# Report from Monaco: Waste management and the sea

*Environmental R&D at IAEA's International Laboratory of Marine Radioactivity*

**by R. Fukai**

The sea covers approximately 70% of the earth's surface and its protection is considered vitally important for human life. At the same time, the oceans are known to be an ultimate "sink" for many anthropogenic products, including artificial radionuclides deposited directly or even released on land or into the atmosphere.

When it comes to waste management practices related to the sea, information on the complex behaviour and fate of radionuclides in the marine environment is important for predicting and evaluating radiological effects on people. Since most of the sea is international territory, international collaboration is essential in this regard.

### Methods for environmental monitoring

A fundamental requirement for implementing any scientific programme is the availability of appropriate methods for making necessary measurements to achieve its goal. This is especially true for environmental monitoring of some long-lived radionuclides. For example, the extreme environmental importance of plutonium isotopes in radiation protection related to marine waste management was not well understood until a method (alpha-spectrometric) became available to enable their measurement in environmental samples.

The behaviour of many radionuclides in the marine environment is hard to predict just from results of laboratory experiments, since processes controlling their behaviour are too complex to be simulated in the laboratory. The best approach for deducing it, therefore, is to conduct measurements on environmental samples and to construct reasonable models based on these results. Since concentrations of artificial radionuclides in samples normally are low (except for some special areas), sufficiently sensitive methods must be developed.

For more than 10 years, the Monaco Laboratory has been developing analytical methods for measuring transuranic and other long-lived radionuclides present in environmental samples at low levels. In the late 1970s, the Laboratory developed a method for low-level measurements of americium-241 in sea water, marine sediments, and biological materials, for example. This method has been applied to various samples taken from the Pacific Ocean and the Mediterranean, Baltic, and Arctic seas, among others. Results of measurements enabled the Laboratory to deduce this isotope's specific behaviour in different sea regions.

Today the Laboratory still is counted among the few that are capable of carrying out reliable low-level measurements of americium-241 on environmental samples. Based upon that work, a method for estimating plutonium-241 also has been developed that has proved useful for identifying sources of plutonium isotopes in certain areas of the marine environment.

In recent years, the Laboratory has engaged in developing methods for other long-lived radionuclides in low levels, including technetium-99 (half-life of 2.1 times $10^5$ years) and neptunium-237 (half-life of 2.14 times $10^6$ years). Even though these radionuclides have been in the marine environment since the 1950s, their presence and behaviour did not attract attention previously since there were no methods for measuring them in the environment.

In the case of technetium-99, the measurement method has been applied to various environmental samples collected from different sea regions. Results revealed that it is specifically concentrated in species of brown seaweed, and that the radioactive discharge from Sellafield in the United Kingdom can be traced to the Norwegian coast or Greenland, more than 5000 kilometres from its origin.

The Laboratory also has developed a sequential method for measuring natural radionuclides, especially for radium isotopes. Results are useful for understanding geochemical processes such as dissolution and particle formation.

Future plans call for development of methods for long-lived radioisotopes such as nickel-63 (half-life of 100 years) that originates from decommissioning operations of nuclear installations, and iodine-129 (half-life of 1.51 times $10^7$ years), which comes from reprocessing wastes, for example.

### Ensuring accurate measurements

In close collaboration with the Agency's Seibersdorf Laboratory in Austria, the Monaco Laboratory also has worked since 1968 in a programme for ensuring the quality of environmental measurement results

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On-board preparation for deploying a sediment trap.

produced by national laboratories in Member States. Since the major part of the sea is international territory, ensuring the accuracy of marine environmental measurements is not only scientifically important, but also politically significant.

The programme deals with two aspects: (1) organization, evaluation, and reporting of intercalibration exercises, and (2) issuance of standard reference materials. In practice, these aspects are closely related: A homogeneous marine environmental material with unknown radionuclide concentrations is prepared in large quantity and, at first, distributed to laboratories that have expressed interest in taking part in the intercalibration exercise. Measurement results for specific radionuclides from participating laboratories then are evaluated through statistical treatments, and the most probable concentrations for each radionuclide are computed. These are considered to represent the best estimates of the true concentrations of the radionuclides contained in the sample. Remaining quantities of the sample then can be designed as a standard reference material, about which the most probable concentrations of several radionuclides are known.

Since initiation of this programme, which is the Laboratory's most direct contribution to specialized institutions of Member States, approximately 20 standard reference materials have been issued whose matrices include sea water, marine sediments, and marine biological samples. The list includes probable concentrations of plutonium-238, plutonium-239 and 240, americium-241, as well as cobalt-60, strontium-90, caesium-137, and other natural radionuclides.

**Technology transfer and training**

Another area of direct contribution is the training of scientists from developing countries in radionuclide measurements and tracer experiments. In collaboration with the Agency's Division of Technical Assistance and Co-operation, the Laboratory since 1981 has accepted fellowships for in-service training from Member States, including Greece, Hungary, Philippines, Portugal, Spain, and Turkey, at the average rate of two per year. (The training period normally is 1 year.) Scientists are trained in methodologies that are new to them by working together with Laboratory staff on specific subjects. In many cases, Laboratory staff make consulting visits to the trainees' home institutes to ensure that the methodologies are working effectively there.

