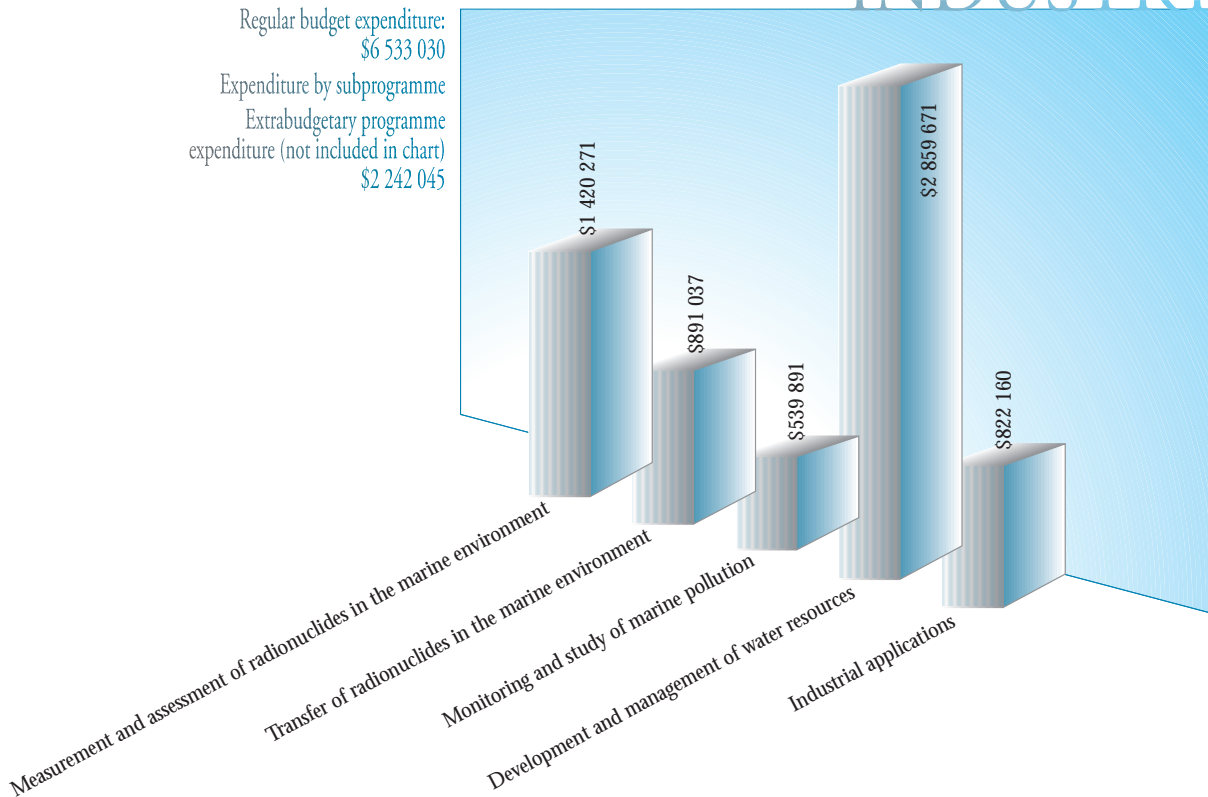


# MARINE ENVIRONMENT, WATER RESOURCES AND INDUSTRY



Agency activities to protect the marine environment focused on monitoring and assessing marine radioactivity and on using nuclear and isotopic techniques to enhance understanding of the oceans and marine pollution. In the realm of water resources development and management, the Agency worked to enhance the socioeconomic benefits of isotope hydrology activities. The impact of urbanization on water resources and pollution of surface waters were two new areas of study. The focus of work in the industrial applications of radiation technology was on promoting the use of radiotracer techniques, nucleonic control systems and non-destructive testing. Another important activity was the incorporation of radioisotopes into a variety of labelled compounds, radiopharmaceuticals, tracers, gauges and special radiation sources for use in medicine, agriculture and industry.

## Measurement and assessment of radionuclides in the marine environment

The analysis of seawater, sediment and biota samples collected during the 1996 expedition to the Mururoa and Fangataufa Atolls in French Polynesia was completed. Another expedition to the atolls carried out underground sampling of water from cavities and monitoring wells.

In related work, compartmental modelling was carried out to simulate the dispersion of radionuclides from

Mururoa and Fangataufa Atolls over a long time-span, i.e. up to thousands of years, and on an intermediate spatial scale covering French Polynesia using defined source term functions.

Seawater samples collected during the 1996 expedition to the Caspian Sea were analysed. The results show that concentrations of radionuclides (strontium-90, caesium-137 and plutonium-239 and 240) in water can be explained by global fallout, and no extra sources (e.g. dumping, contamination by rivers) need be taken into account.

