

# MARINE ENVIRONMENT, WATER RESOURCES AND INDUSTRY

## MARINE ENVIRONMENT, WATER RESOURCES AND INDUSTRY

### PROGRAMME OBJECTIVE

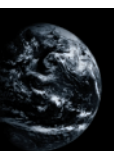
To improve Member State capabilities to: monitor and assess radioactivity in the marine environment for its protection, and use nuclear techniques and environmental isotopes to understand better and assess marine processes and pollution; integrate appropriate isotope and nuclear techniques in the planning and resource management of the water cycle, and better understand human induced hydroclimatic impacts; and adapt and utilize radiation and radiotracer technologies to improve industrial productivity and minimize environmental hazards.

### OVERVIEW

The Agency's programme on the marine environment continued to focus on the protection of the oceans and coastal seas through radioactivity monitoring and assessment and the use of nuclear and isotopic techniques to understand the fate and behaviour of pollutants. Capacity building, quality assurance, the provision of reference materials and methods, training and participation in cruises to collect marine samples in the Southern Ocean and along the coast of Morocco were among the most important of the Agency's contributions in 1999.

As part of its work in water resources management, the Agency developed an isotope methodology to assess groundwater renewal in areas where water is scarce. This will help Member States in the management of their water resources. Efforts to develop improved techniques for the measurement and interpretation of isotopic data continued, with specific water resource management issues in Member States addressed through the Agency's technical co-operation activities.

In the area of industrial applications, radiation processing techniques for making biomaterial and vulcanized rubber latex were promoted through



CRPs. Work focused on the use of electron beams for treating organic contaminated industrial effluents and polluted water, resulting in many pilot studies for possible large scale application. Documentation and training in non-destructive testing procedures and in the use of tracers and nucleonic gauges in industry were provided to developing Member States.

## **MEASUREMENT AND ASSESSMENT OF RADIONUCLIDES IN THE MARINE ENVIRONMENT**

An innovative system for the monitoring of marine radioactivity using stationary gamma monitors with satellite data transmission was developed by IAEA-MEL. The new system was deployed in April in Monaco Bay to test its performance and to evaluate the results. This equipment can record and transmit information on gamma emitting radionuclides in sea water and on a suite of parameters, including sea water temperature, salinity, current speed and direction, and can generate long term continuous records of marine radioactivity at locations distributed throughout the world's oceans. This is of particular interest for assessing the impact of nuclear facilities in normal or emergency situations and for surveying radioactive waste dump sites, but can also be used for a sentinel system in coastal or open sea locations, fishing grounds, or along major shipping routes. The monitoring system performed well over an eight month testing period, reaching the projected sensitivity of 4 Bq/m<sup>3</sup> for caesium-137 concentration in water. It is planned to deploy the monitor in 2000 in the Irish Sea to investigate the long term transport of caesium-137 released from the Sellafield nuclear fuel reprocessing plant.

Within the framework of a project on Marine Radioactivity Studies in the World Oceans, supported by the Government of Japan, the Agency participated in the ANTARES IV expedition to the Southern Ocean organized by French institutes. Surface water samples and three water profiles down to a depth of 5000 m were collected, as well as samples of plankton

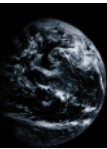
and fish. The aim is to study the vertical movement of radionuclides in the ocean. Direct on-board analyses of short lived thorium-234 were carried out for the first time by IAEA-MEL, using the most recent techniques. Thorium-234/uranium-238 disequilibria were used to study particle transport from the upperphotic zone down to deeper waters.

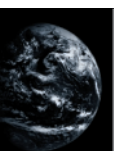
During the first Research Co-ordination meeting for a CRP on worldwide marine radioactivity studies, a geographical information system was developed for the assessment of marine radioactivity in the world oceans and seas. Hydrogen-3, carbon-14, strontium-90,

***“An innovative system for the monitoring of marine radioactivity using stationary gamma monitors with satellite data transmission was developed by IAEA-MEL.”***

iodine-129, caesium-137, plutonium and americium isotopes were chosen as being representative of anthropogenic radionuclides in the marine environment, and their main distribution patterns were established. The evaluation of sources of anthropogenic marine radioactivity has shown that global fallout is still the dominant source in the oceans, although in some areas releases from nuclear fuel reprocessing plants (e.g. in the Irish and North Seas) and the Chernobyl accident (the Baltic and Black Seas) have exceeded the contributions from global fallout.

