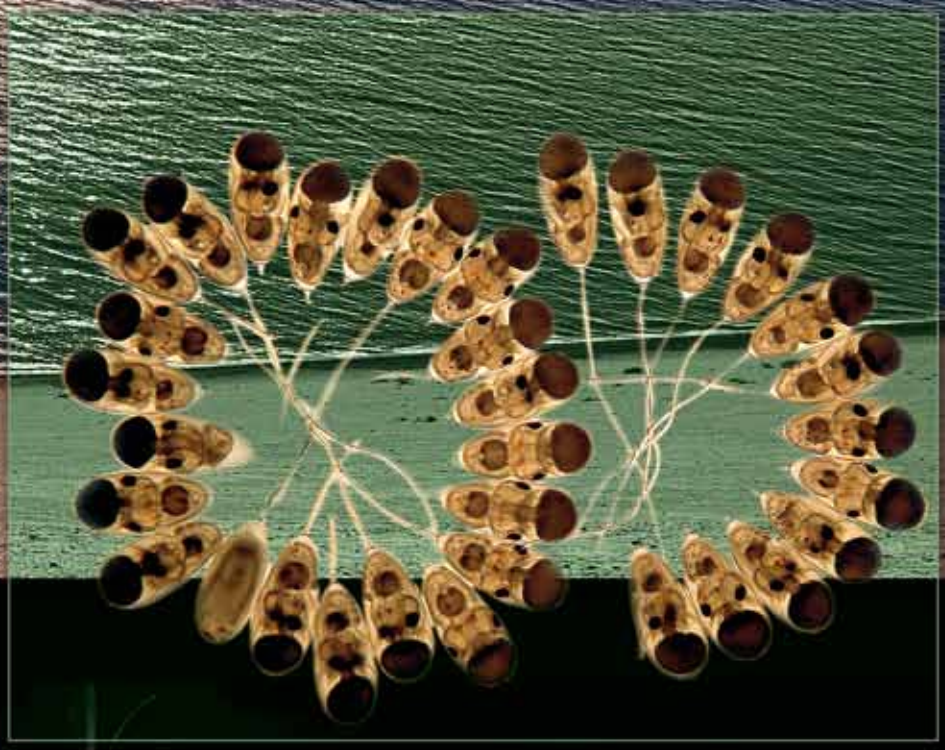
IAEA
International Atomic Energy Agency

ISOTOPIC TOOLS
for Protecting the Seas

MARINE ENVIRONMENT LABORATORIES MONACO



Contents

1961 — Laboratory established in the Oceanographic Museum **(left)**

1988 — Temporary facilities in the Stade Louis II **(right)**

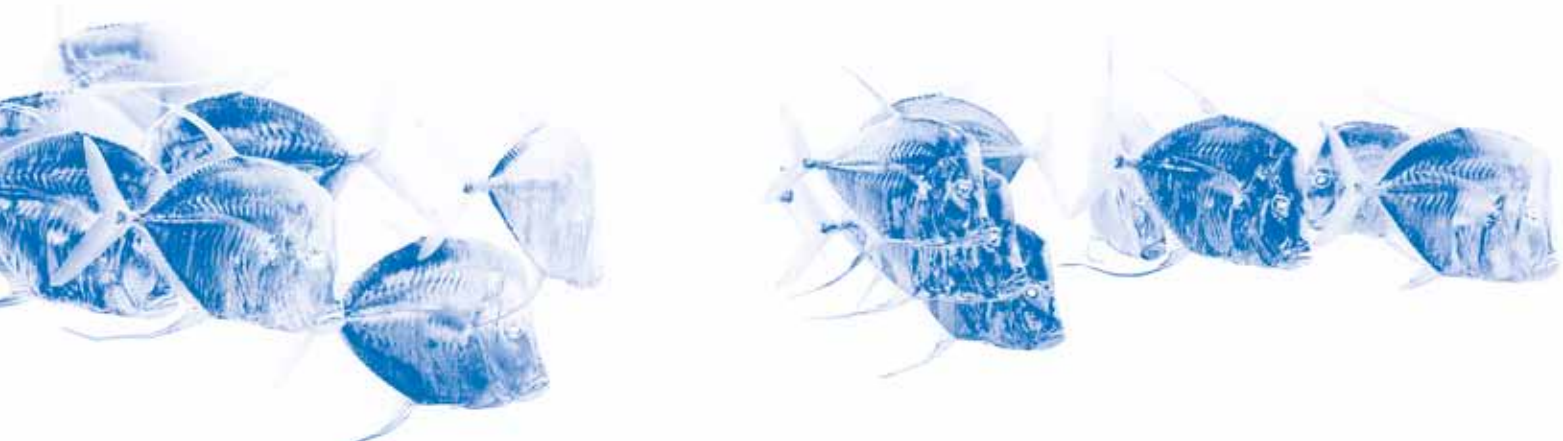
1998 — Permanent facilities in the Port of Monaco **(bottom)**

"We are very proud that the IAEA established its Marine Environment Laboratories in Monaco, the only marine laboratory in the United Nations system. Their first purpose-built facilities, dedicated to marine research, launched a new era in the investigation of the marine environment. We are pleased that the Principality of Monaco has been actively engaged in these developments and is continuously supporting activities of the Monaco laboratories."

H.S.H. Prince Albert II, Monaco
(With his father, the late Prince Rainier III)

MEL's Mission

- Conduct studies for the protection of the marine environment from radioactive and non-radioactive pollution;
- Develop applications of nuclear and isotopic techniques to increase the understanding of oceanic processes, marine ecosystems and pollution impacts;
- Provide expertise, training and reference materials to assist Member States' commitments to monitor marine environments and promote their sustainable development;
- Establish and sustain strategic partnerships with the United Nations (UN) and their international agencies to deliver the World Summit on Sustainable Development (UN-WSSD) programmes on sustainable development of the ocean;
- Act as a networking centre for IAEA Member States, with an increasing focus on normative activities.



Foreword

Respect for and protection of the environment are investments in our common future.

The seas and oceans that cover 80% of the Earth's surface are our greatest natural resource. They help to maintain the broad ecological balance and the climate of our planet, while ocean based activities such as fishing, coastal tourism and shipping generate more than US $900 billion per year.

Coastal zones, supporting about 60% of the global population, require special attention because of their contribution to the world's food supply and their sensitivity to pollution. Pollution of the ocean is extensive, and in many cases, irreversible. Our greatest guarantee against global warming — the ocean's vast ability to act as a carbon sink — may be at risk. In addition, coral reefs around the world are suffering a rapid decline.

For nearly 50 years, the IAEA's Marine Environment Laboratories (IAEA-MEL) in Monaco have been making radionuclides and stable isotopes available for the study of environmental processes, the fate of contaminants in ecosystems, atmosphere–ocean interactions, surface and groundwater systems and the response of atmospheric, hydrological and marine systems to climate change.

This brochure summarizes activities at the Laboratories, which will turn 50 in 2011. We are grateful for the commitment of the Grimaldi family and the Monegasque Government, as well as of other IAEA Member States, which has made our work possible. As the interface between advanced applied research into the most challenging environmental scientific problems and the transfer and dissemination of knowledge to Member States laboratories, MEL works to strengthen scientific cooperation and coordination. It provides training, strategic advice, methodological harmonization and quality support for the monitoring and assessment of marine contaminants.

The scientific advances of IAEA-MEL, together with those of other advanced organizations and laboratories, can lead the way in preserving our precious ecological inheritance. Together, we can help to ensure that we bequeath clean and healthy oceans to our children and grandchildren.

Yukiya Amano
IAEA Director General

Global Threats to the Marine Environment

Radioactive and Chemical Pollution

Pollution of the oceans is essentially a 20th century problem, associated with rapid industrialization. Up to 80 percent of all ocean contamination originates from human activities on land. The biggest problems are presented by agricultural nutrients, heavy metals, and persistent organic pollutants, such as pesticides and plastics. Oil spills from ships and tankers continually present serious threats to birds, marine life and beaches.

Many pesticides that have been banned in industrial countries are still used in developing countries. Ocean dumping of radioactive waste has occurred on a large scale at various points in the past.

Fisheries and Coral Reefs in Decline

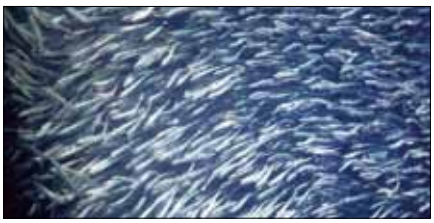
The UN Food and Agriculture Organization (FAO) estimates that about one-quarter of the oceans' wild fish stocks are lightly or moderately exploited and still offer some scope for further fisheries expansion while roughly half are fully-exploited — that is, producing catches that are already at or very close to their maximum sustainable production limit. Of the remaining, nearly a quarter are over-exploited or depleted.