A Global Marine Radioactivity Database (GLOMARD) was developed and data on radionuclide concentrations in seawater, sediment and biota of the Arctic Seas and the north Pacific Ocean were evaluated to provide Member States with information on radionuclide levels and time trends.

As part of the Agency's Analytical Quality Control Services (AQCS) programme, an intercomparison exercise was completed on radionuclides in Arabian Sea sediment (IAEA-315) with the aim of determining anthropogenic and natural radionuclide concentrations. Data from 159 laboratories in 50 Member States were evaluated and the results point to the improvement in the performance of Member State laboratories in analysing radionuclides in marine sediment.

A sampling cruise, the 'IAEA '97 Pacific Ocean Expedition', was conducted in October and November as part of a five year project supported by the Government of Japan to study worldwide marine radioactivity. The first time that the Agency has fully organized an oceanographic cruise to the open ocean, the expedition was arranged in co-operation with laboratories in Germany, India, Japan, the Republic of Korea and Sweden. The objectives were to sample seawater, sediment and biota and to carry out oceanographic measurements. These investigations will help to determine the contributions from global nuclear fallout, from former nuclear bomb testing at sites in the north and south Pacific Ocean and from former radioactive waste dumping sites in the north Pacific to the total radioactivity observed in the Pacific Ocean. Several oceanographic parameters such as salinity, surface water temperature, air temperature, longitude and latitude were continuously recorded during the cruise. These records will be compared with averaged data for the region with the aim of searching for possible changes introduced by the 'El Nino' effect. The vertical profiles of salinity, temperature, dissolved

oxygen and density have shown typical patterns found in the northwest Pacific Ocean. Deep sea sediments were characterized by the presence of manganese nodules on a red clay mineral matrix.

## Transfer of radionuclides in the marine environment

Within the European Union sponsored Aegean Sea Hydrothermal Fluxes project, two cruises took place in the hydrothermal vent zone off Milos Island to examine geochemical inputs to the sea from these shallow vents. Preliminary results from moored sediment traps have shown that vertical fluxes of sinking flocculent particles were often one order of magnitude higher near the vents than in an area just outside the vent zone. Sinking particles, marine organisms and sediments collected near the vents are being analysed for natural radionuclides and analogue trace elements to see if injections from vents lead to enhanced element levels in such marine areas. Characterization of the sinking particles suggests that vent-derived bacterial flocs, rather than the plankton in the waters surrounding the vents, may be responsible for much of the vertical flux of carbon in these relatively infertile waters.

Efforts were made to broaden the funding base for projects applying nuclear techniques to understand marine processes. A subcontract was established under the European Union sponsored Mediterranean Targeted Research Project II (MATER) through which the Agency will use natural radionuclides to measure particle scavenging and sedimentation rates in the western basin of the Mediterranean Sea.

Nuclear applications in experimental radioecological work focused on the use of radiotracers to evaluate the relative bioavailability and transfer factors of heavy metal contaminants in marine waters. Methods were developed to measure the low energy gamma rays of lead-210 directly in living organisms, such as echinoderms and molluscs, using high purity germanium detectors and whole body counting techniques. Initial results with starfish have shown that lead is taken up from water principally by the outer tegument and is then transferred to the inner skeleton, where it is fixed and retained. The strong retention and very slow

depuration half-life of lead in these organisms will limit their usefulness as bioindicators of lead, particularly in areas where levels of the metal in water fluctuate according to short time-scales. This observation has important implications for establishing the appropriate sampling frequency of a bioindicator organism like starfish in monitoring programmes involving lead.

In a collaboration with French environmental toxicologists, field and laboratory experiments using radio-tracers demonstrated that prior exposure of clams living in contaminated sediments in the natural environment to mercury and silver could affect their potential to bioaccumulate these metals from water. However, lower metal uptake rates in clams living in contaminated sediments did not reduce their sensitivity to the toxic effects of these metals, suggesting that for silver and lead biochemical and genetic levels of adaptation to metal toxicity may be of greater importance than bioaccumulation potential.

The natural radionuclide polonium-210, which is responsible for the major portion of the radiation dose received by many marine species, was examined in zooplankton collected from French Polynesian waters which have a low level of biological production. A detailed analysis of existing data demonstrated enhanced polonium-210 uptake in zooplankton when their biomass was low. A mathematical model was developed which suggests that in very productive waters with high zooplankton biomass, polonium-210 is rapidly removed from the water column in a rain of biodebris which concomitantly lowers the dissolved polonium-210 available for bioaccumulation. These findings indicate the possibility of enhanced vulnerability of low productivity marine systems to contamination by artificial radionuclides which behave similarly to polonium.

