The work of the International Laboratory of Marine Radioactivity

by A. Walton*

It is only during the past three decades that international interest has focused on the need to manage and nurture one of our most valued resources – the oceans. In spite of this growing recognition, however, it is only during the past ten years that international agreement has been reached on the control of dumping of wastes (including nuclear wastes) at sea.

The International Laboratory of Marine Radioactivity was established in 1961 well before the international agreement came into force. Indeed the Laboratory came into existence as a result of the foresight and appreciation by the International Atomic Energy Agency of the need to attack the problem of the behaviour of radioactive substances in the oceans – a subject about which little was known prior to the 1950s. With the co-operation of the Government of Monaco and the Institut Océanographique, the Laboratory was established in 1961 in the Musée Océanographique, Monaco. It is appropriate that the Laboratory was established in a building created by one of the most prominent pioneers in oceanography – Prince Albert 1er of Monaco.

Since 1961 the programme and activities of the Monaco Laboratory have expanded and changed with the changing emphasis in pollution problems in the oceans. Throughout the many changes in emphasis which have occurred during the past 20 years, however, it is probably fair to say that the broad objectives have remained the same. The Laboratory exists therefore:

- to perform research on the occurrence and behaviour of radioactive substances and other forms of pollution in the marine environment;
- to ensure the quality of the performance and comparability of studies of radioactive substances and other forms of pollution in the marine environment by national laboratories through inter-laboratory comparisons, calibration and standardization of methodology;
- to assist Member States with regard to marine radioactivity and environmental problems by training personnel, establishing co-ordinated research programmes and providing advice and assistance.

It will have been noted that the work of the Laboratory is not devoted exclusively to questions concerning radioactivity. Indeed, with the co-operation and support of the United Nations Environmental Programme (UNEP) and UNESCO it is agreed that the Laboratory will pursue studies of "non-nuclear pollutants" in addition to its normal programme in radioactivity. Such a programme is logical and sensible in view of the similarities in field and laboratory activities in these subjects.

In order to fulfil these objectives the laboratory personnel and activities are grouped into three main sections: Marine Chemistry, Marine Biology and Marine Sedimentology/Geochemistry – the latter group replacing the Environmental Studies section in late 1980.

Marine chemistry

Transuranic elements in the marine environment: one of the principal programmes of the Marine Chemistry Section is the study of the behaviour of transuranic elements in the marine environment. Measurements of Pu-238, Pu-239, 240 and Am-241 have recently been carried out on sea-water, river water, suspended matter, rain water and sediments collected from throughout the Mediterranean region. These data make it possible to follow the behaviour of transuranics from their input into the sea by river run-off and atmospheric fallout to their removal, where this occurs, by sedimentation processes to the benthic boundary layer. Unexpectedly, the results have demonstrated the fallout plutonium in Mediterranean sea-water occurs in rather soluble form, while americium tends to associate more easily with particulates, the result being that the americium is transported vertically by sinking particles more quickly than the plutonium. The precise mechanisms for this fractionation between plutonium and americium in the upper layers of the Mediterranean is being further explored. A better knowledge of the rate and extent of transfer of transuranic elements to bottom sediments is obviously of considerable importance in assessing the consequences of sea disposal of radioactive wastes.

Trace elements in the Mediterranean: as part of a UNEP programme on the geochemistry of trace metals in the Mediterranean the Laboratory has studied the distribution of certain trace elements to provide baseline data against which any long-term trends might be established. During several recent cruises sea-water and sediment samples were collected from various regions of the open Mediterranean Sea. For purposes of