In 90 of the 109 countries with major coral reefs, cruise ship sewage and anchors are causing irreparable damage, often compounded by exploitative seafood harvesting, including dynamite and cyanide fishing.

Global Warming and Carbon Balance

The oceans are one of the earth's largest carbon sinks — their microscopic phytoplankton absorb vast quantities of the atmospheric carbon generated by burning of fossil fuels in cars, power plants and homes. Normally oceans absorb these "greenhouse gases" and help to prevent global warming. Polluted oceans are less able to moderate the carbon balance and thus contribute inevitably to uncontrolled climate change.

Much of the Earth's bounty comes from the oceans and seas. Yet today, the marine environment is profoundly threatened by human activities.


Oceans: Our Greatest Natural Resource

The oceans are the earth's greatest natural resource, origin of most life forms and the source of survival for hundreds of millions of people. They cover 70 percent of the globe's surface — 330 million square kilometres. All seven Continents could fit comfortably into the Pacific Ocean alone.

A few facts illustrate the oceans' profound significance for livelihoods and the global ecological balance:

- The economic value generated by the oceans is roughly US $1 trillion per year.
- 12 million fishermen operating 3 million vessels land roughly 90 million tonnes of fish each year, providing work for over 200 million people worldwide.
- 80 percent of the world's biodiversity resides in the sea — much of it still undiscovered. Up to 100 million unnamed species live on the ocean floor alone. At least 3000 pharmaceuticals have been isolated from marine animals and plants.
- 2 billion tonnes of carbon dioxide (CO_2) are absorbed by the oceans every year, making them one of the Earth's key defences against global warming.

Oceans In Peril

Numerous signals are giving warning that mankind's management of the Planet's environment and resources is failing badly: melting ice caps; depleted fish stocks; harmful algal blooms; changing coastlines; massive oil spills; polluted beaches; pollution by sewage and litter; rising sea levels; and more powerful and frequent storms; and ocean acidification provoking rapid changes in ocean chemistry. The pertinent facts reveal a pattern of widespread resource destruction and unsustainability:

- Poorly managed industrial scale aquaculture is leading to the severe destruction of marine habitats and the frequent occurrence of Harmful Algal Blooms — or "Red Tide".
- The world's fishing fleet is currently 2.5 times larger than what the oceans can sustain. 75% of the world's fisheries are classified as "fully-" or "over-exploited".
- More oil reaches the sea each year from sources such as leaking cars than was released by the Exxon Valdez oil spill in 1989. It released 11 million gallons.
- Some 65 000 chemicals are used in households, gardening, industry and transport, with about 1000 new ones added every year. Many are discharged into the oceans, but few have been analysed for marine toxicity.
- The possibility of climate change resulting from an increase in "greenhouse" gas concentrations in the atmosphere is a growing global problem.

Building on 150 Years of Knowledge Sharing

Origins and Evolution of IAEA's Marine Environment Laboratories

The Principality of Monaco has long demonstrated a strong commitment to guarding the integrity of the seas. But it was with considerable foresight that, in response to atmospheric nuclear weapons testing, Prince Rainier III hosted the first worldwide scientific conference on the disposal of radioactive wastes on land and at sea in 1959.

Two years later, the IAEA, with support from Monaco's government, established the International Laboratory of Marine Radioactivity, dedicated to building knowledge about the behaviour of radionuclides in the seas and promoting use of nuclear and isotopic techniques in protecting the marine environment.

With the continuing support, the Laboratory expanded the scope of scientific research and field activities over the course of three decades into many related fields and established itself as a valuable source of technical assistance for IAEA Member States. In 1991, it was renamed the "Marine Environment Laboratory" (recently changed to 'Laboratories') to convey more accurately the broad scope of responsibilities it had assumed in providing scientific expertise and technical support to Member States. MEL is part of the IAEA's Department of Nuclear Sciences and Applications.

Today MEL operates on a regular budget of about US $4 million and has a full time staff of about 40 scientists, technicians and administrative personnel. Extrabudgetary resources and contributions in kind for specialized research and services from a variety of governments and international bodies total some US $ 3 million annually.

MEL activities concentrate on six principal areas:

Understanding Radioactivity in the Oceans & Seas

Diagnosing Marine Ecosystems and Pollution

Enabling Analytical Excellence

Building Strategic Partnerships for Research and Sustainability

Analysing Ocean Carbon and Climate Change

Capacity Building & Networking

Monaco's Royal Legacy

An unwavering commitment to guarding the integrity of the oceans and seas has come naturally for the people of Monaco, given the Principality's reliance on the Mediterranean. H.S.H. Prince Albert I (1848–1922) was one of the pioneers in marine sciences, exploring and cataloguing thousands of marine species worldwide.

Prince Albert I *(middle)*, known as the "Navigator Prince", dedicated himself to understanding and protecting the seas. His passion for the sea was best manifested in the establishment *(top)* of the Oceanographic Museum in Monaco in 1910, and the development of an extensive collection of marine species gathered during expeditions

throughout his life. The well preserved marine specimens — from giant whales to microscopic plankton — are still appreciated by hundreds of thousands of Museum visitors every year.

One hundred and fifty years after his birth, the legacy of Prince Albert I grew still greater with the opening of the new purpose-built Marine Environment Laboratories (MEL) *(bottom right)* in the Port of Monaco in October 1998, constructed with the help of a US $10 million donation from the Monegasque Government. Today, the words from his 1921 "Speech on the Oceans" echo across the seas with continuing veracity:

"The time has come for Humankind to tackle the great problems of the Ocean, deploying its best resources so as to make quicker progress in overcoming the backwardness which is still so strong at the very roots of civilization."

For generations, Monaco's royal family has contributed greatly to scientific knowledge of the oceans and seas.

Permanent premises of MEL (pink buildings in the background).

Highlights of MEL Programmes & Activities

Understanding Radioactivity in the Oceans and Seas

Founded in the wake of atmospheric nuclear weapons tests, MEL's core mission has been to deepen scientific knowledge about the behaviour of all forms of radioactivity in the marine environment. Over the ensuing decades, this foundation research has broadened to include analysis of a broad range of non-radioactive pollutants — from pesticides to petroleum hydrocarbons to heavy metals — employing both nuclear and isotopic techniques.

MEL has built a solid capacity to analyse radionuclides and model their dispersion in the marine environment. This helps numerous IAEA Member States in assessing the radiological impacts of past weapons testing, nuclear waste dumping and nuclear accidents at sea. MEL has conducted in-depth investigations into underwater disposal of nuclear waste and reactors in the Kara and Barents Seas, the Sea of Japan and the Northeast Atlantic. It has documented the environmental consequences of recent nuclear weapons tests in the South Pacific. And the dispersion of radionuclides from nuclear facilities has likewise been extensively documented. MEL has applied this capacity to assist Member States to measure and assess radioactivity in areas such as the nuclear weapons test sites in the Southern Pacific Atolls of Mururoa and Fangataufa, the dumpsites of high and intermediate level nuclear waste in the Arctic (Kara Sea), the Irish Sea offshore the Sellafield nuclear reprocessing plant, the Black Sea and the Caspian Sea.

With its own measurement results and those published by scientists worldwide, MEL has established the Marine Information System Database MARIS *(http://maris.iaea.org)*, a web-based platform that gives access to more than 100 000 data entries on radioactivity levels in seawater, sediment and marine organisms. The data provided by MARIS can be used as the international reference source on radionuclide contamination of the marine environment so that any further contributions from the nuclear industry, radioactive waste disposal sites, nuclear weapons test sites and possible nuclear accidents can be identified.

An expedition in the Southern Pacific and Antarctic Oceans undertaken by MEL scientists retrieved new data from some of the last radioactively uncharted and remote waters in the world. The expedition's goal is to document the biological, biogeochemical and bio-optical properties of different marine nutrient systems, and to analyse carbon "export" in contrasting environments. This pioneering mapping project is supported by the French Research Council, the US space agency NASA and the European Space Agency.

