria break down sewage, recyling its nutrient elements for the phytoplankton, by using dissolved oxygen in the water. An overload of sewage can starve fish and larger animal life in the sea of this oxygen, at the same time as it produces a quickly-rotting bloom of the sea's plants. Eventually the waters may be surrendered to bacteria and completely depleted of oxygen.

This has been a chronic problem since the beginning of the century in the bottom waters of the Baltic Sea (71), though there it has been exacerbated by the slow exchange of water between upper and lower levels. The conditions favour bacteria producing hydrogen sulfide (a gas that smells like rotten eggs). In less than half a century the bottom waters containing measurable amounts of this poisonous gas increased to 84,000 square kilometres in 1975. Today huge areas of the Baltic Sea bottom are oxygen free, but this may partly be due to the large amounts of organic material reaching the water from land-based sources. As a result of oxygen depletion, commercially-important fish died in massive numbers over thousands of square kilometres off the east coast of the United States in 1976 (62). The plankton blooms can be toxic for humans, sometimes flaring up regularly in the same coastal spot (62).

Sewage dumping can also gradually alter the bottom or sea-floor sediments, making the ground uninhabitable for commercial shellfish (61), or anything more than a few resistant species of worms (40). Tainting - or even the rumour that a particular stock is affected - can injure the reputation of a fishing area and harm sales (63). Unpleasant changes in colour and taste can be caused by a variety of contaminants. But metals such as zinc and copper in shellfish, and oil in fish and shellfish, are probably the most common (63).

There are ways of treating sewage chemically and biologically, though, to remove contaminants?

Outside the most advanced industrial countries, even drainage systems are rare, and confined for the most part to the prosperous sections of cities. Some 60 per cent of the islands in the Caribbean have few or no sewerage services. Less than 10 per cent of the total domestic waste in the Caribbean region receives treatment of any kind. Hardly 50 per cent of the 950 million people living in the 19 countries which border the Indian Ocean have sanitation arrangements (81,82). During low tide large coastal areas become very unpleasant, with high levels of faecal organisms (82). But in fact, most places do not have to think of how to find the money for expensive chemical or biological treatment. Planning, proper siting and construction of waste pipes, together with a functioning management, control and monitoring system may be perfectly adequate.

As things stand today, what are the dangers?

Wastes are the major carriers of bacteria and viruses of diseases such as typhoid, cholera and dysentery. Sewage on beaches and in shallow waters can cause an offensive odour and for a tourist resort be economically disastrous (4).

But the possible health risk is a more important consideration (40). These organisms can survive sometimes for days in the sea and viruses can attach themselves to the animals on the bottom of the sea such as oysters and shellfish (40). Recent studies tend to support the assumption that bathing in sewage-contaminated water can result in disease, particularly where enteric diseases (illnesses of the gut) are common(40).

Climate and living conditions play a role, but typhoid is about 100 times more frequent in the Mediterranean than in northern Europe (75). Mussels contaminated through sewage discharges or releases of wastes from ships into illegal mussel beds is thought to have been the cause of an Italian cholera outbreak in the Seventies in which at least 19 people died (75).

Germs are not the only threats to human health caused by the stresses which our activities put on water supplies and coastal environments, are they?

By no means. Toxic waste pollution is proving a growing problem. At Minamata Bay, Japan, mercury discharged into the water by a chemical plant led to an epidemic of nerve disease among fish consumers (51). At least 77 people died. It should be noted that the inorganic mercury had been biologically transformed in the sea into a very toxic compound - which indicates something of the very serious problems we are facing.

High mercury levels have been found in commercially important fish of the Mediterranean, such as the bluefin tuna, striped mullet and Norway lobster caught far away from human mercury-producing sources (75). The levels are thought to be mainly due to natural sources (6), but they are higher than the legal limits in many Mediterranean countries. A large part of the catch would be confiscated if these limits were enforced (75).

The results suggest we need to be careful about the amounts of mercury we add to the Mediterranean environment as a result of human activities. Fishermen, fish sellers and their families have been shown to have above-average levels of mercury in their hair and blood. So far there has been no sign of mercury intoxication but further research is needed (75,51).

There hasn't been any sign of a drastic environmental change as a result of human activities over the past two centuries, though, has there?