**Evaluation of environmental impacts**

To understand the behaviour and distribution of certain radionuclides in different levels of ocean water columns, important studies focus on their "vertical transport fluxes". The major objective of such studies is the quantitative assessment of the downward vertical fluxes of radionuclides and other anthropogenic pollutants via sinking biogenic particles (such as faecal pellets, molts, carcasses, etc.) produced at the sea's upper layers. To determine vertical fluxes, materials collected in sediment traps deployed at various ocean depths are analysed. The release or scavenging of the radionuclides by sinking biogenic particles can be estimated by combining the results of measurements on sediment trap materials with those of source-term measurements of biogenic particulates released in the surface water.

Study results demonstrate that vertical-sinking biogenic particles contain high levels of radionuclides, and that, therefore, their vertical transport is considered responsible for moving various radionuclides and other pollutants from the ocean's surface layers to its depths.*

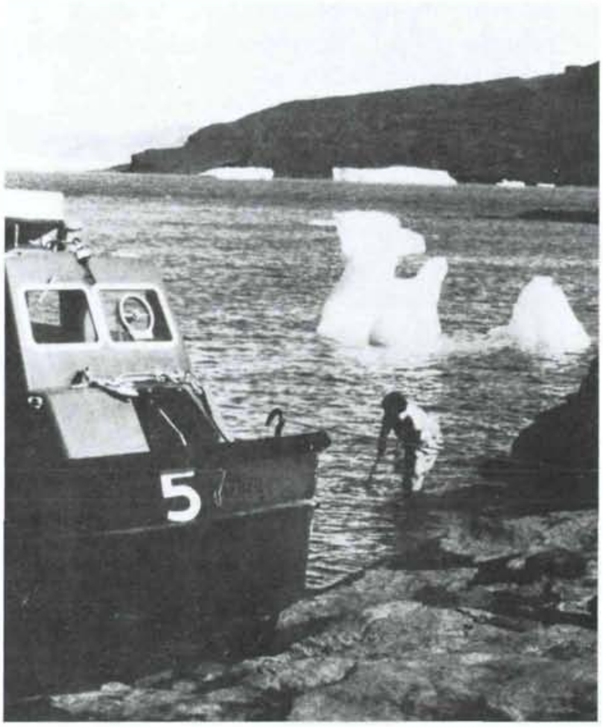
**Biokinetics and food-chain transfer**

The Laboratory has acquired much experience in using radioactive tracers for measuring uptake and loss of radionuclides by various types of marine organisms (including phytoplankton, zooplankton, crustaceans, and molusks). Recently, research efforts have been concentrated to deduce biokinetics and food-chain transfer of long-lived transuranic and other nuclides. Radioactive tracers used for these studies include technetium-95m, neptunium-235, plutonium-237, americium-241, curium-244, and californium-252.

* In implementing this programme, the Laboratory participated in national programmes (such as VERTEX in the USA and ECOMARGE in France) by offering specific expertise. Participation broadened the project scope by presenting opportunities to apply investigation methodologies established in the Laboratory to different water bodies in the Pacific Ocean and Mediterranean Sea.

Results of studies are important for estimating concentration factors of transuranic and other radionuclides in a variety of marine organisms, as well as for understanding biokinetics of these elements in specific food-chain transfer. In particular, the concentration factors of radionuclides in various marine organisms are essential for assessing radiological effects on humans from any radionuclides released into the sea. In view of this importance, a compilation of existing concentration factor values was attempted by the Agency's Division of Nuclear Fuel Cycle with a consultants' group. The Laboratory participated by submitting concentration factor values obtained through its work.

Apart from experimental studies using artificial radionuclides, the distribution and food-chain transfer of natural radionuclides have been studied, especially in view of very high concentrations of polonium-210 found within the tissues of some marine organisms. Data are useful for comparing the dose from natural background radiation with that received from artificial radionuclides released into the marine environment.



Seaweed collection off the coast of Thule, Greenland.

**Comparative studies**

By comparing results of radionuclide measurements on various matrices collected from various locations, it has been possible to deduce specific behaviour of certain radionuclides released into different sea regions. Studies have been carried out in close collaboration with national institutions from Canada, Denmark, Federal Republic of Germany, Finland, France, and Sweden, for example, covering areas of the North Atlantic Ocean and the Arctic, Baltic, North, and Mediterranean seas.

Samples of sea water, sediments, and marine organisms were extensively collected from various locations, with measurements carried out on strontium-90, technetium-99, caesium-134, caesium-137, plutonium-238, plutonium-239 and 240, and americium-241, among others.