The recurring phenomenon known as 'El Niño' is most revered — and feared — marine environmental phenomena, with wide ranging effects on polar sea ice, fish production in Peru, maize growth in Africa and rainfall in Florida. While El Niño occurs periodically, its intensity and characteristics in terms of salinity and temperature vary widely, thus making its impacts hard to predict. Through a new research project coordinated by MEL, scientists are collecting radionuclide, stable isotope and trace element records in corals and ocean sediments in order to reconstruct the patterns left by past El Niños going back several hundred years. These studies will enable scientists to predict the sea-surface temperature, salinity, frequency and intensity of future El Niños with much greater accuracy.

Coastal Pollution: Sharing Local Knowledge

Monaco: Researchers from over 10 developing countries — from Brazil and Cuba to the Philippines, Pakistan and Thailand — have gathered here to exchange insights and information on how to better manage polluted coastlines in their countries. They collect mussels, cockle clams, fish and other marine specimens in coastal waters and test them for various toxins and contaminants using nuclear-based techniques that yield new knowledge about how pollution is moving around the marine ecosystem. It's all part of an IAEA Coordinated Research Project (CRP).

Heny Suseno has come from Indonesia to explain his investigations of green mussels in Jakarta Bay and how molluscs can be used as "bioindicators" of marine pollution. Through the CRP, he's learning from more advanced laboratories to better employ nuclear techniques in documenting the biological processes of toxin accumulation.

"There's a big gap in knowledge between the labs in industrial and developing countries," Mr. Suseno explains. "The CRP is designed to help bridge that knowledge gap and bring us up to speed with the latest nuclear techniques."

Nikom Prasertchiewchan has come from Thailand's "Atom for Peace" agency to share his research on the uptake of various radioactive materials — such as cobalt, caesium and strontium — in blood cockles, a type of clam. Thailand is constructing a new nuclear research reactor, and Nikom's research will provide the baseline data for an environmental impact statement and subsequent monitoring of the reactor facility.

Other CRP participants come from South Korea, the USA and Australia. All share experience and knowledge about their local research on coastal zone management and get additional training during the exercise in advanced laboratory techniques.

MEL's activities help to better understand marine contamination and how the oceans help to moderate climate change.

Fish Facts

- Over 100 million tonnes of fish are eaten worldwide each year, providing two and a half billion people with at least 20 percent of their average per capita animal protein intake.
- Fisheries and aquaculture provide incomes to around 200 million people worldwide.
- 38 percent of all fish is traded internationally. The total world export value for fish and fish products is nearly US $60 billion annually. The volume share of developing countries in fishery exports represents just over half, about 55 percent, of the total.

Diagnosing Marine Ecosystems and Pollution

Nuclear and isotopic techniques are used in many ways at MEL to enhance understanding of marine ecosystems and to improve their management and protection. Radiotracers help track the movement of various types of heavy metals and industrial pollutants; radioactive and stable isotope tracers improve knowledge about marine biological processes; and nuclear methods enhance understanding about the history and evolution of the marine environment.

One of the most damaging and widening problems facing coastal waters around the world is the occurrence of harmful microalgae. In some cases this phenomenon is known as "red tides", scientifically called Harmful Algal Blooms (HABs). The rapid growth of microalgae stimulated by changes in their environment or by an oversupply of nutrients, leads to the toxic contamination of shellfish and fish and the deadly Paralytic Shellfish Poisoning (PSP) or Ciguatera Fish Poisoning (CFP). HAB events have become a common problem in tropical areas and in almost every place where shellfish and fish farming have become commercialized, from Chile to Mexico, South Africa to Tunisia and the Philippines to Thailand.

Precise measurement of the levels of toxin in shellfish is critical to decisions about marine management and human health. In most countries, accurate monitoring determines whether fisheries are closed; whether warnings are issued to harvesters; or whether trade in shellfish is completely banned.

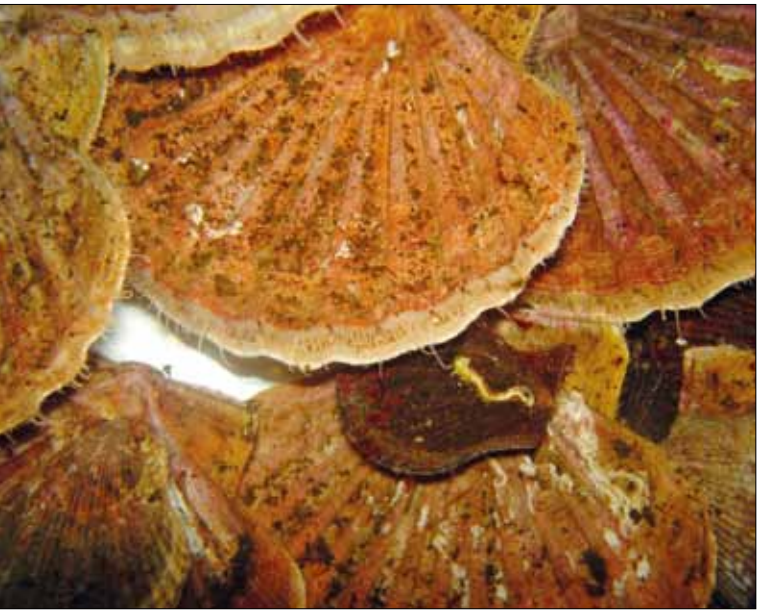
The coastline of the Philippines stretches over 17 000 metres providing vast shelf areas well suited for fisheries and shrimp farming. Over the past two decades, as fish farming has blossomed, nine major coastal areas have been hit with serious toxic red tides. More than 2000 people have been afflicted with PSP resulting in more than 100 deaths. Economic losses to the seafood industry alone at the height of these HAB incidents have surpassed US $300 000 per day.

Until very recently, the best means available to test for toxins was to extract them from the shellfish and to inject them into live mice and measure how long it took for the mouse to die. With the help of the IAEA and MEL, a more advanced nuclear-based technique, know as Receptor Binding Assay (RBA), is being introduced into the government's shellfish monitoring programme with success. At the same time, radiometric data of sediment cores from the sea floor is helping to date past red tide occurrences.

Applications of Radiotracer and Radioassay Technologies to Seafood Safety Assessment

Radiotracer and radioassay nuclear techniques are very useful tools for generating information on the biokinetics, bioaccumulation and food-chain transfer of metals and HAB toxins in marine organisms, including those that are valued as seafoods. The results of these types of studies can be used in analyses that support risk-based management decisions with respect to the safety assessment of seafood for human consumption.

MEL scientists are working to better integrate the application of nuclear techniques with risk management decisions relating to the assessment of seafoods suitability for human consumption.



Top left:
Particular contaminants in fish and shellfish are a major focus of the Seafood Safety Project.

Top right:
Feeding and maintaining of seabreams in MEL aquariums for further investigations on the behaviour of contaminants.

Above:
Trainees viewing acclimation facilities for maintaining of experimental fish.

Top right next page:
Using radiotracers for an ocean acidification experiment.

The Marine Radioecology International Laboratories Network (MARLIN)

- is a network of potential collaborators to initiate, coordinate and pursue original research work in marine radioecology;
- gives the possibility to access expertise, equipment, radioisotopes and expensive facilities that may not be available at a given location;
- provides a forum of discussion and exchange about techniques used and their possible improvement; and
- is a competitive task force when it comes to submitting research proposals to international funding bodies.

Red Tides Cloud Chile's Seas

Mario Luis, Russie Luengo and millions of fishermen in Chile are facing cloudy futures. Their nemesis is "red tides" — harmful algae that can poison shellfish and other seafood, taking it off the market.

Sometimes the scares of contaminated seafood are real; often they are not. How food safety authorities tell the difference is a big issue internationally, with "red tape" high on the list of concerns in fishing communities worldwide. A complicated bureaucratic road has delayed a new test to certify that shellfish exposed to red tides are safe to sell and eat.

The test relies on a nuclear-based scientific technique, called receptor binding assay, RBA for short, that more quickly and precisely measures levels of "red tide" toxins that shellfish might contain. Fishing and health authorities in Chile, the Philippines and elsewhere are seeing RBA as a key tool, and the IAEA is working with partner countries and organizations to help them learn and apply it. Their goal is to get RBA approved as the global "gold standard" for certifying the safety of shellfish and other seafood.

Today the fight to get RBA approved faster is intensifying. Fishing is a mega-business for coastal countries, and how the story of red tide and red tape turns out is of growing social and economic importance, especially in the developing world where fishermen and women like Mario and Russie make their living from the seas.

Enabling Analytical Excellence

To produce reliable scientific results, monitoring laboratories need quality control that includes regular measurements of contaminants in marine reference materials. They also require participation in inter-laboratory comparisons and proficiency tests.