That's not quite true. A major problem today worrying environmental scientists is acid rain produced by the increase in gases such as sulphur dioxide and nitrogen oxides . This may well constitute a drastic environmental change due to human activities. Another major source of concern to environmental scientists is the increase in our production of carbon dioxide (CO_2), as a result of our burning of fossil fuels such as petroleum, natural gas and coal. Carbon dioxide is a significant environmental contaminant and several international bodies are investigating the situation (1). We are certainly producing a lot more than the planet has been used to over the past couple of centuries. The unresolved question is: what is the effect? The increase in CO_2 worries many scientists because carbon dioxide is a minor component of the Earth's atmosphere in ordinary circumstances. Plants are major consumers of carbon dioxide in the photosynthesis of carbohydrates. But the ocean is also considered a major sink for the CO_2 injected into the atmosphere. Some scientists fear the present output from our industrial societies may be too great for plant life and the oceans to absorb.

What could be the result?

In the atmosphere carbon dioxide can act like glass in a hothouse, forming a shield which can stop heat from the sun being radiated back into space. Some scientists fear heat could be trapped in the lower atmosphere by this "greenhouse effect", which could alter temperatures around the globe, and in particular in polar regions. Only a small change could produce a cataclysmic shift in agricultural patterns. At worst the polar ice caps could melt, flooding the world's coastal regions and putting many of the world's most heavily populated areas under water.

VII BIOCIDES AND SUICIDE

We are not free to use today, or to promise tomorrow,
because we are already mortgaged to yesterday.

Ralph Waldo Emerson

What is the evidence that environmental contamination from industrialization has been unprecedented and far-reaching?

It is not hard to find. For example, by analysing cores taken from the bottom of the Baltic Sea and the waters off Southern California, scientists found that recently deposited sediments contained much higher levels of lead, cadmium, zinc and copper than in the lower layers. The increased loads generally started after the Industrial Revolution some 200 years ago.

Where do these human-derived metals in the environment come from?

Chemical producers are large users of mercury, some of which inevitably finds its way into the waste water systems. Burning of fossil fuels puts large amounts of zinc into the atmosphere and waste systems. Internal combustion engines that use anti-knock fuels release lead into the air (26). Mining and industrial activities release cadmium, and ore-smelting and fossil fuels put out arsenic at levels rivalling the natural rate (26). The food, mining, metallurgical, photographic plating, printing, textile and tanning industries as well as chemical plants all produce metallic wastes.

In view of the dangers of mercury in the water environment, why don't chemical producers do without it - or try to recuperate as much as possible?

Mercury plays a crucial role in producing synthetic organic chemicals, ranging from detergents and plastics to pesticides such as organochlorines. You can see these are synthetics most people would be reluctant to do without in modern society. The chlorine used in synthetics is normally produced by passing an electric current through a solution of common salt (sodium chloride). Mercury conducts electricity and traps sodium produced in the reaction, and so is used in producing many of the half a million man-made chemical compounds in existence. Despite efforts to recover as much mercury as possible, some is inevitably lost and ends up in the drainage system. Cement production is also a major source of mercury in the environment. However, it should also be mentioned that other substances are now substituted for mercury in some industries, and its use has been greatly reduced in some regions and in countries like the United States and Sweden its use has been controlled by environmental legislation. We can see the effects already in reduced levels of mercury in the environment in those areas.

What about the dangers from DDT?

Introduced in the 1940s, DDT is now out of favour or even banned in many of the countries that first used it. Yet it has been the most extensively used pesticide on a global scale and is the best known example of a persistent synthetic organic chemical - stable for a long time in the environment and resistant to complete breakdown (42). What has happened is that most insect species against which DDT was was first used in northern regions have developed a tolerance to it (43). This has not been so for fish, birds and seals which concentrate it in their tissues (44). In fact, DDT and the other synthetic compounds used by farmers to kill pests and weeds have been dubbed biocides because their fundamental effect is to destroy all kinds of life, not just their intended targets.

What has been the result?

DDT has been blamed for interfering with the calcium metabolism of pelicans, so that birds with above-average levels of pesticide in their tissues produce eggs whose shells are so thin they crack easily and do not hatch. In the Baltic Sea, seals with DDT and the PCB synthetic in their bodies have failed to reproduce. Failures of white-tailed eagles to produce new generations have been linked with the levels of DDT and PCB in their eggs (72). High DDT residue levels in fish can lead to death even some time after they are transferred to clean water (44). Organochlorine insecticides such as DDT can accumulate in fish eggs (44). This can result in the death of larvae at a critical stage of growth and a lowering of reproductive rates, as well as making fish less able to handle external stress such as water temperature changes (44). As with mercury, legislation controlling the use of DDT has led to a gradual reduction of concentrations found for instance in Baltic Sea fish.