Radioanalytical analyses were completed on a wide variety of samples from the Indian and Pacific Oceans and the Caspian Sea. Uniform distributions of strontium-90, caesium-137, plutonium and americium isotopes were found in the north Indian Ocean, confirming that global fallout is the dominant source of anthropogenic marine radioactivity in this region. Higher activity ratios of plutonium-238/plutonium-239+240 observed in the Indian Ocean are due to plutonium-238 remnants in surface water from the SNAP satellite, which burned up at high altitude over the Mozambique Channel in 1964. By





comparing plutonium profiles in the water column from various expeditions to the north-west Pacific Ocean, it was possible to establish temporal and spatial trends in the concentrations and inventories of this element in sea water which show a considerable decrease with time. Plutonium sediment inventories calculated from data stored in the Global Marine Radioactivity Database indicate a latitudinal and longitudinal decrease from the Marshall Islands test sites to the central northwest Pacific Ocean, as well as the northeast Pacific. This is in agreement with previous observations that the northwest Pacific has been affected both by global (stratospheric) fallout and tropospheric fallout (from nuclear weapons tests carried out at Bikini and Enewetak Atolls, Marshall Islands), while the northeast Pacific shows only contributions from global fallout. Analyses of hydrogen-3, strontium-90, caesium-137, plutonium and americium isotopes in surface waters and in the water column of the Caspian Sea indicate that the deep basins of the sea are rapidly ventilated, with the estimated turnover time of the sea being approximately 200 years. The radionuclide levels observed in sea water can be explained by global fallout and, therefore, at the sampling sites visited there were no signs of extra sources of anthropogenic marine radioactivity.

In the Agency's Analytical Quality Control Services (AQCS) programme for radionuclides in the marine environment, an intercomparison exercise on IAEA-384 Fangataufa lagoon sediment was completed and a reference material was issued which has been certified for 20 anthropogenic and natural radionuclides, increasing the total number of these materials to 38. These reference materials have been widely used by Member State laboratories for analytical quality assurance/quality control, development of new analytical methods and for training purposes.

Support to the Agency's technical co-operation programme included scientific and technical backup to the technical co-operation project 'Marine Environmental Assessment in the Black Sea Region'. Enhanced capabilities to assess marine radioactivity and to co-ordinate monitoring on a regional scale have been

developed through this project. Furthermore, the project highlighted the lack of previous data from the Black Sea on natural polonium-210, which is the main deliverer of dose through marine exposure pathways. Using the capabilities developed through this project, new polonium-210 data have been acquired. Sediment chronologies were studied using the lead-210 dating technique in order to reconstruct the history of contamination in various areas of the Black Sea. The input of strontium-90 and caesium-137 into this sea through the major rivers has been determined, and monitoring was initiated at 14 points along the Black Sea coasts.

A new technical co-operation project on pollution monitoring in the marine environment is assessing the present situation of the contamination of the south Mediterranean Sea by radionuclides, heavy metals and organic compounds. Simultaneously, a regional capability within North African Member States to monitor marine pollution is being developed. Within the framework of this project, a joint Moroccan-IAEA cruise was organized to assess contaminants in sea water, biota and sediment along the coast of Morocco in the Atlantic Ocean and the Mediterranean Sea. In addition, high resolution profiles of physical and chemical parameters, such as conductivity, temperature, dissolved oxygen, and nitrate and nitrite in the water column were obtained from shipboard measurements carried out during the cruise.

## TRANSFER OF RADIONUCLIDES IN THE MARINE ENVIRONMENT

Experimental nuclear application studies were focused on the use of radiotracers to assess the bioaccumulation, retention and transfer factors of radiologically important radionuclides and toxic heavy metals in marine organisms that are of global importance in oceanic food chains. The installation of new, state-of-the-art experimental aquaria systems at IAEA-MEL, which can simulate different marine ecosystems, has greatly facilitated radiotracer studies of species which are very difficult to maintain in captivity. One

such group are the cephalopods, or squid, a predator species which serves as a primary source of food for marine mammals and humans alike. To follow the uptake and distribution of radionuclides and metals in these ubiquitous animals, common cuttlefish were exposed to a mixture of radiotracers in water and in their food. Both exposure pathways led to a strong accumulation of contaminants in the organism's digestive gland. While such bioaccumulation and retention of contaminants in a non-consumable organ of cuttlefish would have little impact on the human population eating these cephalopods, top marine predators such as whales, which consume squid, may be exposed to elevated levels of toxic metals through their food chain. Such a transfer mechanism may account for the very high concentrations of cadmium and various heavy metals noted in whales and other marine mammals.