MEL is a leader in providing marine quality assurance for all types of contaminants, both radioactive and non-radioactive through worldwide and regional exercises. The number of participating laboratories in Member States has increased from 50 in 1971 to more than 200 laboratories now analysing radionuclides, trace organics and trace elements. Some 60 different inter-comparison and reference materials have been produced by MEL, 10 of which are currently available from the IAEA *(www.iaea.org/programmes/aqcs)*.

Today's MEL is housed in a state-of-the-art facility, equipped with aquaria that can mimic the environmental conditions of oceans and seas anywhere in the world, analytical laboratories with a wide array of sophisticated instruments, computer systems and databases to share results with other researchers and a new underground counting laboratory.

MEL uses a wide range of methods and technologies in its analytical work. In order to identify nuclides or molecules under study, samples must first be prepared and purified. A variety of chemical methods are used to isolate, purify and concentrate samples before analysis.

Advanced instrumental techniques, amongst which ultra-low-background high resolution gamma spectrometry, alpha spectrometry, atomic absorption spectrophotometry, gas chromatography and mass spectrometry, are further applied to quantify radionuclides, stable isotopes, organic compounds or trace metals.

Benchmarking Calibration for Low Level Gamma Spectrometric Measurements of Environmental Samples

The increased interest in measuring low levels of radionuclides in the environment has resulted in advances in detector technology, which, in turn, require complex calibration techniques. An accurate determination of detection efficiency is essential to improving the quality of analytical data and the estimation of the total measurement uncertainty. Environmental laboratories are typically interested in calibration methods for a wide range of sample matrices and geometries. Monte Carlo simulation, involving model calibration using a small number of well-selected, low-uncertainty point or volume standard sources, is a cost-effective alternative to the purely experimental approach, which requires multiple volume standards. Additionally, well-calibrated numerical models allow the optimization of measurement geometries and the improvement of data accuracy through the estimation of self-attenuation and coincidence corrections.

MEL scientists are working to coordinate the development of validated calibration methods relying on combined experimental and modelling approaches and to establish traceability of results through comprehensive quantification of measurement uncertainties associated with low level gamma spectrometric analyses of environmental samples.

The project involves 12 participants from 11 countries and extends over the period 2008–2012. The results of the study are expected to be published in an IAEA Technical Report and in the international scientific literature. It is expected that this study will allow Member State laboratories to increase the reliability of their environmental radioactivity data.

MEL produced over 70 Reference Materials for radionuclides, metals and organic compounds in materials of marine origin (sediment, water, fish, mussels, seaweed) since it started its programme in support of analytical quality in Member States laboratories, more than 40 years ago.

Bottling reference materials for intercomparison exercises.

Building Research Partnerships

To obtain the highest quality research results, MEL forges partnerships with international organizations, such as UNEP, UNDP, IMO, FAO, IOC/UNESCO and UNIDO, that implement programmes for sustainable development of the oceans. In a typical year MEL works with some 50 to 60 government partners. Through such direct collaboration, Member States gain confidence that the marine environmental research and advice they obtain is of the highest scientific quality, relevance and independence. MEL is becoming a networking centre, increasing its focus on normative activities for IAEA Member States.

MEL is able to investigate non-nuclear pollution in the marine environment. Thus, the UN and Regional Organizations often call on MEL's expertise to assist in ocean pollution assessment. Some examples:

MEL has worked with the Mediterranean Pollution Programme (MEDPOL) of UNEP (UN Environment Programme) for more than 30 years. One major contribution of MEL has been improving quality assurance of marine monitoring data across the Mediterranean region. Through MEDPOL, MEL has also helped to build the analytical capacities of numerous laboratories in participating States.

MEL worked together with the Global Environment Facility (GEF) and the UN Office of Project Services in the Black Seas Ecosystem Recovery Project, which helped the six coastline countries — Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine — to upgrade both their staff and facilities to better analyse key marine contaminants such as heavy metals, petrochemicals, and organic pollutants.

MEL worked together with the UNDP and UN Office of Project Services in the Yellow Sea Large Marine Ecosystem Project, which helped China and Korea to produce quality assured data of key marine contaminants such as heavy metals, petroleum hydrocarbons, and organic pollutants in the marine environment.

MEL worked with UNEP on the project Addressing Land Based Activities in the Western Indian Ocean (WIOLaB) to help eight Western Indian Ocean countries to better analyse key marine contaminants such as nutrients, trace metals, petroleum hydrocarbons and organic pollutants, and to establish a long term regional marine monitoring programme.

Through an IAEA Regional Technical Cooperation Project and with the support of MEL, 12 countries are expected collaborating on the use of nuclear techniques to address coastal zone management problems. Results show pollution trends in coastal ecosystems, help to harmonize the use of bioindicators to monitor pollution and identify zones where ground water discharges below the surface in sensitive coastal environments.

MEL also collaborated with these countries through an IAEA Regional Technical Cooperation Project to upgrade their capabilities to measure radionuclides and apply nuclear techniques to study pollution.

The advanced laboratory facilities and skilled staff at Monaco have made MEL a world leader in quality assurance services for all types of nuclear and non-nuclear pollution.

With financial aid from the Japanese government to equip its underground laboratory, MEL supports developments in advanced gamma-ray spectrometry. Its underground low level counting facilities are used for methodological developments, characterization of reference materials, research projects and training.

Uncovering Marine Pollution in the Gulf Region

Marine pollutants are of particular concern in the Gulf region because of its fragile ecosystem and the high volume of maritime traffic. In response to requests from Member States in the region, MEL and the Regional Organization for the Protection of the Marine Environment (ROPME) investigated several non-radioactive pollutants in the Gulf region. During a 2006 oceanographic cruise, the levels of trace metals, petroleum hydrocarbons and organic contaminants in marine sediments were examined. MEL researchers determined that current levels of those pollutants pose no immediate public health threat to the region.

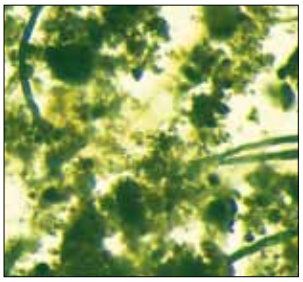
A series of training courses were held in Member States in 2006–2009 to upgrade their staff's preparation to better analyse key marine contaminants such as heavy metals, petroleum hydrocarbons, organochlorine pesticides, PCBs, dioxins/furans, and organotins.

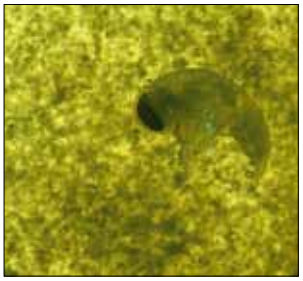
To better understand the temporal and spatial distribution of contaminants, identify hot spots, establish a permanent regional monitoring station network, provide sufficient data for possible management alternatives, elucidate the factors controlling pollution, evaluate countermeasures, and assess health hazards and risks, MEL and ROPME will collaborate on the following projects in the coming years:

- Assessment of organotin compounds in the marine environment of the ROPME Sea Area (RSA);
- Reconstruction of oil pollution history in RSA marine environment;
- ROPME Mussel Watch Programme; and
- Development of a scientific programme for baseline assessment towards the determination of radionuclides in the RSA.

The Oceanic Carbon Sink

"Marine snow" is an aggregate mixture of microscopic biota and other particles suspended in the ocean. This snow can be used to study the biological processes in the ocean, particularly the processing of carbon dioxide (CO_2). MEL's current research grew out of investigations some 20 years ago that analysed the transfer of radioactive plutonium in the ocean environment. Today alongside natural radioactive tracers (such as uranium and thorium), the low levels of plutonium in ocean waters are used to track the movement of CO_2 as it is exchanged between the atmosphere and the ocean. By sampling suspended particles and sediment, MEL scientists are tracking such movements to learn more about the equilibrium of carbon isotopes in open ocean waters. Because changes in this equilibrium can be affected by temperature, this research is contributing to the development of models of climate change in the ocean environment.