Could sea food containing traces of DDT pose a threat to our health?

It is unlikely. But there is a risk that in some coastal zones residue levels will make some marine organisms such as clams and oysters unacceptable as human food (44).

Like DDT, PCBs are chlorine based, have been widely used and are now controlled in several countries because of their toxic effects. What do we know about their impact on the marine environment?

Before the restrictions, PCBs were widely used in hydraulic fluids, paints, plastics, paper products and in electric equipment. As a result, they are widespread in surface waters and in bottom sediments in the more industrialized regions of the world (41). Recent investigations indicate that marine micro-organisms can transform PCBs, but the process is very slow. In many areas, the amounts of PCBs reaching the ocean are known to have declined but the residues have remained at constant levels or are even increasing - presumably as a result of accumulation. We have no firm evidence that PCBs are disappearing from the marine environment once they reach the sea (41).

What do we know about PCBs' effects?

It has been suggested PCB ingestion by mammals can disturb sexual functions. Reproduction defects in seals in the Baltic and Dutch Waddensea have been linked with high PCB levels in the parents (42).

Laboratory studies have shown that high concentrations can affect fish and invertebrate reproduction, retard growth and impair reactions by marine organisms to stress and disease (42). However, fish generally do not accumulate PCBs in their tissues, in contrast to mammals (42).

So what are the dangers likely to be for humans?

Since man is one of the species most susceptible to PBCs, residues in marine organisms used as food could present a public health problem, and some countries have laid down legal limits for importing or selling seafood. But there do not appear to be any confirmed records of illness caused by eating PCB-laced seafood (42).

VIII OIL AND ENERGY

> Power, like a desolating pestilence,
> Pollutes whate'er it touches.
>
> Percy Bysshe Shelley

Oil has been the cause of probably the most common and certainly the most spectacular pollution incidents - either as a result of shipping accidents or pipeline and offshore blow-outs (60). How bad is oil pollution around the world?

> Nearly every region of the world shows some evidence of contamination by petroleum but oil slicks and floating tar balls are particularly common along the main tanker routes. According to one recent estimate, between 15,000 and 20,000 tonnes of oil residues are spread across the surface of the North Atlantic (45). The amount of floating tar in the Arabian Sea has been estimated at 3,700 tonnes, and you can see the tar-like residues from oil spills on the beaches of every country bordering the northern Indian Ocean, a major tanker route (82). Oil transported through the Mediterranean accounts for almost an eighth (75) of the estimated 1,750 million tonnes carried internationally by ships (82). About one million tonnes of various oils are discharged into the Mediterranean each year and this ecologically fragile region is among the more contaminated areas, as is shown by recent analyses (75). The Middle East provides around 58 per cent of the oil shipped internationally (82), and much of that goes across the Arabian Sea, which has an even more vulnerable ecosystem. Tar ball contamination of beaches is a growing and serious problem in many tourist areas of the world.

What do we know of its effects?

> Oil pollution can jeopardise local populations of sea birds (46). Adult fish, because they are mobile, can often avoid high concentrations of oil, but the generation to come - the eggs and fish larvae - remain susceptible (60). Fresh slicks can cause high mortality (60). Oil slicks at sea kill or damage zooplankton at the surface, including the copepods, which play an important part in marine food-chains (46). It has been shown experimentally that their

populations can be reduced by oil at the concentrations found near offshore platforms (6). Oil can also change the make-up of a local environment, favouring bacteria, algae and salt-marsh plants which can tolerate repeated oiling (46).

What sort of habitats are particularly threatened?

A great number of factors govern the effects that an oil discharge can have on marine life (46). In general, the biological damage is more severe if the discharge occurs in a coastal environment or an estuary, rather than in the open sea (46). Oysters, scallops, softshell clams - marine organisms that live in the tidal and other coastal zones - have suffered particularly from accidental spillages of oil or from the chemical treatment of oil spills (46). The ecological balance can be upset, while complete recovery can take years or decades (46).

In talking about oil pollution, we also have to recognize the special circumstances of the polar regions (46). The oil breaks up slowly there because of the low temperatures, exposing marine life to the toxic substances for longer periods. Intensive oil exploration in the Beaufort Sea, the Canadian Arctic and Alaska has brought into focus a long-standing concern about the damage a major oil spill might cause to the Arctic ecosystem (79).