Another group of organisms currently the focus of interest are gelatinous plankton, or jellyfish, outbreaks of which cause difficulties for both the fisheries and tourism industries. Such attacks are thought to occur in areas under the impact of pollution and following changes in nutrient loads. Benthic and pelagic jellyfish were exposed under controlled experimental conditions to the same suite of metals and radionuclides which were subsequently accumulated and retained in their tissues. Most striking was the enhanced accumulation of silver by a bottom dwelling species, *Cassiopea*. This suggests that this particular species could be used as a bioindicator of silver contamination which, in turn, is a chemical marker for domestic sewage. Furthermore, this species of jellyfish obtains much of its nutrition through the photosynthesis of small plant cells located in its own tissues. Radiotracer studies carried out in the light and dark suggest that these cells may actually play a major role in the uptake and retention of these contaminants by the jellyfish.

Lead is another toxic metal which, in areas like estuaries where large salinity variations are typical, can be released from particles into a dissolved, more bioavailable form. Estuarine shrimps exposed to lead-210 rapidly accumulated dissolved radiotracers reaching concen-

tration factors as high as 100 after only two days. In the case of lead, nearly one-half of the amount taken up was located in the shrimp's exoskeleton which it periodically sheds as it grows. For surface reactive metals like lead, such a physiological mechanism can account for the low metal retention in this species of shrimp, and ultimately limited transfer of lead through the marine food chain to people.

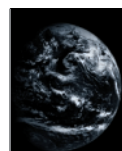
The transfer and fate of toxic organic contaminants can also be assessed by nuclear techniques. For example, bottom dwelling sea stars and sea urchins were exposed to the

***“Radiotracer methodologies offer great promise as a rapid and relatively inexpensive means for tracing contaminant behaviour and identifying target organs and tissues in specific marine species.”***

highly toxic, carbon-14 labelled polychlorobiphenyl (PCB) congener No. 153 in sea water and in their natural food. It was found that the predominant uptake pathway was from water, and that this PCB congener was mainly concentrated in the body wall and tube feet rather than in internal organs. The radiotracer foodchain study also demonstrated that the nature of the contaminated food strongly influenced the degree of PCB assimilation into the animal and its subsequent distribution among the various tissues.

One of the most striking results to come out of all the laboratory radiotracer studies undertaken are the major differences in tissue localization of different contaminants in different marine organisms. This demonstrates the difficulty in generalizing about the behaviour of a class of contaminants in marine biota. Clearly, radiotracer methodologies offer great promise as a rapid and relatively inexpensive means for tracing contaminant behaviour and identifying target organs and tissues in specific marine species.

Field work at sea continued to focus on assessing carbon sequestration and removal from



the surface waters of the northwest Mediterranean Sea. Long term time-series studies now covering over a decade (1987–1999) have begun to bear fruit in revealing trends with frequencies greater than one year. Superimposed on an annual cycle, where high carbon exports occur in the winter–spring and low exports during the summer–autumn, there appears to be an inter-annual oscillation of about four years in the flux of carbon to depth. In addition, sporadic but intensive inputs of Saharan dust transported to the sea surface can act to increase carbon fluxes both by direct contribution of fine crustal particles and by increasing water column biological productivity (fertilization effects). These changes at different time-scales highlight the complex mechanisms involved in the production of particulate organic material in the surface ocean, the concomitant reduction of dissolved carbon dioxide gases, and the subsequent increase in the ocean's ability to take up atmospheric carbon dioxide.

In connection with these climate oriented studies, nuclear techniques were used in a field experiment to compare measurements of the downward flux of particles and carbon with computed estimates of particle removal from surface waters. During one month in the spring, three models of sediment traps commonly used by the international oceanographic community were deployed at sea, and the measured fluxes were compared with indirect estimates of carbon fluxes using the degree of disequilibria between thorium-234 and uranium-238. Results showed that records from all three models of traps were

consistent with particle dynamics in the water column during the period sampled, and that carbon flux estimates based on the disequilibria of these natural radionuclides agreed quite well with direct in situ measurements.