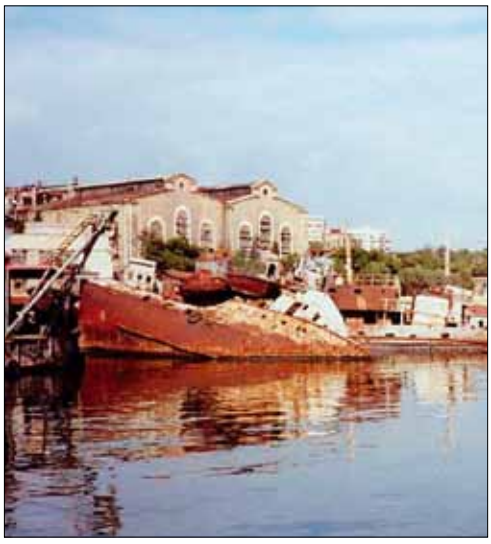




Survey vessel "Halul 32".

Below:
Over the past 25 years, MEL has carried out training courses on analytical techniques of trace metals and organic pollutants in the Member States and Monaco on behalf of ROPME.

Training course on organometallic speciation in Kuwait.



Surveying the costs of two Gulf wars: MEL scientists carried out the first environmental survey of shipwrecks in Kuwaiti and Iraqi waters. Surface sediments were collected by divers from around the wrecks and the samples were delivered to MEL in Monaco for analysis.

Analysing Ocean Carbon and Climate Change

The insulating effect of so-called "greenhouse gases" between the Earth and its protective ozone layer can cause climate changes on a global scale. Even subtle drops or rises in temperatures can alter weather patterns, disrupt food production and cause severe droughts or floods. CO_2 is the greenhouse gas of most profound concern. CO_2 is produced by both natural and human activities: thus controlling its levels is a complex task.

Current global efforts to reduce climate change are attempting to strike a balance between CO_2 sources and sinks — processes that release CO_2 into the atmosphere and those that trap or sequester it. The ocean is a major carbon sink and the trapping of increasing quantities of CO_2 is provoking its acidification.

MEL and several American and European institutes are participating in a global study of the biological processes involved in carbon sinking in the ocean. By analysing suspended particulate matter from various ocean depths, the study is assessing the influence of various factors controlling the transfer of carbon from the surface to the deep ocean. These suspended particles are the major vehicle for exporting carbon from the surface to the ocean floor. As these particles fall to the ocean floor, the organic carbon they contain becomes remineralized into an inorganic form, which is much more easily released and redistributed into ocean waters at various depths. The extent of this redistribution determines how much CO_2 the ocean can absorb from the atmosphere.

MEL is also studying coral growth bands as indicators of climate change, particularly of the El Niño effect, which has important socioeconomic impacts. Growth bands can be dated, for example with carbon-14, and analysed for diverse components to study past environmental events and reconstruct the temperatures changes of the ocean.

The International Arctic Programme MALINA (Mackenzie Light and Carbon), 2008 to 2011

An international collaboration effort jointly organized by Canada, France and USA, MALINA is a programme aiming to assess the impact of permafrost melting due to climate warming in the coastal Arctic Sea (McKenzie Bay/Beaufort Sea).

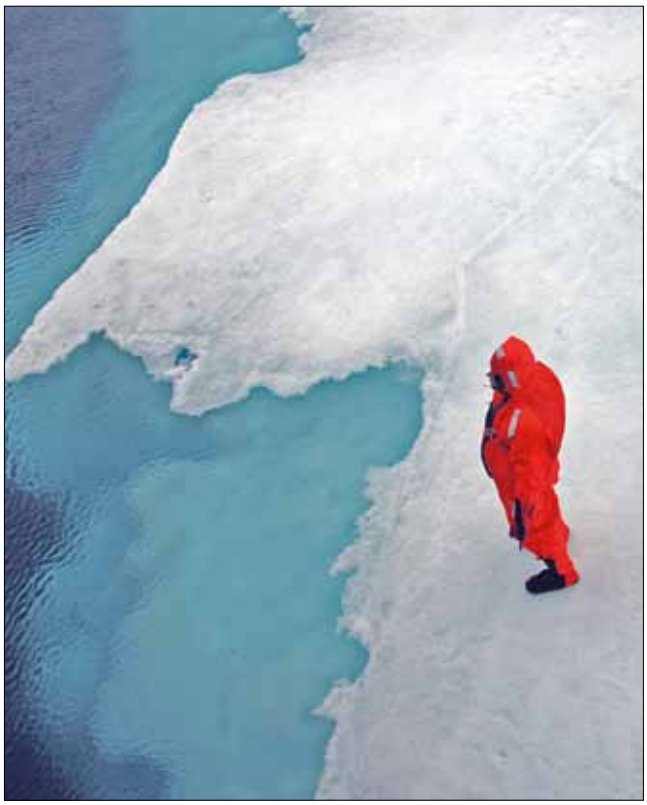
Key actions include the study of the fate of terrestrial carbon exported to the ocean in the Mackenzie River/Beaufort Sea system, an area of major carbon sink and the impact of climate change on primary production, bacterial diversity and photo-oxidation of organic material.

IAEA-MEL contributes to this experiment by measuring natural radionuclides, assessing particle export from surface waters and water mass exchanges between shelf and offshore areas, as well as downward particle flux at several depths and areas. MEL will also identify the source of particles using stable isotope signatures and molecular biomarkers.

SEM photomicrographs of two species of single-celled microalgae. Their carbon-rich biomineral ($CaCO_3$) skeletons settle out to the deep sea and contribute significantly to the oceanic sink of carbon and the removal of metals and radionuclides.

The ice-breaker "CCGS Amundsen" navigating in Arctic waters.

Below:
Sampling seawater with a CTD-Rosette in the South-East Pacific Ocean.



Rapid melting of ice in the Arctic and changes in ocean chemistry affecting marine organisms, food webs, biodiversity and fisheries have brought deep concern to the world community.

The legacy of MALINA is expected to be an extensive and self-consistent dataset for future regional studies, diagnostic and predictive models for future monitoring of the Arctic environment and an assessment of the fate of carbon fluxes in the Arctic ocean over the next decades (linked to earth observation remote sensing). Furthermore, the project will contribute to the ongoing effort toward transferring knowledge to Arctic local communities.

Nuclear and Isotopic Studies of the El Niño Phenomenon in the Ocean

The recurring natural event known as "El Niño" is one of the most revered — and feared — marine environmental phenomena, with wide ranging effects on the polar sea ice, fish production in Peru, maize growth in Africa and rainfall in Florida. While El Niño occurs periodically, its intensity and characteristics in terms of water salinity and temperature vary widely, thus making its impacts hard to predict. Through a new research project coordinated by MEL, scientists are collecting radionuclide, stable isotope and trace element records in corals and ocean sediments in order to reconstruct the patterns left by past El Niños going back several hundred years. These studies will enable scientists to predict the frequency and intensity of future El Niños with greater accuracy.

One Day of Coral Core Sampling in the Republic of Palau, Pacific

"We had been tied that night to a buoy in Ulang Channel, in Palau. All permits were in place and we had started the previous afternoon the operation to sample a coral core from a large *Porites lutea* head under the inspection of the Koror State Rangers. It had taken 3 hours to anchor the Reel Time safely in this protected environment, with the invaluable assistance of the professional diver Shinji. We woke up with the first signs of light, at about 6 am. René, the cook, had already prepared breakfast and Rob was already waiting for the rest of the project[1] team. We were all very excited to continue our work. Before 7 am we were in the water setting again the drilling equipment. When everything was prepared, the order to start the hydraulic compressor was given by Dave. The currents were very strong and Dave, Stéphanie, Saber and Rob were working in very demanding diving conditions. Coral cores were drilled carefully, one after the other, deeper and deeper, older and older, only stopping to change air bottles and briefly for lunch. It was raining, but of course divers did not mind! By mid-afternoon the complex manoeuvre had finished. Coral core pieces came up to the surface first, then all sorts of drilling tools, and finally the submarine drill, with more than 10 m tubes connected to the compressor. By 17:30 Jim, the Reel Time captain, started the boat engines and routed us to the Rock Islands, our next sampling station. We were all tired but extremely satisfied. We had collected the longest and hopefully oldest Porites climatic record in this key region of the Pacific. Now, laboratory work starts and, in a few months, maybe a year, scientists will have produced the longest coral high-resolution climate record in these Seas."
— Text: J. A. Sanchez-Cabeza

[1] IAEA Coordinated Research Project on the Nuclear and Isotopic Studies of the El Niño Phenomenon in the Ocean.

Coral Reef environment in Ulang Channel, Koror State, Republic of Palau.

Top:
View of large dead Porites lutea *head drilled in* Ulang Channel, Koror State, Republic of Palau *on 28–29 November 2008. This coral is purported to have died during the 1998 bleaching event.*

There is relatively little bioerosion or recolonization by other corals. This view shows the channel side lobe with the coral head top at about 41 feet. The depth of the sand channel to the left is 61 feet. Currents are strong, particularly during outgoing tide.