Are our fish harvests threatened by oil in the sea?

So far the effects of oil spills and accidents have all been local and transient (61). There is no documented case of an entire fishery being destroyed or even of a whole year's fish supply being eliminated (61). Crude and heavy fuel oils do not seem to cause widespread mortalities of adult fish except in shallow, enclosed waters (46). Light and refined oils are more damaging (46). Experience to date suggests that, in general, oil does not pose a long-term threat to fisheries (61).

The taste of oil-tainted shellfish and fish may make them unsaleable or force the closure of a fisheries area (48). But only a small part of petroleum has a distinct odour (48). Boiling or frying may remove the smell.

But this will not eliminate the more harmful long-term poisons. What are the dangers to us of eating oil-tainted seafood?

Iceland and Newfoundland, where smoked fish are a major food, both report a significantly higher than average rate of stomach cancer (47). It is known that the smoking process increases the polynuclear aromatic hydrocarbons (PNAHs) in flesh. These compounds cause cancer in mammals. Compared to combustion of organic material, for example, oil does not provide a significant proportion of the PNAH input to the marine environment on a global scale (47). At present it seems reasonable to suppose that the PNAHs found in marine produce may add to the risk of cancer but do not cause it by themselves (47).

The wastes and radioactive fallout from atomic explosions were the first substances recognized by the marine science community as a potential threat to the sea's resources on a global scale. What is the public health risk from radioactivity?

This issue has probably received more attention than any other type of contamination (53).

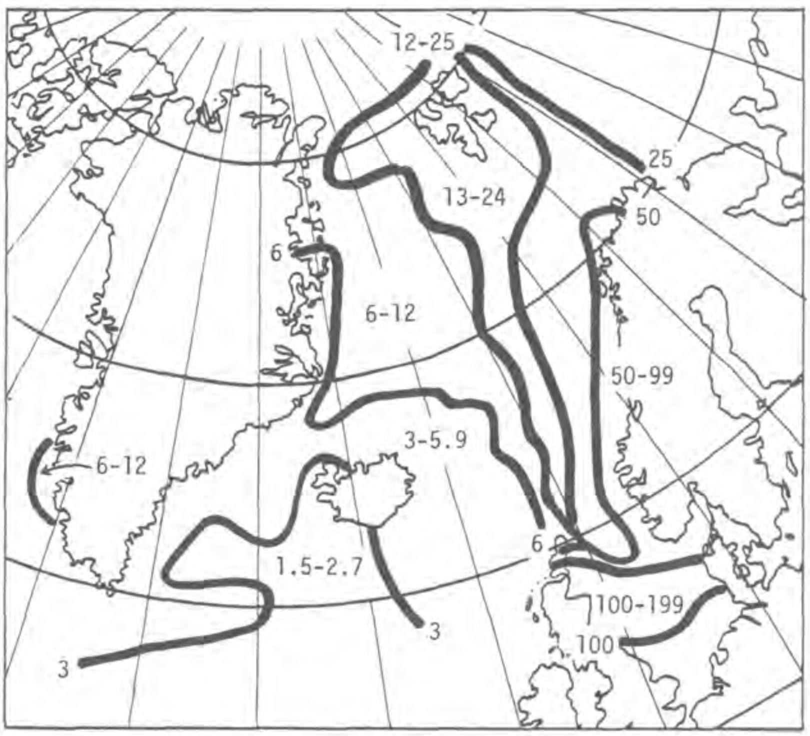
Nuclear weapon explosions have been the main source of radioactivity in the oceans resulting from human activities. It is not clear how dangerous this contamination has been for marine life. Radioactive wastes are extremely persistent, sometimes remaining toxic for thousands of years. On the other hand, some authorities calculate that artificial radioactivity constitutes only a minimal fraction of the total found in the ocean. The rest comes from natural sources: cosmic rays, radioactive volcanic debris, including eruptions under the sea, and run-off from the land. Since the USA, USSR and UK signed a Partial Test Ban Treaty in 1963 pledging not to hold atmospheric nuclear tests, radioactivity in the ocean as a result of fall-out has diminished to the point where only the ocean's natural level is recorded (52).

Nowadays the radioactivity is more likely to have come from nuclear power plants than a weapon. What do we know about their impact on the oceans?