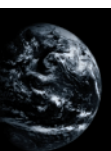
## MONITORING AND STUDY OF MARINE POLLUTION

The use of carbon isotope techniques, coupled with gas chromatographic separation, to identify and assess the sources of organic materials such as carbon in the marine environment was further developed. Studies of the change in carbon-13 composition among lipid molecules synthesized by cultures of diverse photosynthetic organisms were also performed. Significant differences in the carbon isotope ratios were observed among the lipid molecules synthesized by the same organism and among homologues of the same lipid class. All these differences will be considered for the correct assignment of biomarker sources and for a better understanding of the biogeochemical processes in the environment.

The installation of a Finnigan Element high resolution inductively coupled mass spectrometer was completed in 1999. Sample preparation and analysis routines were refined to make full use of the low flow sample introduction options. The instrumental capabilities, notably high resolution and femtogram detection limits, have benefited several projects. Samples from the Aegean Sea and the Persian Gulf have been analysed for trace metals, rare earth elements and uranium isotopes.

### New Experimental Aquaria at the Marine Environment Laboratory in Monaco

This year saw the startup and expansion of IAEA-MEL's new state-of-the-art experimental aquaria facilities, which are used for research and training in marine radioecology. These specially designed laboratories are outfitted with individual mesocosms ranging in size from 70 to 3000 litres. The controlled aquaria can be automatically regulated at various temperatures and salinities in order to closely simulate different marine ecosystems, ranging from estuarine to the open ocean. This has allowed the application of radiotracer and isotope methodologies to assess the transfer, behaviour and fate of radionuclides and toxic trace contaminants in critical marine environments (e.g. Mediterranean and Atlantic coastal zones, tropical coral reefs and temperate pelagic regions). Agency Fellows and other trainees from Member States have begun to make use of these facilities in order to evaluate the usefulness of a variety of marine organisms as 'bioindicator species' for different contaminants being measured in their respective national monitoring programmes. ■



One new reference material (IAEA-408, Estuarine Sediment) was produced and is now available to the international scientific community. It was certified for pollutants such as organochlorine pesticides, petroleum hydrocarbons and PCBs.

As part of the Agency's programme of assistance to pollution monitoring efforts by Member States surveys of contamination by petroleum hydrocarbons and toxic metals were carried out in the area covered by the Regional Organization for the Protection of the Marine Environment (ROPME) in the Persian Gulf. In addition, intercomparison exercises for metallic and organic contaminants in sediments and biota using split sample techniques were undertaken with the national laboratories in the ROPME, Black Sea and Mediterranean regions.

## DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES

The tenth symposium on 'Isotope Techniques in Water Resources Development and Management' was held in Vienna in May. This symposium, organized by the Agency at four year intervals, was co-sponsored by UNESCO, WMO and the International Association of Hydrological Sciences (IAHS). Presentations were made on: isotope applications in surface water hydrology; groundwater resource management; climate change phenomena; and environmental management. The future research and development needs in isotope hydrology and the role of the Agency, both in support of research and applied work, were considered in a roundtable discussion.

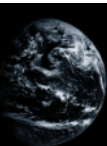
Methodologies for the application of isotope techniques using fallout caesium-137 and lead-210 concentrations to assess soil erosion and sedimentation rates were improved in a CRP that was completed in 1999. It has been demonstrated that environmental radioactivity can be used to evaluate soil erosion, soil redistribution (sedimentation in lower areas or in flood plains) and the fraction of eroded soil which is transferred as sediment to surface water. The CRP succeeded in defining stan-

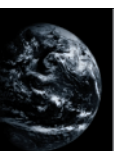
dardized methodology which will be made available as a handbook. In addition, reference inventories for the two radionuclides in different parts of the world were assembled, resulting in the identification of areas where soil concentrations were high enough to use the methodologies developed in this CRP. A description of the CRP and the results obtained were also presented at a meeting of the European Network for Research in Global Change (ENRICH), which uses caesium-137 and lead-210 for the establishment and calibration of global atmospheric circulation models.

***“The results of a CRP on isotope techniques for the assessment of slow moving deep groundwater provide an additional tool for safety assessments of geological nuclear waste disposal sites.”***

The integration of isotope techniques with other hydrological and geochemical methods for evaluating the rate and history of groundwater recharge was further improved through a CRP on the isotope based assessment of the groundwater renewal rate in water scarce areas. Detailed isotopic and hydrogeochemical information was collected at 44 benchmark field sites, mainly located in arid regions. These data provided recharge rate estimates, verified through applied field research, ranging from fractions of a millimetre to tens of millimetres per annum. The methodology provides a unique approach to estimating the natural renewal rate of groundwater, which is difficult to assess in arid environments through conventional hydrological methods. The final report on this CRP will be published in 2000.