Bottom:
Pteropods *sensitive to ocean acidification and one of the important links at the base of the Arctic foodchain.*

Ocean Acidification and the Monaco Environment Group

The oceans absorb one fourth of the CO_2 emitted into the atmosphere from human activities. As this dissolves in seawater, it forms carbonic acid, increasing marine acidity. The current average concentration of atmospheric CO_2 is 385 parts per million [ppm], 38 percent higher than the pre-industrial level of 280 ppm. Half of this increase has occurred in the last 30 years. The ocean's capacity to absorb anthropogenic CO_2 to defend the earth against global warming is diminishing, therefore exacerbating climate change and seawater chemistry. This in turn impacts reproduction behaviour and psychological functions of marine organisms like oysters, sea urchins and squid. If the marine environment no longer produces life-sustaining proteins, the Western world could find other food sources. But what of the developing world, which depends on fish protein for survival? And what of the economies it supports? The ocean, one of our greatest natural resources, provider of food and air, is one of earth's last frontiers.

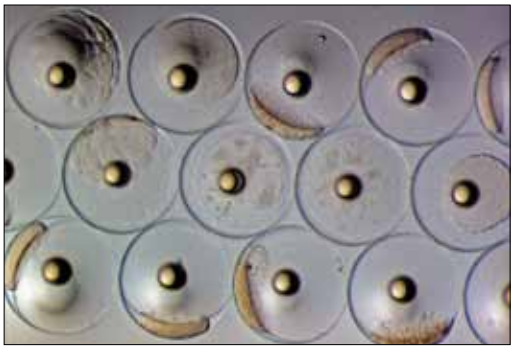
Observations collected over the last 25 years show consistent trends of increasing acidity on the surface waters that follow increasing atmospheric CO_2. These trends match precisely with what is expected based on elemental marine chemistry and continuous measurements of atmospheric CO_2. A range of field studies suggests that impacts of acidification on some major marine calcifiers may already be detectable.

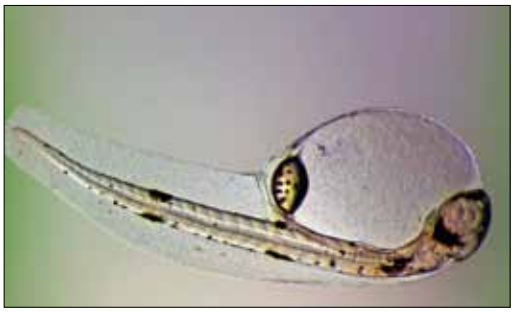
In October 2008, as a result of an International Symposium held in Monaco and co-chaired by NAML, the Monaco Declaration was approved by 155 leading scientists from 26 countries researching in ocean acidification and its impacts.

Left: *Second International Symposium on the ocean in a high-CO_2 World, October 2008.*

Below left: *Eggs of cephalopods that will be maintained at different pHs in the MEL Laboratories.*

Below right: *Eggs and larvae of sea breams used in the MEL laboratories to test the effects of ocean acidification.*





Above: *Reef of Kiribati Island, Pacific Ocean.*

Above right: *Juveniles of cuttlefish maintained at different pHs in the MEL laboratories.*

Mediterranean mussels, **Mytilus galloprovincialis (above)** *and limpets,* **Patella caerulea (right)** *transplanted near CO_2 vents in Ischia, Italy, at mean pH 7.4 and 6.8, respectively. Although the effect of low pH was evident, after only one-month incubation, on the dissolution of exposed carbonate shells, the species seem to be able to survive and potentially calcify. On-going experiments, through radiotracers, are evaluating the long term effect of acidified conditions on a range of ecologically important Mediterranean key-species..*

In the spirit of the Monaco Declaration, MEL and the Scientific Centre of Monaco (CSM) have established an expert group to assess the economic impact of ocean acidification. Bridging the gap between environmental science and economics, the Monaco Environment and Economics Group brings together leading scientific experts on ocean acidification and natural resource economics. They investigate both what is known about ocean acidification, its biological effects and predicted global impacts, as well as ways to evaluate its potential economic costs to fisheries, aquaculture and tourism.

The Effects of Ocean Acidification on Marine Calcifying Organisms

Future anthropogenic emissions of CO_2 and the resulting ocean acidification may have severe consequences for marine calcifying organisms and ecosystems. Ocean acidification has raised serious concerns about the potential effects on marine organisms and ecosystems, especially those organisms producing shells, tests or skeletons out of calcium carbonate ($CaCO_3$).

In this particular context, the radioecology laboratory started a new research strategy to better understand the long term vulnerability of marine organisms from Tropical, Mediterranean and Arctic Seas to this phenomenon. MEL is using radiotracers to assess and predict the physiological responses of these organisms to ocean acidification. The Marine Environment Laboratories developed its own system for small scale manipulations of CO_2 and seawater acidity.

Cephalopods play a key role in many marine trophic networks and can constitute alternative fishery resources.

- ❒ How can temperature increase and pH decline affect the metabolism of the eggs of cuttlefishes and squids?

Sea breams represent the largest economic sector of fish aquaculture along the Mediterranean and Atlantic coasts.

- ❒ How can an elevated CO_2 partial pressure modify the physiology of their early life stages (eggs and larvae)?

Coral reefs are one of the most important bioconstructions in the world.

- ❒ What will be the effect of ocean acidification on the incorporation of pollutants in tropical corals?

- ❒ Will this phenomenon be amplified in lower pH conditions?

Prince Albert II Foundation Project

Effects of Ocean Acidification on the Biodiversity of the Mediterranean Sea

Our understanding of how ocean acidity may affect marine ecosystems is currently very limited, as almost all studies done *in vitro* do not consider long term ecosystem processes and the interactions between species. Acidic conditions will lower the amount of calcium carbonate available in seawater and may disrupt calcification in a range of ecologically important organisms such as coralline algae, foraminifera, corals, echinoderms and molluscs. Thus, as oceans continue to acidify, there is an increasing risk of loss of biodiversity and profound ecological shifts.

With support from the Prince Albert II Foundation, MEL is evaluating the impact of ocean acidification on the biodiversity of benthic communities of the Mediterranean Sea in a naturally acidified environment and through radiotracer experiments to better predict its ecological consequences.

Technical Cooperation & Capacity Building for Member States

In collaboration with the IAEA's Technical Cooperation (TC) programme, MEL supports capacity-building in developing Member States through applied marine environmental research. Subjects include marine radioactivity and radioecology, radiochemistry and marine pollution assessment. MEL also hosts yearly dozens of trainees from developing countries to work at the Monaco laboratory and enhance their scientific skills and knowledge.

MEL has been a focal point of many collaborative initiatives in areas of expertise such as certification of reference materials, marine radioactive and non-radioactive pollution monitoring and assessment, training and methodological development and harmonization. These areas expanded during the past decade to include advanced analytical techniques and a wide range of radiotracer applications to marine studies, such as climate and environmental change, submarine groundwater discharge, HABs, seafood safety. At the same time, this past decade increasingly complex regional and inter-regional technical co-operation projects required a more integrated approach, including several of the areas of expertise mentioned above. In order to increase the effectiveness of the support provided by MEL to regional networks of laboratories and its contribution to other networks of excellence, MEL has started to formalize its existing network collaborations.

MEL contributes to the implementation of dozens of national IAEA-TC projects throughout the developing world, addressing key problems like petroleum pollution, red tides, and radioactive, heavy metal and pesticide contamination. In Angola, MEL is helping to determine the quantity and type of hydrocarbons in the water column, sediments and mussels on the Benguela coastline. In Southern Guatemala, MEL researchers are assisting with the analysis of toxic metals in the marine environment. And in Pakistan, MEL is supporting the evaluation of pollutant behaviour and contaminant transport in inland and coastal industrial zones through the application of both nuclear and non-nuclear techniques.

In the framework of regional and inter-regional TC projects, the IAEA provides support to developing Member States laboratories, transferring its knowledge and skills to carry out marine environmental studies using nuclear analytical and radiotracer techniques in the following areas:

- Capacity building: group and individual training, provision of equipment, expert advice;
- Methodological support: sampling, sample preparation, and analysis for the measurement of radionuclides in the marine environment;
- Applications of radiotracer, isotopic and radioecological techniques to assess radioactive and non-radioactive contaminants in the marine environment;
- Support for coordinated monitoring of radionuclides in coastal regions; and
- Networking.