In contrast to weapons fallout, radioactive wastes from nuclear power plants tend to be strictly localized sources of contamination. The popularity of water-cooled systems for nuclear plants has made coastal zones the choice site for reactors. But studies of local populations around the Windscale nuclear reprocessing plant, recently renamed Sellafield, on the coast of the Irish Sea indicated that the dose from fish, crustaceans and mollusks eaten by local consumers did not go beyond 26 per cent of the internationally recommended maximum (54). However, some of the substances, such as cesium-137, have spread gradually on a region-wide scale. Traces of Cs-137 from Windscale have been observed at the entrance to the Arctic Basin. Other substances, including plutonium - perhaps the most toxic material we know - are largely retained in the coastal zone.

More and more countries are trying to use the sea's own energy to get power from ocean waves, currents and tides, and even from exploiting the differences in temperature and salinity between the parts of the water. What will be the effect?

A separate GESAMP Working Group has been studying this problem. Ocean thermal energy conversion (OTEC) plants are likely to change local environmental conditions simply because of the way they operate, by exchanging cold and warm water. How important this can be we do not know, and they have not been introduced on a wide scale (64-5). But if any of the several attempts to win energy from the sea by unconventional methods prove successful, they should be operated under proper control (5).



Radioactive cesium-137 in the surface layer of the North Atlantic, in Bq per cubic metre, based on data up to 1982 from Riso National Laboratory, Roskilde, Denmark (Dr. A. Aarkrog).

IX A PRESCRIPTION FOR THE OCEANS

With the oceans we have an opportunity to be wise
and we need not repeat errors committed on land.
But we must hurry.

Sylvia Earle, U.S. marine scientist

Let us look now at some of GESAMP's conclusions. We have to get rid of our wastes somewhere, so what do you propose about sewage?

The organic component of sewage is largely degradable - it is broken down and used by the creatures of the environment. So it cannot be regarded as a long-term contaminant if its introduction to the sea is properly controlled (40). Birds are attracted to sewage disposal sites and clearly thrive there (40). Mobile marine organisms can avoid contaminated areas (40).

What do you mean by proper controls?

It is worth noting that full chemical and biological treatment of sewage - which is very expensive and rare outside the richest parts of the most industrialized nations - is not necessarily the optimal procedure (41). Often primary treatment, separating the sludge from liquid wastes, is enough. Secondary treatment, with chlorination, reduces bacteria. But viruses are less affected and long-lasting chlorinated organic compounds can be produced in larger quantities by such treatment (40).

Where deep water is available close to shore, disposal through long pipelines after reasonable, even minimal, treatment may be satisfactory (41). When disposal of sewage sludge at sea is planned, the wastes should not be dumped where water movements could transport them back to beaches or shellfish beds (40). Pipelines can be located at sites most likely to aid dispersal; they should be fitted with proper diffusers (61). The discharge can often be arranged to ensure tidal conditions achieve optimal dilution and dispersal (61). It is usually possible to treat sewage-affected shellfish so that there is no threat to human health, but the correct approach is to ensure that waste outfalls do not contaminate shellfish beds (63).

Fortunately, there is increasing awareness at local and national levels of the problem of sewage disposal (41). Various international conventions now potentially provide the means for controlling discharges and documenting indicators of effects to ensure there is no unacceptable risk to the marine ecosystem (41).

What about the persistent organochlorines such as PCBs?

Scientists are still learning about PCBs in the marine environment (44). If we could measure exactly what happens to this synthetic compound, it could be used as a model for analysing other persistent chemicals which have come onto the market (44).

And DDT?

Most of its harmful effects on life have been related to doses which are much higher than those found in the open ocean, either in water or in prey organisms (44). Much work on organochlorines remains to be carried out, but GESAMP concluded it is unlikely that by consuming sea food humans will take in more DDT than they can tolerate. There is a risk that in some coastal zones, residue levels are being reached that might make some marine organisms unacceptable for us to eat (44).

What did GESAMP decide about petroleum?

The answer to this had two aspects. One deals with the way oil behaves. The other considers its effect on marine ecosystems.

Recent research suggests that petroleum films on the sea surface can concentrate contaminants such as organochlorines and organic forms of trace metals (45). Scientific findings on cancer-causing compounds in petroleum, particularly in refined oil, suggest we need to carry out further medical research to assess the added risk from contaminated marine products and the extent of our exposure to carcinogens (47-8). The results could help set threshold levels for closing fisheries or ordering cleansing operations (48).