The final Research Co-ordination meeting for a CRP on isotope techniques for the assessment of slow moving deep groundwater and their potential application for the assessment of waste disposal sites was held in Vienna in August/September. The krypton-81 dating method was used in this CRP in the Great Artesian Basin of Australia to estimate groundwater ages in the range of several





thousands of years. This joint effort of seven institutes and the Agency is believed to have provided for the first time reliable information on groundwater age in this range. In addition, the results of the CRP provide an additional tool for safety assessments of geological nuclear waste disposal sites.

Emerging techniques for the determination of stable isotope ratios of light elements and their requirements in terms of reference materials were reviewed in an Advisory Group meeting on the state-of-the-art in gas chromatography/continuous flow isotope ratio mass spectrometry (GF-IRMS) and its applications in water resources and related environmental studies. In addition to isotope hydrology and geochemistry, the range of disciplines using isotope signatures has broadened significantly. As a consequence, the requirements of analytical instruments have changed drastically in some fields. Several new instrumental developments were discussed in the meeting with a focus on CF-IRMS and optical techniques for stable isotope determinations. The meeting defined the most urgent needs for internationally available stable isotope reference materials for organic substances and provided guidelines for setting priorities in the Agency's Stable Isotope Reference Materials Programme.

Final drafts of six volumes of teaching material covering the entire range of environmental isotope applications in hydrology were completed. To be published in 2000 in a UNESCO publication series entitled 'Technical Reports in Hydrology', this joint publication is aimed at participants in Agency training courses, as well as teaching institutes and universities worldwide.

A scientific steering committee was constituted as prescribed in the recently signed Memorandum of Understanding between the Agency and WMO on the Global Network of Isotopes in Precipitation. The committee, which advises the two organizations on operational aspects of the network, held its first meeting in Vienna in July. The long term evolution of the network was discussed and specific measures for this purpose were defined at the meeting.

The development of software to facilitate the integration of isotopes in hydrology through a common database on hydrological studies and investigations conducted in Member States was completed. Named 'ISOHIS' (Isotope Hydrology Information System), this software is available on the Internet and is being distributed to national counterparts in Agency technical co-operation projects and to about 50 institutes.

An instruction manual for using isotopic and chemical techniques in geothermal reservoir development and management was completed. The manual provides the theoretical basis and procedures for using isotope techniques for geothermal reservoir exploration and management. It is expected to facilitate the development of trained personnel in Member States and improve the implementation of Agency technical co-operation projects in this field.

Analytical laboratories in Member States were assisted in the improvement of their procedures for chemical analysis through a series of intercomparison exercises. About 60 laboratories in Asia, the Middle East, Africa and Latin America participated in these exercises, which identified areas where improvements in procedures are needed to ensure acceptable chemical results. In one year, 47% of the laboratories have shown improvement in their laboratory performance.

Synergy with other international organizations was pursued through a consultative process for a new activity entitled 'International Programme for Isotopes in the Hydrological Cycle' in co-operation with WMO, UNESCO and scientific institutes in Member States. The goals of this initiative are to: fully integrate isotope hydrology in water sciences at universities; and establish, through the UNESCO/IHP (International Hydrological Programme), national committees hydrology to facilitate the application of isotope hydrology in the water and climate sectors of Member States. At a consultative meeting with UNESCO and WMO in December, it was decided to make a formal proposal to the UNESCO/IHP Inter-governmental Council meeting in 2000 for the formation of such

national committees within the framework of the IHP committees.

One of the Agency's missions is to provide reference materials for isotope analysis worldwide. To this end, the analytical precision and accuracy of work in the Isotope Hydrology Laboratory of the Agency's Laboratories was improved through the use of a new equilibration device for oxygen-18/hydrogen-2 stable isotope analysis of water. This device, constructed at much lower cost than a commercially available device, improves precision for both  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  analysis by about a factor of two compared with that possible from the commercial devices currently in use. In addition, use of twofold  $\delta^2\text{H}$  analysis, using a standard procedure and a precise equilibration procedure for all water samples, further improved the reliability of isotopic results.