To help address the widening red tide phenomenon throughout the world, MEL is introducing the receptor binding assay method to numerous countries of SE Asia, Africa, Latin America and the Caribbean and Latin American regions. A new Mediterranean regional project is assisting States — from Albania to Cyprus to Serbia and Montenegro — with assessment of radionuclides in the Sea. An ongoing regional project in Asia is

improving the States' capacity for planning and responding to marine radiological emergencies. The project includes Bangladesh, China, Indonesia, Korea, Malaysia, Mongolia, Thailand and Vietnam. An ongoing regional project in Africa (RAF7008) is improving the Member States' capacity for the assessment of contamination in the marine environment.

Right and below:
Training course on radioecology techniques.

Young scientists come from IAEA Member States around the world to expand their knowledge through on-the-job training at MEL's advanced research facilities. Support for them is provided through IAEA Coordinated Research Projects, Internships and Technical Cooperation Fellowships.

TC project with the National Nuclear Energy Agency in Tangerang, Indonesia

The Muria peninsula, Jepara is a candidate site for the first Indonesia Nuclear Power Plant, planned to operate in 2016. The goal of this TC project is to implement a radioecology laboratory in this region to develop nuclear techniques and address coastal zone management problems. In this particular context, MEL will welcome trainees to study the dispersion, distribution and accumulation models for various radionuclides in different biomonitor species.

Coast of Indonesia that will possess its first Nuclear Power Plant in 2016.

Experiment of cadmium bioaccumulation in the Chilean blue mussel Mytilus chilensis.

TC project with Chile

In Chile, local fish and shellfish farmers have to face important problems of bioaccumulation of toxic trace metals in fish and shellfish. Among these, the Chilean blue mussels have suffered several bouts of rejection by European countries due to their high levels in cadmium. Local producers have requested help to develop industrial processes to depurate their shellfish. In the framework of a TC project between the IAEA and the Universidad Australe de Chile, Pedro, a Chilean student, visited MEL to learn the use of radiotracers to examine accumulation and depuration processes in bivalves. The student was trained in designing, executing and analysing the uptake experiments with radiotracers.

Uncovering Contaminants in the Caspian Sea

The Caspian Environment Programme (CEP) is a cooperative effort of five Caspian littoral states — Azerbaijan, Iran, Turkmenistan, Kazakhstan and the Russian Federation — to improve regional environmental monitoring and management. MEL has been collaborating with CEP in a contaminant-screening campaign with support from the Global Environment Facility, UNDP and the UN Office of Project Services (OPS).

During the initial phase, an assessment of marine pollution revealed important new scientific data, most notably that sizeable coastal areas in Azerbaijan and Iran are seriously contaminated with DDT pesticide-related compounds. Mining activities, moreover, have raised heavy metal contamination (copper and zinc) levels to dangerous levels in numerous "hotspots" along coastal zones of the two countries. In the project's follow-up phase, MEL is assisting the participating countries with expert advice and technical support in establishing a sound pollution monitoring capability at the regional level.

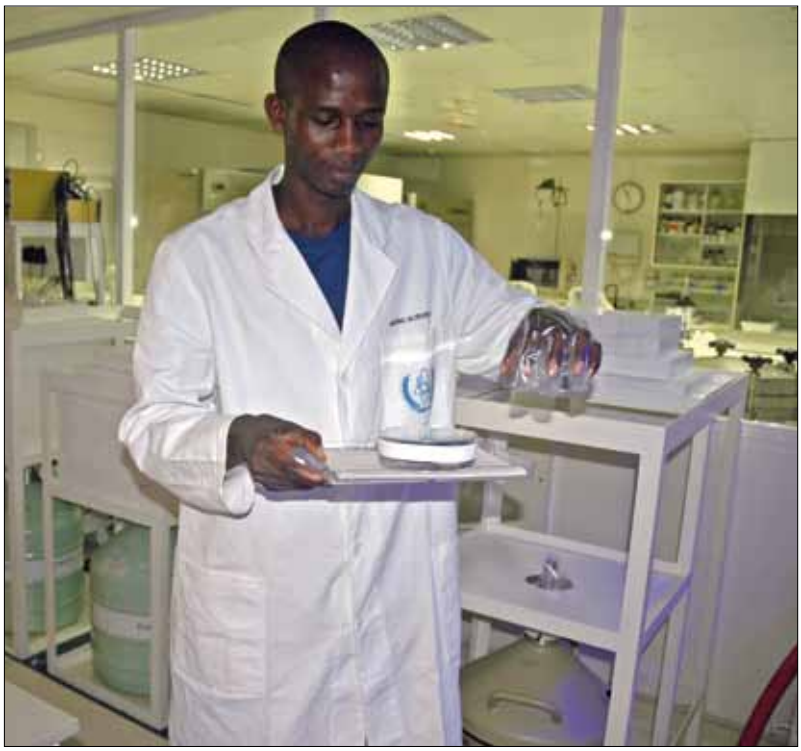
MEL is carrying out similar scientific capacity building efforts for the marine environment in the countries bordering on the Red Sea, the Gulf of Aden, the Persian Gulf and the Southern Mediterranean.

Research Fellows and Training Initiatives

MEL offers a wide range of training and provides internships for recent graduates interested in acquiring new laboratory skills and other expertise. Intended for Member States, regional organizations and other UN agencies, MEL's training courses cover a broad range of topics related to the use of radionuclides in marine studies, as well as analysis of non-radioactive pollutants.

Under the IAEA's Technical Cooperation (TC) programme, regional courses are offered several times a year to provide training on equipment use and methods customized to regional needs. This approach helps build local expertise and strengthens networking by bringing together researchers and technicians from across the developing world.

Equipment and techniques used in nuclear and non-nuclear methods often must be adapted to conditions in national laboratories. TC fellowships provide researchers from IAEA Member States with the opportunity to learn first-hand about the methods used at MEL and then customize them for their own research. Because of this adaptability, the fellowship programme attracts not just marine radiochemists and radioecologists, but also geologists and biologists.



Trainee preparing biological samples for radiotracer analyses.

Above left:
Over the past five years, more than 30 long term TC fellows and professional trainees from 17 countries have honed their research skills through on-the-job laboratory research at MEL and in training courses organized in collaboration with Member States laboratories.

Above right:
Fish samples from the Persian Gulf are being dissected and extracted for petroleum hydrocarbons and metals using clean techniques followed by analyses using mass spectrometry.

A New Era for IAEA-MEL

Preservation of a healthy marine environment and the sustainable development of marine resources are major tasks of the IAEA. As the unique group of marine laboratories in the UN system, IAEA-MEL responds to regular requests for technical assistance not only from other UN agencies, but also its Member States, providing a better understanding of the monitoring and protection of the oceans through training courses and technical cooperation projects.

IAEA-MEL is also a networking international centre for analytical quality control services for radioactive and non-radioactive marine pollutants in the marine environment.

Four priorities will influence our activities in the coming years.

Marine Environment and Prosperity: Chemical pollution, intensive agriculture, sewage discharge and aquaculture, over-fishing, irreversible damage to coral reefs and challenges to marine biodiversity are recognized as key threats to which the international community needs to respond. IAEA-MEL is becoming a network centre for Member States focusing on normative activities.

Marine Environment and Solidarity: IAEA-MEL is committed to equipping new generations of marine scientists with the knowledge and training necessary to understand the threats to the marine environment through the unique diagnostic power of isotopes. Our experience shows that almost all major pollution problems facing the marine environment can only be investigated using nuclear and isotopic techniques, which offer the diagnostic and dynamic information needed to identify the source of contamination, its history of accumulation, the environmental pathways and its impact. Such information is needed to make cost effective mitigation decisions.

Marine Environment and Security: IAEA-MEL will build on the service provided to Member States by providing independent marine radioactivity environmental assessments. The global marine levels of artificial radionuclides continue to decline, and they are now well below both radiological thresholds and the levels of natural radionuclides found in the marine environment. IAEA-MEL will, however, maintain and update its capability to provide timely assessments for any future marine radiological incident.

Marine Environment and the Global Perspective: The potential of isotopic techniques to study the Earth's climate and climate change has been extensively exploited in recent years by marine scientists investigating ocean currents, water masses, and the ocean as a sink for carbon. Past ice ages, present-day warming trends and other phenomena have been tracked through their isotopic signatures in the coral bands and in microfossils of deep sea sediments. IAEA-MEL will continue to collaborate with other international organizations to understand and help preserve the marine environment.