As a pre-requisite for evaluations of radionuclide transport in marine systems that may be potentially impacted by radioactive wastes, information on the degree of sorption to particulate matter is essential. In this context, the radionuclide distribution coefficients ( $K_d$ s) between water and sediment were determined under Arctic conditions in field and laboratory experiments for the waste derived nuclides americium, europium, plutonium, cobalt, caesium and strontium. The study, which focused on two separate regions in the Kara Sea, demonstrated that  $K_d$ s for individual radionuclides varied greatly depending upon the sediment type of the region. Such observed differences exemplify the importance of using site specific  $K_d$ s in

model simulations of radionuclide dispersion in order to provide a realistic view of contaminant sorption behaviour in the Kara Sea. Moreover, such site specific differences in radionuclide  $K_d$  values can also have a major bearing on radionuclide bioavailability for the Arctic organisms living in contaminated sediments.

## Monitoring and study of marine pollution

Certified reference materials, reference methods, inter-comparison samples and analytical standards were supplied to 415 laboratories around the world, to regional programmes in the Mediterranean Sea, Black Sea, Latin America and Asia, as well as to support three CRPs for the measurement of environmental contaminants. Two new marine reference materials were produced.

A three year extrabudgetary CRP on the distribution, fate and effects of pesticides in the tropical marine environment was extended for two more years. The results demonstrate the presence of organophosphorus pesticides in estuaries and coastal lagoon systems in Costa Rica and Jamaica, and the presence of organochlorine pesticides in estuaries in Bangladesh, Brazil, Colombia, Ecuador and Viet Nam. In several cases, the presence of these residues in aquatic systems was associated with the use of agrochemicals in agriculture fields. Another important part of the research was the series of experiments conducted on carbon-14 labelled pesticides and on non-labelled compounds applied in model ecosystems. The results confirm the long persistence and bioaccumulation of DDT as compared with chlorpyrifos. An intercomparison exercise on the measurement of radiolabelled pesticides and radiotracer techniques was carried out to ensure that the quality of data was high.

Analytical support and technical assistance for the implementation of marine monitoring programmes were provided to riparian countries of the Black Sea, and to India, Viet Nam, Nicaragua and Monaco. In cooperation with the Mediterranean Action Plan, missions for laboratory performance assessment and advice to the MEDPOL regional monitoring programme were carried out in Albania, Egypt, Lebanon, the Libyan Arab Jamahiriya, Morocco, the Syrian Arab Republic, Turkey and Tunisia.

A new two year project was set up in which the Agency will support the Regional Organization for the Protection of the Marine Environment (ROPME) monitoring programme in the Persian Gulf by implementing a further contaminant screening study and overseeing the quality assurance of contaminant measurements made by regional analysts.

## Development and management of water resources

The final Research Co-ordination meeting of a CRP on the application of isotope techniques to groundwater pollution was held in Vienna in December. This CRP saw the completion of 16 investigations dealing with the more traditional isotopes oxygen-18, hydrogen-2, hydrogen-3, carbon-13 and carbon-14, as well as with applications of sulphur-34, of oxygen-18 in the sulphate ion, nitrogen-15 and boron, which complement the classical hydrological tools of investigation.

A CRP on the use of isotope techniques in lake dynamics was completed with the convening of the final Research Co-ordination meeting in March in Rehovot, Israel. In this CRP, a number of isotope and geochemical studies of small and large surface water bodies were carried out, leading to a better understanding of the dynamics of these systems under growing anthropogenic influence. A regional survey of the isotopic composition of East African lakes was also completed. A new tool, the hydrogen-3/helium-3 technique, was applied to determine the ventilation rate of deep, large lakes such as Lake Baikal and the Caspian Sea. Using this method, a low apparent age of the deep water in the Caspian Sea (15–20 years) was found, indicating great vulnerability to surface pollution. This finding is important in designing proper management strategies for this unique system. Isotopic tools were also used in relatively small lake systems to determine the components of water balance and the sources of salinity (e.g. Lake Mar Chiquita, in Argentina), and complex mixing patterns in lakes (e.g. Lake Köyceğiz, in Turkey).

At the final Research Co-ordination meeting of a CRP on isotope techniques in water resources investigations

in arid and semi-arid regions, held in Vienna in October, positive results were reported on evaluations of groundwater replenishment under present climatic conditions. The aim was to correlate this information with past environmental conditions in order to protect groundwater resources against overexploitation and pollution. One of the conclusions was that there remains a need to further develop isotopic methods for studying the infiltration of water and pollutants through the soil zone into groundwater.