Results revealed several interesting features. For example, although the amounts of plutonium-239 and 240 delivered to the Mediterranean and Baltic seas are similar, surface concentrations in the Mediterranean are approximately five times higher than those in the Baltic. About 60 to 80% of the plutonium delivered into the Mediterranean still remains in the water column, while in the Baltic, 99% of it is deposited in the sediment. This difference can be explained by differences in average depths of the two seas. (The studies also demonstrated that technetium-99 is an excellent tracer for the transport of waterborn radionuclides.)

**Radionuclides in sediments**

Many radionuclides released into the marine environment become associated with terrigenous and biogenic particles. Since these particles sink under the gravity field, the radionuclides also move down and sooner or later reach the sea bottom. If they stay there without moving again, this would be an ideal solution for waste management of these isotopes. However, depending on various factors (for example, chemical characteristics of radionuclides, nature of the sediment, water movements, benthic fauna), the radionuclides may be remobilized and reintroduced into geochemical and biogeochemical processes occurring in sediments and at the water/seabed interface. The scope of studies is to clarify these processes systematically.

So far, geochemical partitioning of various radionuclides has been studied on different types of marine sediments, and a series of laboratory experiments has determined sediment-animal transfer factors. Separate studies have been initiated on the degree of bioturbation effect on the distribution of some natural radionuclides in marine sediments, and on chemical speciation of metallic radionuclides, such as cobalt-60 and nickel-63, in interstitial waters. In view of the complex nature of processes involved, results obtained in laboratory experiments are considered to have limited relevance to processes taking place *in situ.* It is felt that continued guidance towards correct orientations of research projects in this field are especially important for conducting relevant and useful work.

**Inventory of marine radionuclides**

Work also is under way on the compilation and evaluation of radionuclides entering the marine environment. The task includes estimations of input and output fluxes of radionuclides to and from the marine environment, and of radionuclide inventories deduced from environmental measurements. Subsequent examinations should determine if the inventories are consistent with the estimated fluxes and to identify discrepancies.*

Initially, based upon recommendations of a consultant's group, the following radionuclides will be studied: carbon-14, caesium-134, 135, and 137; radionuclides in the uranium-238 decay series, with priority on polonium-210 and lead-210 followed by radium-226; and plutonium isotopes.

#### Co-ordinated research programme

For the period 1986-88, the Laboratory is organizing a co-ordinated research programme (CRP) on methods and strategies for monitoring radionuclide releases in the coastal marine environment, with emphasis on the use of bioindicators. Several institutes in developing countries are participating. Through the CRP mechanism, the necessary scientific data for evaluating environmental impacts of radionuclide releases into the marine environment are obtained, collected, and published.**

* The work is based upon the recommendation of the Laboratory's scientific review panel in March 1984. It was reviewed in July 1985 by a consultants' group, which concluded that such a task could be useful to the IAEA and the scientific community at large and may contribute to a future review of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

#### Other international co-operation

Apart from scientific activities directly connected with the Agency's waste management programme, the Laboratory co-operates with other international organizations in the area of monitoring and research on pollution of the marine environment. These organizations include the Food and Agriculture Organization (FAO), the United Nations Environment Programme (UNEP), and the International Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC/UNESCO).

In particular the Laboratory has been supporting the UNEP's Ocean and Coastal Area Programme, by providing scientific and technical expertise. Assistance includes development, testing, and publication of guidelines and references for pollutant measurements, helping with pollutant measurements, organizing intercalibration exercises, and training scientific personnel. The work covers regions of the Mediterranean, Kuwait, and West, Central, and East Africa. Expertise for this assistance has been acquired by the Laboratory through similar activities in the field of marine radioactivity studies.

** Other CRPs organized by the Laboratory were entitled "Transuranic Cycling Behaviour in the Marine Environment" (1978-81) and "Behaviour of Long-Lived Radionuclides Associated with the Deep-Sea Waste Disposal of Radioactive Wastes" (1981-84). It also participated in two CRPs organized by other Agency divisions on the "Study of Radioactive Materials in the Baltic Sea" and "Role of Sediments in Transport and Accumulation of Radionuclides in Waterways".

### The Monaco Laboratory

The IAEA has the responsibility for establishing guidelines and making recommendations for internationally acceptable waste management practices that protect the human environment. In view of this mission, the Agency in 1961 established the International Laboratory of Marine Radioactivity at Monaco on the basis of the tripartite agreement with the Government of Monaco and the Oceanographic Institute at Monaco. Since then, the agreement has been renewed several times to enable the Laboratory to continue its programme. A new seat agreement between IAEA and the Government of Monaco — which gives a firmer basis for their collaboration on the subject — is expected to be concluded in the near future.

The Laboratory's scientific programmes are reviewed at regular intervals by a group composed of highly competent experts in the field of marine radioactivity studies. Programme modifications are made based on their recommendations. The most recent expert group met in March 1984.

The Laboratory has continued to concentrate its efforts on research subjects closely related to radiation protection aspects of radioactive waste management in the marine environment. Scientific programme areas related to the Agency's overall waste management programme cover technical support activities for marine radioactivity monitoring and investigation, and data collection activities for evaluating environmental impacts of radionuclide releases into the marine environment.

**Home of the Laboratory: Musée Océanographique, Monaco.**