IAEA-MEL will continue to serve Member States by doing its utmost to carry out its mission: Promoting nuclear and isotopic techniques to improve the understanding of the marine environment and preserve its health for future generations.

Maria Betti
Director, IAEA Environment Laboratories

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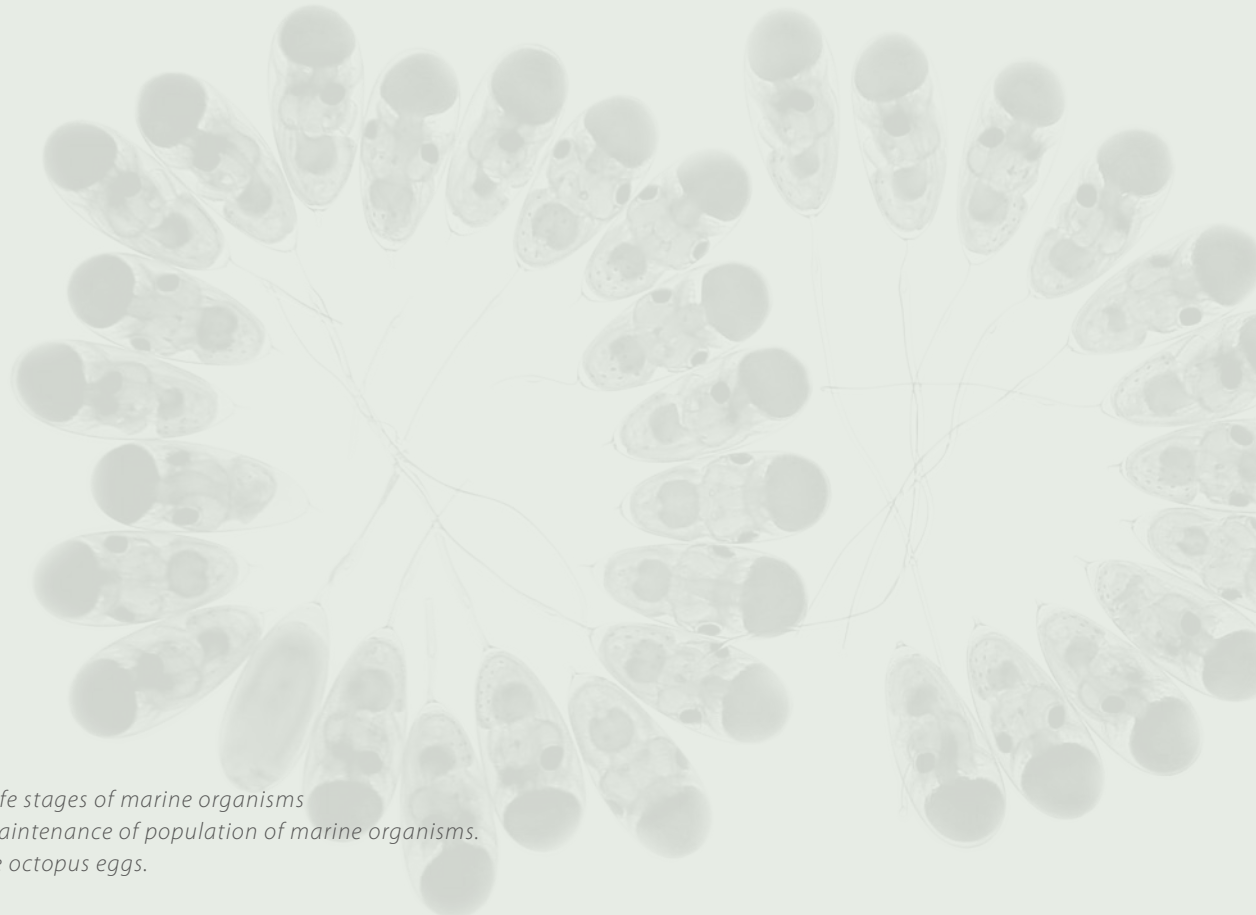
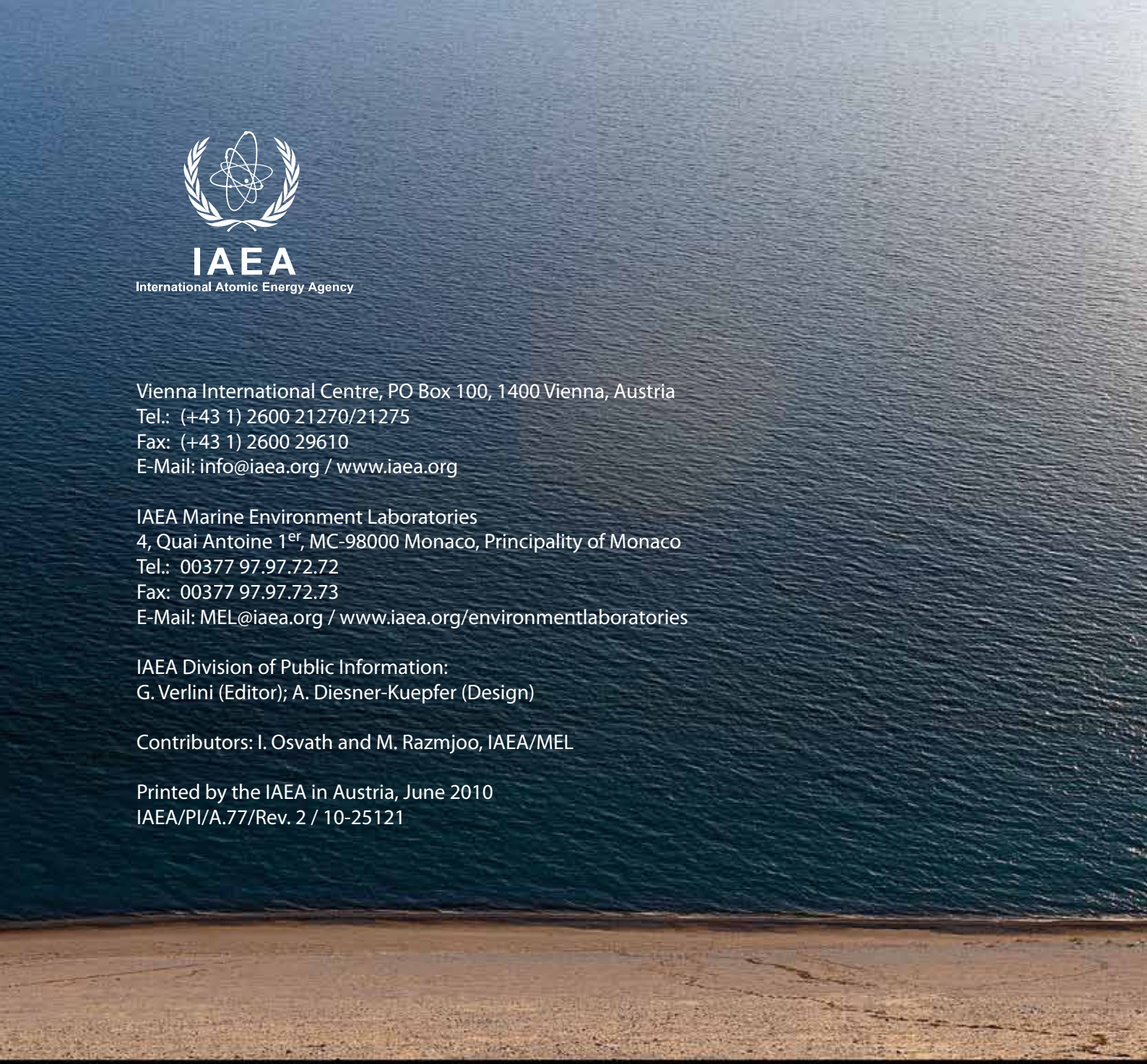


Front Cover:
The health of early-life stages of marine organisms
is essential for the maintenance of population of marine organisms.
Photo shows juvenile octopus eggs.



IAEA
International Atomic Energy Agency

Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Tel.: (+43 1) 2600 21270/21275
Fax: (+43 1) 2600 29610
E-Mail: info@iaea.org / www.iaea.org

IAEA Marine Environment Laboratories
4, Quai Antoine 1er, MC-98000 Monaco, Principality of Monaco
Tel.: 00377 97.97.72.72
Fax: 00377 97.97.72.73
E-Mail: MEL@iaea.org / www.iaea.org/environmentlaboratories

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Contributors: I. Osvath and M. Razmjoo, IAEA/MEL

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