A new and reliable method to determine the isotopic composition of air moisture was developed. This method uses molecular sieves to adsorb moisture for laboratory analysis and obviates the need for a cooling agent for sample collection. One of the important applications of this method is in lake water balance studies in remote areas where a supply of liquid nitrogen or dry ice, necessary for conventional sampling methods, is not available. The new method will improve the implementation of future technical co-operation projects on lake dynamics.

Two new analytical methods to analyse the carbon isotope composition of organic matter

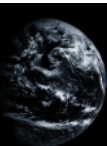
and the isotopic composition of oxygen gas were introduced in the Agency's Isotope Hydrology Laboratory. These procedures will improve quality assurance efforts for reference materials of organic substances, including re-evaluation of the isotopic properties of nine existing standards and the production of new organic, stable isotope reference materials suitable for advanced analytical techniques.

In order to ensure the ready availability of basic reference materials, attempts are being made to produce successor materials well ahead of the depletion of the available stock. Accordingly, a successor material for the primary reference material, VSMOW, was produced in a large quantity (300 litres). The isotopic composition of the new standard, VSMOW-1, is very nearly the same as the existing VSMOW standard, though production costs were a fraction of the currently estimated commercial price of about \$1.2 million.

Two interlaboratory comparison exercises were conducted to strengthen the analytical precision and comparability of data produced in isotope hydrology laboratories around the world. The first focused on stable isotope composition in water samples. Ninety laboratories sent in results for four water samples shipped to them for analysis. The evaluation showed the need for such exercises, since a considerable fraction of laboratories reported data outside the acceptable range. Corrective action was taken by some of the laboratories to improve their analytical precision.

### Isotope Techniques for the Mitigation of Arsenic Poisoning

Exposure to arsenic contaminated drinking water has affected millions of people in Bangladesh, resulting in a major public health crisis. The World Bank has initiated a \$44 million project to address the mitigation of this serious problem. One of the options available is to exploit deep aquifers as alternative sources of drinking water. However, reliable criteria are not available to evaluate the long term consequences of this option. A new technical co-operation project was begun in 1999 to demonstrate the benefits of integrating isotope hydrology in arsenic mitigation efforts in Bangladesh. This project was formulated following initiatives taken by the United Nations Administrative Committee on Co-ordination, Subcommittee on Water Resources, where the Agency was designated as the lead organization for hydrogeology and geochemistry activities. The Agency's project has resulted in the development of isotopic criteria to assess the safety of deep groundwater, and has provided crucial information that was lacking in spite of substantial efforts that were expended in the use of non-nuclear technologies. ■



In Ethiopia, a new groundwater field is being developed to meet approximately 40% of the water demand of Addis Ababa, the capital city. At present, about 25 production wells have been prepared, but production has been delayed owing to the lack of an appropriate groundwater exploitation and management strategy. An Agency technical co-operation project is helping to integrate isotopic techniques for obtaining hydrological information that would assist in the development of an accurate exploitation and protection strategy for the well field. These efforts are complementary to those of other bilateral and multi-lateral donors who are also assisting the local water authority in water supply management.

*“The ability to use isotope hydrology techniques for dam sustainability investigations is being developed through several technical co-operation projects.”*

Hydrological conditions of groundwater in multiple aquifers in the Tadla Plain, an economically important region in eastern Morocco, are being characterized through the use of isotope hydrology techniques under a technical co-operation project. This project is complementing the work of a UNDP/UNDESA-supported project for developing a model for water resources management in the Tadla Plain. Isotopic analysis of about 150 samples during 1999 provided crucial data for testing many of the assumptions previously made in the development of the hydrological model. Hydrology and isotope specialists from the water authority and the nuclear centre in Morocco participated in a workshop to review and interpret the data collected in the project.

A new regional technical co-operation project on the sustainable development of groundwater resources was initiated. This project, involving seven countries in southern and eastern Africa, has the objective of facilitating the integration of isotope techniques with non-nuclear techniques for water resources development and management. Isotope techniques were also used in a technical co-operation proj-

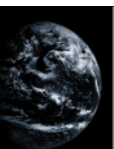
ect involving China, Costa Rica, El Salvador, Indonesia, Philippines and Thailand to monitor hydrological conditions in producing geothermal reservoirs, leading to lowered costs for electricity generation costs. In addition, the project in El Salvador developed the capacity to use geochemical techniques for predicting and controlling scale formation in the reservoir and increase its usable life for electricity generation.