What about the damage by oil to ecosystems?

Whole populations are seldom at risk, except possibly for some bird species, as a result of its lethal effects and destruction of habitats (45). But we also have to note the chronic effects of oil: feeding and reproductive anomalies, abnormal growth and behaviour, increased susceptibility to predators, disrupted chemical communication between animals, and disturbance to the chemical senses birds use in migration (45). Even some salt-marsh and seashore plants which tolerate repeated light oilings can die from heavy fouling, though the effects may take several years to appear (46).

And GESAMP's proposal?

We suggest that in general the effects of oil should be studied at the ecosystem level rather than by concentrating on a single species. We also advise giving attention to the chronic and sublethal effects, including genetic changes (47).

What was the verdict on metals?

The effects of metals on marine organisms are difficult to detect in the field. You seldom find them discharged without other wastes, and any deterioration cannot usually be attributed to metal sources alone (50). Many invertebrates on the sea bottom can stand high doses of metals in the environment (50). But experimental studies indicate that marine organisms in their juvenile stages can be two to four times as sensitive as adults to many trace metals (50). Phytoplankton and invertebrates such as shellfish are often more affected than fish. Attempts at realistic experimentation using floating bags in the sea or underwater chambers on the ocean floor tend to confirm that even at a sublethal level, relatively small additions of metals to the environment can damage organisms and be detrimental to their survival (51). We need to make further studies on this issue (51).

You have said there should be no public health problem from disposal of low-level radioactive wastes in the oceans as long as the international recommendations are followed. What about marine life?

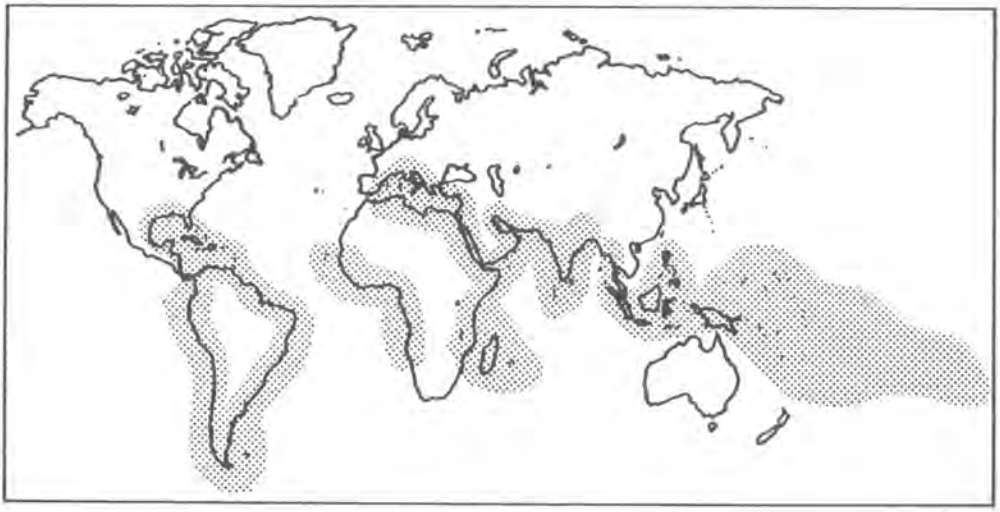
GESAMP found that results of laboratory research indicate that even in the environments most contaminated by radioactive waste, current dose rates are not expected to result in significant somatic or genetic effects (54).

X SIGHTS ON THE FUTURE

> Our survival depends on farsightedness. I am infuriated to see people drawing cheques that will be paid by future generations.
>
> Jacques-Ives Cousteau, ocean explorer

You found the oceans as a whole are not sick, even if they are not exactly healthy. You diagnosed several regional ailments and many coastal zone maladies. Is there any cure?

To answer that we need to consider what causes the damage and where the effects are worst. The pollution problems discussed by GESAMP all arise directly or indirectly from the rapid increase in industrial and agricultural activity around the world (4). So we can expect that in the future we may need to dispose of a larger volume of sewage, industrialization will spread, and further energy production will be required, even if economic cycles periodically slow down development (4). Even very limited



Areas covered by action plans of UNEP's Regional Seas Programme foresight tells us that action is required now to provide adequate control and management, effective international agreements, reliable regional data bases where these do not exist and, last but not least, research.