An Advisory Group met in Vienna in November on the potential of isotope methods for water resources management in major urban areas. There was agreement on the need for: improved methods and tools to obtain depth discrete samples in the analysis of dissolved gases in groundwater; a laboratory inter-calibration programme to standardize techniques for the measurement of oxygen isotope compositions of nitrates; analytical standards for the oxygen isotope analysis of nitrates; and further research on the analysis of hydrogen, carbon and chlorine isotope ratios in organic compounds.

The Global Network for Isotopes in Precipitation (GNIP) provides basic data for applications of isotope techniques to the assessment of water resources and for studying past and current changes in climate. To facilitate access to the database, a GNIP home page was set up on the Internet. New software was also developed to improve system efficiency and reliability.

A symposium on isotope techniques in the study of past and current environmental changes in the hydrosphere and atmosphere was held in April in Vienna. It was concluded that isotopic measurements in natural archives such as deep ice cores, palaeo-groundwater, lake deposits or organic matter are a necessary prerequisite to reconstruct past climate and environmental changes, and to forecast the impact of present global changes on forest ecosystems, desertification, water resources availability and the occurrence of floods and droughts. Isotope methodologies are also essential to precisely determine the atmospheric 'budget' of greenhouse gases, especially their sources and sinks, in order to predict and identify the impact of climate change.

The first issue of a quarterly newsletter on the development and management of water resources was published in September. The goal is better dissemination of information to national nuclear and water resources authorities, chief scientific investigators of

research contracts and agreements and experts involved in Agency activities.

The number of reference materials distributed increased by about 40% as compared with the average for the preceding three years. Five new reference materials were produced, two of which have been made available (IAEA-C7 and IAEA-C8), while the remaining three are still being investigated for their suitability.

## Industrial applications

The sterilization of disposable medical products and devices by radiation is a well established industrial process that helps to ensure the safety of health care services. This methodology has now attracted the attention of the pharmaceutical industry. To study this technique, a CRP was initiated on the use of radiation processing for the sterilization or decontamination of pharmaceuticals and pharmaceutical raw materials.

The danger of graft versus host disease in immunodeficient patients has long been recognized in many countries. However, it can be prevented by irradiating blood and blood components. A technical document was prepared with information and data to facilitate decision making regarding the feasibility of irradiating blood and blood products.

As a result of the increasing use of radiation processing in the modification, cross-linking, curing and degradation of polymers, the Agency prepared guidelines for training personnel working in this area. The material will provide a better understanding of radiation induced cross-linking and degradation phenomena in polymers and harmonize the content of Agency training activities.

Two new CRPs were initiated in the RCA region. The first seeks to improve the tensile strength, tear resistance and ageing properties of radiation vulcanized natural rubber latex (RVNRL) and develop standard procedures for the hydrogel coating of RVNRL dipped products. The goal of the second CRP is to develop radiation processing techniques for indigenous natural polymers. The natural polymers to be modified by irradiation will be selected from polysaccharides, cellulose and proteins. The properties will be affected by depending on the base structure of the natural

polymers. After radiation induced degradation, cross-linking and grafting processes, the modified polymers can be used in the pharmaceutical, textile and plastic industries.

A CRP was initiated on the validation of protocols for the evaluation of corrosion and deposits in pipes by radiography. It incorporates quality assurance aspects of non-destructive testing (NDT) measurements, including a round robin test and implementation of a quality plan. Metallic pieces are being prepared and exchanged within the network for interlaboratory quality control testing. Other work in the area of NDT and evaluation included the preparation of training materials for ultrasonic, penetrant and magnetic particle testing, a guidebook on NDT for industrial management and quality control personnel and guidelines on using NDT on concrete.

The beneficial environmental impacts and the opportunities to apply radiation technologies were examined at a symposium in Zakopane, Poland, in September. The technical and economic advantages of using radiation technologies for the purification of exhaust gases, decontamination of municipal and industrial liquid wastes, treatment of sewage sludge and the recycling and treatment of plastic, solid and hospital waste were the main subjects of discussion. The role of the Agency in the transfer of this technology to developing Member States (for example, Argentina, Brazil, Bulgaria, Chile, Poland and Ukraine) was highlighted during a panel discussion. One of the main conclusions of the symposium was that with recent improvements in the efficiency and design of new electron beam accelerators, radiation technology will provide one of the most promising solutions for the management of industrial and municipal wastes.

A Research Co-ordination meeting on the irradiation treatment of water, wastewater and sludges, as well as other meetings on the feasibility of electron beam flue gas treatment and radiation degradation of industrial waste, clearly indicate the increasing attention being devoted to the problem of waste treatment. There was agreement that good progress has been made in the past ten years in the utilization of irradiation processes for treating gaseous, liquid or solid wastes leaving industrial or municipal complexes.