Dam sustainability is an issue of great concern for many Member States. It is an issue that has different components. One of them is dam leakage, where the loss of water may endanger the stability of the dam itself or may be a waste of the natural resource. The second problem is related to reservoir siltation which, if not managed correctly, may drastically reduce the expected life of the dam. The ability to use isotope hydrology techniques for dam sustainability investigations is being developed through several technical co-operation projects, including one on dam leakage in Africa. Use of these methodologies is being extended to the Asia and Pacific area, incorporating the concepts included in the ‘Thematic Plan on Dam Sustainability’ that was developed this year.

A technical co-operation Model Project on groundwater resources in the Caracas Valley of Venezuela was completed with the final calibration of the mathematical model developed for the aquifer. The application of the model, which is based on isotopic data, showed that an increase of only 20% in the present pumping rates may exhaust the water in the aquifer in less than 15 years, much sooner than previously estimated. The use of this model is expected to improve the exploitation and management of this important urban aquifer.

## INDUSTRIAL APPLICATIONS

Radiation processing is now emerging as an environmentally friendly technique for less chemical intensive processes and for making effluents free of pollutants. In recent years the use of ionizing radiation in the synthesis and modification of polymer based materials used



in the health care and plastics industries has also grown significantly.

The results and achievements of a recently completed CRP on irradiation treatment of water, wastewater and sludge demonstrated the advantages of using ionizing radiation to solve problems related to liquid wastes. A combination of treatment methodologies has been studied utilizing ionizing radiation and other agents for the decontamination of polluted water and wastewater. The technology has been taken up by the industry and engineering scale facilities are in operation.

In another recently completed CRP on the use of radiation processing to prepare biomaterials for applications in medicine, the advantages and unique properties of ionizing radiation in the preparation and modification of polymers for biomedical applications were demonstrated. Some of the typical applications achieved included: improvement of the sensitivity of microtitration plates for diagnostic purposes; stimuli-responsive radiation grafted coatings for on-off control devices; radiation synthesis of micro and nano particles for enzyme immobilization and drug

delivery systems; preparation of hydrogels for wound dressings and drainage; and radiation synthesis of hydrogels for controlled drug delivery purposes and for contact media in ultrasonic applications.

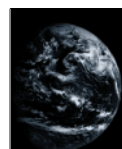
Improvement of the physical properties of radiation vulcanized natural rubber latex (RVNRL) was the subject of a CRP that was concluded in 1999. As a result of extensive research and development activities, RVNRL films with improved tensile strength, increased tear resistance and minimum residual protein were synthesized. The results have already been transferred to the relevant industries, and India, Malaysia and Thailand have started manufacturing products made from RVNRL. There are also indications that, especially for retrofit installation, the use of low energy self-shielded electron beam accelerators for the vulcanization of natural rubber latex will provide technical, environmental and economic advantages.

An expert meeting was held in Takasaki, Japan, on the radiation synthesis of 'intelligent' membranes, hydrogels and adsorbents. The present status and emerging applications

### Electron Beam Technology for the Remediation of Water and Wastewater

Improvements in electron beam accelerator technology in recent years (e.g. increased power conversion efficiency and power output) and research in Member States have indicated that accelerators are suitable for the large scale treatment of polluted water. Pilot scale operations have also indicated that decontamination and disinfection of wastewater and drinking water are economically feasible. The results of R&D work carried out in a CRP on the irradiation treatment of water, wastewater and sludges have been successfully adapted by a number of Member States. Typical examples of large scale operations are the following:

- Groundwater containing chlorinated organic compounds in Lower Austria was treated using electron beam radiation in conjunction with ozone addition. Complete demineralization of pollutants has been achieved and all toxicity tests on treated water have proved negative.
- The city of Voronezh, in the Russian Federation, used ionizing radiation to treat groundwater which contained a detergent from an industrial process.
- A mobile electron beam accelerator developed in the USA has been used to demonstrate treatment of all forms of aqueous wastes. Highly contaminated groundwater in Germany and groundwater contaminated with a petroleum additive in the USA have been successfully treated with this mobile system.
- Effluents from a large chemical company in Brazil have been treated on a pilot scale with electron beams.
- A pilot plant constructed in a textile dye wastewater plant in the Republic of Korea has proved successful in treating effluents. ■



of ion track membranes, these products, analysed and evaluated, especially in relation to their use in separation processes.

