radionuclides in the sea

Water covers a little more than two-thirds
of the earth's surface.
What is thrown into the sea from a ship may be washed
up on a shore thousands of miles away;
wastes discharged into the seas or into rivers
flowing into them can affect marine life and possibly
also the health of man.
The study, prevention and control of pollution of the
seas and oceans by radionuclides
introduced as by-products of man's use of
nuclear energy is thus of global interest.

There has been world-wide concern recently at the detection of mercury in fish products in quantities which exceed limits set by some health authorities for human consumption. A large amount of mercury has always been present in seawater in compounds in solution, from which it may have been concentrated during its passage through the marine food chain; or the high concentrations noted in some fish may have resulted from the discharge of industrial wastes containing mercury to the marine environment in particular areas. Similarly, it has been reported that in some areas herrings have been found to be inedible because they contain an unacceptably large concentration of DDT. Increasingly, in order to avert avoidable contamination of foodstuffs controls over the quality of industrial effluents are being devised and applied.

One aspect of this work, undertaken as part of the strict health and safety precautions associated with the peaceful use of nuclear energy, concerns radionuclides in the sea — a subject in which the International Atomic Energy Agency has a natural interest. This interest was reflected in the convening of a meeting of a panel of experts at Agency headquarters toward the end of 1970 to consider procedures for establishing safe limits for radionuclides in the sea. Man, the oceans and marine life must be protected against unacceptably large concentrations of radioactive substances which may enter the marine environment, especially in wastes discharged from nuclear installations.

Radioactive pollution of the sea is not an immediate problem. National authorities set and apply limits to the discharge of radioactive wastes, one source of radionuclides in the sea; other radionuclides enter ocean water as a result of nuclear weapons testing; by far the greatest quantities, the naturally-occurring radionuclides, have been there since the oceans were formed.

Since 1962 the International Laboratory of Marine Radioactivity of the IAEA, in Monaco, has been making a study of the effects of radioactivity in the sea. This laboratory now has a coordinated research programme in co-operation with many Member States which is directed toward obtaining a better understanding of the behaviour of radionuclides in the sea. Secondly, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has collected data systematically on the concentration and distribution of radionuclides from fall-out, and the IAEA has done similar work in an attempt to determine the distribution of tritium, deuterium and oxygen-18 around the world.

These programmes are relevant to the study of the transport and distribution of radionuclides generally. In addition, the United Nations agencies which have a direct interest in the prevention and control of marine pollution — the IAEA, IMCO, FAO, UNESCO, WMO and WHO — have set up a joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) to act as an advisory body; this group has urged that a world-wide register for all types of pollutants discharged to the sea should be established. Although the discharge of radionuclides forms only a minute part of all industrial releases to the sea, it is of interest to GESAMP in this wider context.

The Director General of the IAEA, Dr. Sigvard Eklund, referred to this work in his address to the General Assembly of the United Nations in December last year. "Over the years I have appealed to governments to provide the Agency, on a voluntary basis, with information on their releases of radioactive wastes into the sea," he said. "GESAMP has now recommended that a single international register be kept for all such waste materials. (The panel of experts referred to earlier) ... re-affirmed the importance of establishing an international registry of marine disposals.

"It should be stressed that there is no scientific indication that the nuclear wastes so far disposed of into the sea have caused harm to man, or have had any significant effect on his environment," Dr. Eklund continued. "The same cannot be said of other industrial wastes. However, it is nevertheless essential that a full record be kept of nuclear waste disposals into the sea, as the first step toward regulation and control."

The general background to all this work has been stated simply by the Director of the Monaco Laboratory, Prof. Joachim Joseph. He argues that the first point to establish in the fight against pollution — whether it is by radionuclides introduced to the seas as a result of man's activity, or by other substances — is what it is that it is desired to protect. "Some people wish to protect the ocean as a whole as it was a million years ago; other people have in mind the health of man; other people think of swimming and beach amenities; other people think of the biota in the sea," he says. "These different things need different protective measures, so as the first step in the battle against pollution we have to make a philosophic decision."