Semi-enclosed waters like the Gulf of Mexico, the Mediterranean, the North Sea and the Baltic Sea receive substantial contamination (3). The use of the coastal zone for sewage disposal is world-wide and increasing (4). Construction, tourism and sea-shelf mining are human activities which add to the growing pressure on the coastal zone ecosystems (4). Local disruption of marine habitats is already common (4). These are all problems we have to tackle.

What is the most pressing problem?

The most damaging effects on ecosystems have been recorded at localized "hot spots" (5). These may range in size from a few square metres around a waste discharge pipe to the whole of a major estuary such as the New York Bight (79). The hot spots may even cover specific habitats or ecosystems. I'm thinking here of salt marshes, kelp beds, mangrove swamps and coral reefs (4). We need to distinguish between local, regional and global issues of concern, and between zones of differing development. Factory wastes may not cause as much damage in a developing area as in an already overloaded industrialized region. On the other hand, sewage can do more harm in a poor country where wastes are poured untreated into the waters that people depend on for food and drinking supplies. We can be sure that most of the threats are and will continue to be in the coastal zone (5).

One of the major problems of marine pollution is the mixing of contaminants after they enter the sea (54). Estuaries and coastal zones are especially prone to this threat. The long-term dangers of such heavy pollution of the coastal zone and continental shelf are that very large areas of the ocean will be destroyed and that contamination and deterioration will gradually spread towards the open ocean (4). Over the past 100 years pollution has spread from rivers to estuaries, to coastal zones, and from these to the shelf sea areas. In this age, too, we see contaminants coming from the open sea towards the coast and polluting our shores. Oil and tar balls on beaches are only the most visible examples.

What's the answer?

The marine environment of the coastal zone is vital to mankind on a global as well as on a local scale (4). We in GESAMP therefore strongly urge an increased effort to protect the coastal zones and semi-enclosed seas by appropriate management and control, supported by research and international agreements (4). This also implies that we need to impose proper limitations on waste and exploitation activities.

How can management make any difference, if the problems are so large? Only an outright ban on pollutants might seem to offer any hope.

There are records of ecosystems recovering and returning to normal when proper control over sewage loads has been introduced in the coastal zone (4). We believe that in a similar way almost every one of the problems we considered can be mastered through rational management of the sea's resources.

Does your optimism extend to fishing? The Food and Agriculture Organization of the United Nations (FAO) in 1981 reported few abundant fish species were left which could be caught readily and marketed by conventional methods. The FAO said it expected the growth of the world catch to remain small during the next few years.

But this does not mean the growth of the benefits we obtain from fisheries will also be small (57). We could get greatly increased returns by improving our management techniques: rebuilding depleted stocks, curbing overfishing and distributing fishing more rationally between competing interests (59). Hatchery-based restocking of fish, sea ranching projects and intensive culture of shallow-water animals such as oysters, mussels and mullet contribute to the rising importance of aquaculture (60). Mariculture certainly offers better management opportunities compared with the increasingly overfished wild stocks, and national authorities can exercise better control in coastal waters (60).

Where do we go from here?

There is plenty of work to be done. We need to make further studies of the spread of pollution from the coastal zone to the deep sea, for example. We need to learn more about how contaminants are dispersed from deep-sea dump sites (5). Environmental conditions in the less developed regions of the world need more study, particularly polar zones and coral reefs. Data bases on conditions and processes in marine environments adjacent to many areas, developing and developed, are lacking. Such data bases must be obtained on a scientific and rational foundation, and will probably be supplied through international cooperation at the regional level.

New techniques for waste disposal should be evaluated, such as incineration of chemical wastes at sea and the burial of contaminated solid waste in the sea bed under a cap of clean sediment (5).

Among the thousands of chemicals brought into use each year, many could become contaminants of the sea. We already know about 30 potential contaminants among the organic chemicals, including the DDT successor toxaphene, and they require examination (6).

But perhaps it is not so important to name new potential pollutants as it is to develop a strategy for approaching the problems they generate, aided by standardized analytical techniques. Over the past two decades we have developed a scientific approach to calculate and regulate the release of radioactive materials into the sea by monitoring the path at critical points. It is worth considering this approach for the controlled release of other materials (6).

How do we prevent these problems from getting beyond our control - to make sure we do not draw on the next generation's environmental bank account?

Man's importance in ecosystems on land has long been recognized. It should also be recognized that the same is increasingly true for the marine environment. Development policies and project studies should be interdisciplinary and ecologists should be represented on the team (5).

About the author

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