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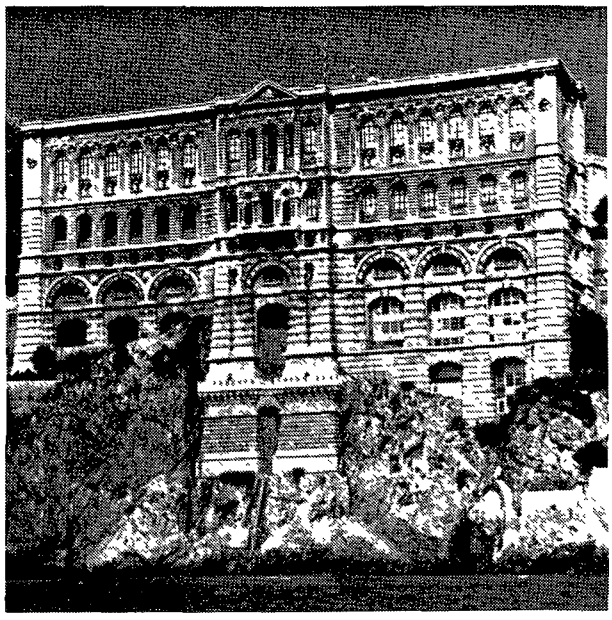
comparison, a limited number of coastal stations were also sampled. The determination of copper, zinc, cadmium and mercury was carried out by anodic stripping voltametry for sea-water samples and by atomic absorption spectrophotometry for the sediments. Although there exist some "hot spots" of these trace metals in coastal regions of the Mediterranean, the levels in open Mediterranean waters are found to be not much different from those in other oceanic areas and are generally lower than those reported for other enclosed seas such as the North Sea, the Irish Sea and the Baltic Sea.

Intercalibration programme: The unique international character of the Laboratory has led to its becoming an accepted institution for the co-ordination of a number of world-wide programmes designed to improve the quality of environmental data by organizing inter-laboratory comparisons and by the preparation and distribution of reference materials.

For radionuclide measurements intercalibration exercises on three sea-water samples, three sediment samples and four marine biological samples have been completed with the participation of about 100 laboratories from more than 30 countries. Homogeneous samples prepared at the Laboratory were distributed to the participating organizations. The results of the survey have revealed, after critical review, that, although the comparability of measurements of fission products has considerably improved in recent years probably due to developments in gamma-spectrometry equipment, the comparability of low-level transuranic measurements has been less than satisfactory. Therefore, during the past few years the intercalibration efforts have concentrated more on transuranic measurements. It has become evident that there is a need for easy accessibility to reference materials, for which the concentrations of the radionuclides of interest are accurately known, to enable the performance of methods to be tested by applying them to the reference materials. At present the preparation of large homogeneous sediment samples is in progress to fulfil such a need.

Intercalibration exercises have also been extended to measurements of trace elements and chlorinated hydrocarbons. For the trace elements some 120 laboratories from 35 countries have so far taken part. During 1976–1980 the intercalibration exercises on four biological samples (oyster, copepods, sea plant and fish flesh) have been completed. The results show that, in general, the comparability of analytical results is much better than expected, except in the case of lead.

The intercalibration exercises on chlorinated hydrocarbons in sea-water, marine organisms and sediments have so far involved some 50 laboratories throughout the world. The examination of the results shows that, although the spread of the reported values for chlorinated hydrocarbons is generally wider than that for heavy metals due to inherent lower reproducibility of the chlorinated hydrocarbon measurements, the comparability of the results reported by different



The Musée Océanographique in Monaco which houses the Agency's International Laboratory of Marine Radioactivity.

laboratories is better than expected, except for a few compounds such as alpha-BHC, gamma-BHC etc. Considering the fact that a number of participating laboratories have only recently begun environmental meansurement programmes, considerable improvement in the comparability of the results is expected in the future. As is the case for the trace element intercalibration programme, intercalibration exercises on chlorinated hydrocarbons also constitute an essential component of UNEP-sponsored projects.

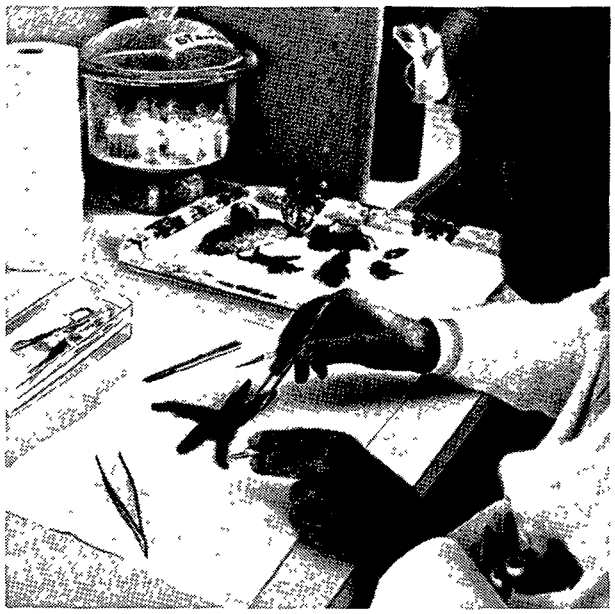
Future development of this intercalibration work will include natural radioactive materials, radionuclides arising from industrial activities and pollutants of non-nuclear origin. The benefits of standardizing sampling techniques will also receive increasing attention.