Considering only contamination of the seas by radioactive substances, the decision is presumably that in the long-run it is the health of man which is of vital concern. For the moment there is no danger, and as Prof. Joseph puts it, "this means that we are asked for prediction: 'if I do this or this, what will be the consequences in one week, one month or one year, and so on?' We have to have exact numbers and scientific laws, so that we can extrapolate to judge the future danger in numbers, and so establish permissible levels." Much of the work of the Monaco laboratory is concerned with attempting to establish these fundamental criteria for assessing the behaviour of radionuclides in the sea.

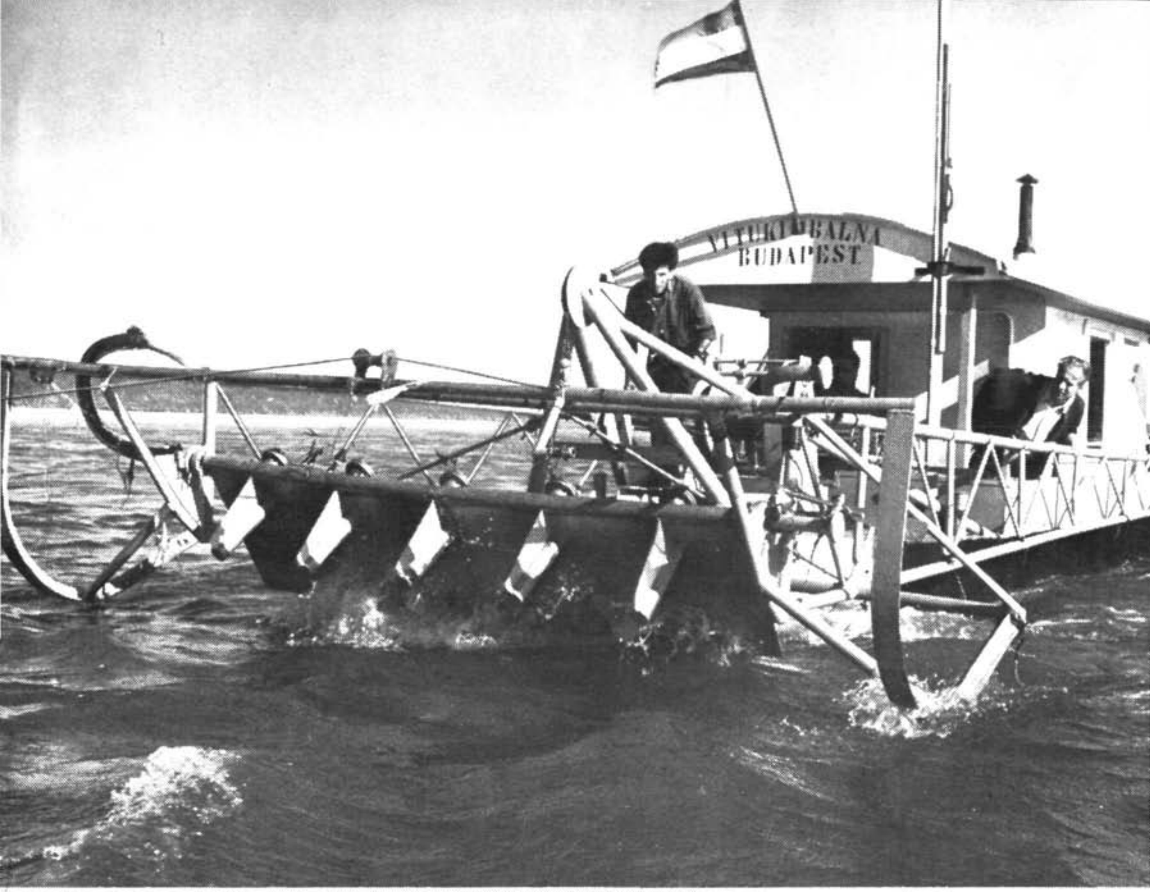
The ocean may be considered as a three-component system: the water; inorganic sedimentary material, both in suspension and on the ocean floor; and organic components, in the forms both of marine biota and of detritus. The relative abundance of a radionuclide in each compartment of this system is determined by the chemical and physical state it is in, and by the way in which it is introduced. A compound containing a radionuclide in an insoluble form may reach the bottom sediment, where it is in effect removed from the system, very quickly. A more soluble compound may tend to stay in solution; some radionuclides, such as Manganese-54 and Cobalt-60, may become concentrated as they pass through the marine food chain — ending, in some cases, in consumption by man.