Another expert meeting in Vienna examined the technical and economic aspects of the radiation treatment of wastewater. Studies have indicated that electron beam accelerators are most suited for large quantities of water and wastewater and, because of the required redundancy in any environmental application, several small size accelerators can be utilized instead of a single large power installation. On the basis of past experience with pilot and full scale systems, the typical costs for the electron beam treatment of wastewater were

***“The typical costs for the electron beam treatment of wastewater were found to compare favourably with other advanced water treatment systems.”***

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A two year regional technical co-operation project in Europe was initiated with the long term objective of transferring radiation technology for the treatment of industrial and municipal wastewater. In the short term, the goal is to increase the awareness and induce wider acceptance of the advantages of using radiation in the treatment of liquid wastes.

The services of consultants were sought to evaluate the status and trends in software development for tracer studies. Residence time distribution software for troubleshooting and process analysis was recommended as the standard for more than 30 Member State tracer groups. This software facilitates the extraction of information on the process, helps its optimization and improves the quality of services to end users.

Radiotracer and nucleonic gauge technologies continue to be an active component of national and regional technical co-operation projects, in particular in the RCA and ARCAL regions. To stimulate training efforts, a number of

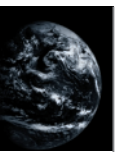
regional activities on radiotracers, sealed sources and nucleonic gauges applications in the petroleum and petrochemical industries were conducted. The major techniques included: residence time distribution analysis for troubleshooting; radiotracers for accurate flow rate calibration and leak detection; tracers for enhancing oil recovery; gamma and neutron scanning techniques for the inspection of columns and tanks in oil refineries; the thin layer activation technique as applied to the monitoring of wear and corrosion; and a cross-correlation technique for multiphase flow rate measurement.

A guidebook on radiotracer and sealed source technology as applied to industry was prepared and practical manuals of procedures, norms and quality control in tracing and gauging work were compiled. These documents will facilitate the transfer of technology and help in the accreditation of tracing and gauging groups in developing countries.

A technical co-operation Model Project on radiotracer applications for enhancing oil recovery was started in China in January. The methodology for interwell communication and residual oil evaluation using a multi-tracer technique was completed and tested at the Dagang Oil Field. A new radiotracer compound was prepared, tested and validated for large scale applications in 30 operating oil fields, with an increase in oil recovery of about 10% being reported.

An Advisory Group meeting was held in December to identify priority problem areas in industry in the Asia-Pacific region, and to formulate project proposals for the Agency in 2001 and 2002. The meeting identified four priority industrial sectors for which project proposals were formulated:

- Process diagnostics and optimization in the petroleum/chemical industry using non-destructive testing (NDT), radiotracers and sealed sources;
- Optimization of mineral resources recovery by using low radioactivity and portable nucleonic gauges;
- Modification of natural polymers through radiation processing;



- Demonstration facilities for the disposal of hospital waste and the treatment of industrial wastewater using radiation.

The expected benefit to Member States in the RCA region will be the establishment of advanced and intrinsically safe nuclear technologies for problem solving.

Encouraged by results in other regions, a project on NDT in industry has been started in the West Asia region. The objectives of the project are to establish and upgrade NDT groups to exploit the potential of this technology in the industrial and civil engineering sectors and to initiate a process for the training and certification of NDT personnel. The main emphasis has been to educate, train and certify a core group of persons in each Member State in order to fulfil the requirements of international standards, such as ISO-9712. These people can then continue the training and certification process in their countries, ultimately developing local NDT capabilities for the quality control of industrial products.

Five Advisory Group meetings were organized on the topics that are considered to be of the most importance for the establishment of NDT technology in Member States. Concrete structures such as buildings, bridges, roads, runways, pavements, retaining walls, dams, sewage lines, tunnels, storage tanks and specialized buildings such as nuclear reactor containments structures, comprise a vast field for the application of NDT. To be able to successfully introduce this technology in developing Member States, it is important to educate, train and certify a large number of people in this field in view of the number of concrete structures requiring inspection and testing. At two of these meetings, guidebooks on concrete structure NDT and on the fabrication of NDT test pieces were completed. The other three meetings defined the syllabus and compiled university examination questions on NDT. In addition, two text books were published, one a guidebook on NDT for industrial management and quality control personnel, and the other on the ultrasonic testing of materials.