To be able to take the lead in this important international work the Monaco Laboratory must maintain the highest scientific and technical competence in this area. Even on the administrative and organizational level the experience acquired over the past years in distributing samples and in following up the results with different laboratories in many different countries is invaluable.

Marine biology

The work of the Biology Section also covers both radioactive and other materials. Many of the radiotracer techniques developed initially for radioactive work have proved particularly valuable in the study of heavy metals.

Vertical transport of pollutants: The principal goal of this project is the quantitative assessment of the downward vertical flux of pollutants such as radionuclides, heavy metals, chlorinated hydrocarbons etc., via the sinking of biogenic particulate matter. The vertical flux of pollutants in biogenic debris such as faecal pellets, molts, carcasses etc., is determined from



One of the Laboratory's scientists prepares to dissect a biological specimen for radioactivity studies.

the analysis of materials collected in sediment traps located at various depths in the sea. In parallel with sediment-trap collections the same materials, freshly released by zooplankton and other marine organisms are collected using specially designed shipboard techniques and then analysed for the same pollutants. Knowledge of pollutant levels in biogenic debris at various depths coupled with that for the same materials released in the surface waters ("source terms") allows estimates to be made of the release and/or scavenging of these pollutants by biogenic debris as it sinks. Laboratory measurements on decomposition and subsequent release of pollutants in these materials using both radiotracer and stable element analyses complement the field studies. This information is being used to test models of the movement or surface-injected pollutants down to the benthic boundary layer. Results to date indicate that sinking biogenic particulates often contain extremely high levels of various pollutants and are instrumental in removing many of these contaminants from the surface layers and transporting them to depth.

An extension of this work on the flux of transuranic elements will form part of the VERTEX (Vertical Transport and Exchange of Materials in the Upper Waters of the Oceans) programme; a multi-institutional proposal by the United States National Science Foundation Office for the International Decade of Ocean Exploration 1980–1990.

Bioaccumulation and food-chain transfer of transuranic elements: Radiotracer experiments designed to measure transfer coefficients of plutonium, americium, curium and neptunium from water, sediments and food in a variety of marine organisms are being carried out. Emphasis has been placed on studying pelagic species such as zooplankton which are instrumental in effecting vertical transport, and benthic species which live in close contact with the sediments. Data from the benthic studies are intended to serve as input parameters for deep-sea disposal assessments. In addition, the fate and behaviour of transuranic elements passed along simulated food chains are being studied at the organ and subcellular level. Results to date indicate that water and food are more important vectors than sediments in transferring transuranic elements to marine organisms. In addition, some benthic invertebrates retain large fractions of these radionuclides for long periods of time following incorporation from water or food. The experimental work has been greatly facilitated by the availability of the gamma emitter Pu-237 which permits *in vivo* measurements to be made.

Distribution of natural alpha emitters in marine organisms: The naturally-produced radioactive nuclide polonium-210 is concentrated very efficiently in marine organisms, and can account for the highest radiation dose received by many species.

The levels of polonium-210 in entire fish can range up to 7000 pCi/kg (wet) while for fish protein concentrate one exceptionally high value of 26 000 pCi/kg (dry) has been reported for anchovy concentrate. The radiation dose to zooplankton from internal polonium-210 has been put at about 400 mrem/year, while in some species the dose to critical organs could be of the order to 10 rem/year. The uptake factor for polonium-210 can range from 10 to over 10 000 times higher than certain transuranic nuclides.