The complexity of the subject may be illustrated by reference to a paper presented at the panel meeting, by Charles L. Osterberg and Victor E. Noshkin, of the Division of Biology and Medicine, United States Atomic Energy Commission. They pointed out that aquatic organisms require manganese, and that ^{54}Mn has been detected world-wide as a component of radioactive fallout, and locally in effluents from nuclear power stations. The half-life of ^{54}Mn is 284 days.

This radionuclide, the authors continued, is concentrated by many marine species and is distributed in differing ways in various organs and tissues. High concentrations have been noted, for example, in the liver of the fin whale and albacore; in the dungeness crab it has been found to concentrate mainly in calcified tissue. It has also been found to be concentrated by certain marine plants such as Sargassum and the cord grass, Spartina. Sponges collected from the west coast of Puerto Rico accumulated one and a half times as much ^{55}Mn (the stable isotope) and three times as much ^{54}Mn as similar species from the south coast, as a result of the addition of river water containing different and more available forms of manganese to the west coast area. ^{54}Mn has been found concentrated in the viscera of Pacific salmon; herring, anchovies, euphausids, crab larvae and rock fish taken from salmon stomach contained measurable quantities of ^{54}Mn, and so on.

Radioisotopes may be introduced deliberately to river or harbour waters for flow and sedimentation studies. Work of this sort was undertaken by the Research Institute for Water Resources Development, Budapest, Hungary, along a stretch of the Danube which was liable to flooding. Radioisotope-labelled pebbles were placed on the river bed and traced by detectors mounted on the stern of the research boat "Bálna" (Whale). Here the detectors are being lowered. Photo: Research Institute for Water Resources Development

An early stage in studies of the behaviour of radionuclides in the marine environment: aquaria at the Laboratory of Marine Radioecology, La Hague, France, where fish may be raised in water containing known amounts of radionuclides. Photo: Commissariat à l'Energie Atomique


BUDAPEST

Choosing a second element at random, three radioisotopes of cobalt have been detected in sea water and in a wide variety of marine organisms. These are ^{60}Co (half-life 5.24 years), ^{58}Co (half-life 71 days), and ^{57}Co (half-life 272 days). Mr. Osterberg and Mr. Noshkin pointed out in their joint paper that in ocean and coastal waters stable cobalt concentrations are extremely variable, even between areas which are close together. In particular regions the variation may be as much as 100-fold. In addition, cobalt exhibits "perhaps the greatest range of concentration factors of any single element among different marine species," the paper continued. "Concentration factors range, for example, from 60 in a salp to values greater than 10^4 in *Sagitta* and *Limacina* ... A number of factors, therefore, influence both the distribution and ability of organisms to concentrate cobalt in the marine environment."

These authors stated, like others, that "for the most part available data does not support any firm generalization about paths of radioelement uptake and accumulation ..." They went on to point out that stable element concentrations must be considered as well in marine studies such as this, "since they offer guides to the equilibrium distribution of any radioisotope whose release may be of concern. Radionuclide as well as stable element content of the environment, other than in the biota, must be determined to adequately assess pathways and the accumulation factors of radioelements in organisms."

Such studies may also be valuable, of course, in determination of the fates of other pollutants which may be introduced to the marine environment.

Much work remains to be done. At this stage one can only repeat, as the Director General stressed in his speech to the General Assembly, that so far there is no scientific indication of harm resulting from the discharge of radioactive wastes into the sea near discharge sites or in the sea at large. Effluents from nuclear installations are monitored and samples taken locally at regular intervals to ensure that no immediate or foreseeable long-term danger to health is created, in just the same way as everything possible is done to ensure the safety of nuclear installations themselves.

A scientist working with the Monaco laboratory draws a water sample from the Mediterranean as part of a study of the behaviour of radionuclides in the sea.