A programme is presently underway to discern the distribution of Po-210 within the tissues of selected marine organisms. Results show that the hepatopancreas or liver of a wide variety of species usually contains the highest levels of Po-210 and special emphasis is being placed on pinpointing the Po-210 binding sites within this organ. Future work will attempt to elucidate the subcellular distribution of this radionuclide with biochemical techniques. The data will be used in the determination of natural background dose rates and in assessments of dosages from other radionuclides released to the environment. This work could make an important contribution to a better understanding of the controversial problem of the effects of low levels of nuclear radiation on living organisms.

Biokinetic studies of heavy metals: These studies provide good examples of how the use of radioactive tracer techniques have been developed and extended to studies of the fate and behaviour of heavy metal pollutants in the marine biosphere. By using the gamma active tracers, cadmium-109, mercury-203, selenium-75, arsenic-74 and vanadium-48 the uptake and loss of these metals by marine organisms can be examined *in vivo*, thus avoiding the stable metal process of killing, extracting and chemical analysis. In this way the bioaccumulation and food-chain transfer are being examined for both pelagic and benthic species. Special emphasis has been placed on assessing the degree to which environmental

Collecting samples at sea. ▶

parameters such as temperature, salinity and metal load affect the biogeochemical cycles of these elements. Laboratory experiments have also been intercompared with similar measurements made *in situ* for the purpose of assessing how well the results obtained in the laboratory reflect processes actually taking place in the natural environment. Results to date indicate that certain environmental factors strongly affect metal flux through many marine species, and, hence, biogeochemical cycles of these metals vary with changes in these factors. Laboratory-field intercomparison experiments have highlighted many difficulties involved in designing laboratory experiments to furnish reliable information about natural processes.

Baseline studies on trace metals in open-Mediterranean organisms: Several oceanographic cruises have recently been undertaken to collect and analyse a variety of pelagic organisms for selected trace metals. Emphasis is placed on the separation and analysis of individual species so as to eliminate the many problems involved with interpreting metal levels in mixed plankton samples. The results show that trace metal levels in pelagic species from the open Mediterranean are generally no different from those measured in similar organisms from other oceanic regions. Mercury concentrations appear to be particularly low in many open Mediterranean species.

Biokinetic studies of chlorinated hydrocarbons: Experiments have been designed to measure the bioaccumulation, tissue distribution and depuration of selected chlorinated hydrocarbon compounds by a variety of marine species. The degree of food-chain transfer as well as bio-availability from sediments is also being examined. Special emphasis is placed on the degree to which laboratory-derived data on chlorinated hydrocarbon biokinetics can be extrapolated to real situations in the natural environment. Information derived from these comparisons between natural conditions and laboratory systems provide a guide for laboratory experiments aimed at obtaining realistic information about *in situ* processes.

Marine sedimentology

This is to be an important extension of the work of the Laboratory. Marine sediments are generally considered to be the ultimate sink of most chemical elements which undergo various geochemical processes in the sea as well as on land. But it is also known that various elements can recycle through water-sediment reactions as well as through biological interaction with marine organisms. The mechanisms and extent of these potential recycling processes need to be better understood. This programme is of particular importance in considering the very long-term effects of pollutants and the eventual fate of materials which are released into the marine environment which will depend on reactions taking place at the sediment-water interface. This warrants special attention from the geochemical point of view.

International co-operation

The Monaco Laboratory accepts visiting scientists on sabbatical leave, and trainees mostly from developing countries. The training activities are considered to be an important component of the UNEP-sponsored activities in the Mediterranean and elsewhere in the Regional Seas Programme activities.

In this UNEP effort which occupies about 20% of the work of the Laboratory a close collaboration is maintained with other national institutions in the Mediterranean and other regions. As part of this collaborative programme the Laboratory hosts an electronics engineer responsible for the installation and maintenance of the measuring instruments such as gas chromatographs, atomic absorption spectrophotometers, current meters etc. This activity is of particular value to those developing countries who are involved in the work. In addition in collaboration with the Scientific Centre of Monaco, the Laboratory has an electronics maintenance unit, formed in 1975 to maintain the sophisticated electronic instruments owned by both the Laboratory and the Scientific Centre of Monaco.