SUSTAINING DEVELOPMENT IN THE BLACK SEA REGION

A SEA OF CHANGING FORTUNES

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Recently uncovered scientific evidence suggests that more than 7000 years ago, in the aftermath of the last glacial period, the level of the Black Sea rose dramatically. More than 150 meters and 100,000 km^2 of land was submerged underwater in a matter of months.

Whether it was indeed a sudden natural catastrophe or proceeded gradually as the global sea level rose, the inflow of Mediterranean waters over the Bosphorus sill changed the Black Sea from a huge brackish lake to a salty sea. A strong stratification effectively locked into place its heavier salty waters below the fresh water brought in by the rivers, preventing any significant mixing. The sea's bottom waters became anoxic (lacking dissolved oxygen) and lost their life-supporting capacity.

But in the surface layers a rich marine life developed. Then, about three decades ago, biodiversity and fish stocks began to dwindle. A new crisis, this time provoked by humans, was facing the Black Sea.

Within this historical backdrop, a multi-disciplinary group of organizations, including the IAEA, through its technical cooperation programme and its Marine Environment Laboratory in Monaco, have been working to help address the Black Sea's pressing enviromental problems. This article reviews major activities within the IAEA's programmes for sustaining development in the Black Sea region.

CRITICAL ENVIRONMENTAL PROBLEMS

Major factors contributing to the deterioration of the Black Sea environment are pollution and inadequate use of natural resources. Scientists consider the Black Sea to be a unique marine environment, one particularly exposed to anthropogenic impact. It is almost landlocked. Besides the link with the shallow inland Azov Sea, its only exchange of water with the world ocean is through the narrow Bosphorus Strait.

The Black Sea encloses the largest body of permanently anoxic water in the world: some 90% of the Sea's 5.37×10^5 km^3 total volume is deprived of oxygen and rich in hydrogen sulphide. Only the remaining 150-meter thick surface water layer is capable of supporting marine life.

The Black Sea drains a surface of land five times larger than its own area, shared by seventeen countries and inhabited by over 160 million people. Rivers, notably the Danube, Dnieper, Don, Kuban and Bug, bring in about 80% of the pollutants (50% from the Danube alone). They include agrochemicals, poorly treated industrial liquid effluents, and domestic wastewater. Atmospheric transport, predominantly from Europe, and coastal sources, such as direct industrial waste and sewage discharges or dump sites, account for the remaining 20%. Riverine input of toxic metals and chemical compounds is a severe problem. Through the Danube alone, 60 tons of mercury, 240 tons of cadmium, 4000 tons of lead, 900 tons of chrome, 50,000 tons of oil, 60,000 tons of phosphorus, and 340,000 of nitrogen enter into the Black Sea every year.

The nutrients in particular have a tremendous effect on the whole marine ecosystem, through complex functional and structural alterations in the food chain. Eutrophication — intensified and extended phytoplankton blooms triggered by the presence of excess nutrients — is responsible for mass death of

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higher organisms. It also has considerably reduced biodiversity and contributed to the demise of fisheries.

Another major factor affecting the fish population is the accidental introduction of several species of opportunistic settlers. The most devastating one is a comb jellyfish, *Mnemiopsis leidyi*, which feeds on fish larvae. An ecosystem already disturbed by pollution is being more exposed to invasion by exotic species.

In the late 1980s, an explosive proliferation of the comb jellyfish occurred. Its total mass in the Black Sea peaked at 10^9 tons (that is more than ten times the entire annual fish catch in the world), a development that coincided with the plummeting of fish catches. Fisheries have also been affected by the change in the water balance, a transition attributed to a drastic decrease in fresh water inflow related to the use of river water in industry and agriculture.

The annual economic and social costs of the degradation of the Black Sea environment were estimated in 1993 at US $1 billion, and they have likely increased since then. Another major environmental protection challenge still lies ahead — namely, the planned construction of an oil pipeline crossing the Black Sea at depths up to 2100 meters.

RADIONUCLIDES IN THE BLACK SEA

Public perception has placed radioactive contamination of the Black Sea high on the list of priority environmental concerns in the region.

The IAEA has been asked repeatedly by its riparian Member States to provide advice and support for a comprehensive and reliable assessment of Black Sea radioactivity. A Co-ordinated Research Programme (CRP) for "The Application of Tracer Techniques in Studies of Processes and Pollution in the Black Sea" was jointly organized by MEL and the Isotope Hydrology Section of IAEA's Department of Research and Isotopes in 1993-96. The CRP showed that concentrations of anthropogenic radionuclides in the Black Sea environment, although considerably higher than in other parts of the world ocean, are such that no significant radiological consequences can be expected for the public.*

Through this research programme, the unique potential of tracers for Black Sea oceanography studies was highlighted. Fallout from atmospheric weapons tests and from the Chernobyl accident provided excellent radiotracers for the Black Sea, such as strontium-90, caesium-137, and plutonium isotopes. The main input occurred through direct deposition on the sea surface. For strontium-90 the Dnieper river became a significant source after the Chernobyl accident. Together with caesium-137, strontium-90 can be used to trace water mixing and circulation on the northwestern shelf, offshore near the mouths of the Danube and Dnieper rivers. Tritium, alongside stable isotope ratios, is also useful in this area, as well as in the deep basin. Caesium-137 and plutonium isotopes can be used as time markers and, alongside natural lead-210, provide sediment deposition chronologies.

Lead-210 sediment dating is a most valuable technique. It allows a quantitative assessment of sediment mixing or sedimentation rates in different types of marine environments on decadal timescales. On long timescales, carbon-14 can be used. Thorium and uranium isotopes also provide information on fluxes of particles and particle-reactive pollutants. Information on the origin of certain water masses, like the cold intermediate layer, or on water mass mixing and ventilation of the deeper layers of the Black Sea off the Bosphorus, has been inferred from caesium-134/caesum-137 isotopic ratios or oxidation states of plutonium-239 and plutonium-240.

In addition to these environmental radionuclides, radiotracers can be successfully used in experiments. These include carbon-14 for primary production studies (relevant to eutrophication), or sulphur-35 for assessment of hydrogen sulfide production. Radiotracer studies span practically the full range of oceanographic processes and timescales ranging from days to millenia. In conjunction with other analytical tools, radiometric techniques can considerably improve our knowledge of oceanographic processes, and have become essential for the understanding of the fate of pollutants in the Black Sea.

The CRP clearly indicated that there were many gaps in the radioactivity data coverage

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of the Black Sea basin and that the region required upgraded technical capabilities to apply nuclear techniques to marine pollution research and monitoring. These needs are addressed through a regional project of the IAEA Department of Technical Co-operation, with scientific and technical backstopping from MEL.

TECHNICAL COOPERATION IN THE REGION

In 1995 the IAEA initiated a regional Technical Co-operation Project for "Marine Environmental Assessment in the Black Sea Region". Its purpose is to assist Member States which border the Black Sea to develop regionally co-ordinated monitoring and emergency response programmes for radionuclides in the marine environment; and to assess key processes controlling the fate of contaminants in the Black Sea by using radioactive tracers.

During the project's first phase, expert field missions sought to identify potential participating laboratories and to define in detail their training, expertise, and equipment needs. A comprehensive programme was then developed and initiated. The project's second phase (1997-98) has been focusing on capacity-building, proficiency testing, and application of acquired capabilities for regionally co-ordinated marine pollution monitoring and assessment. A third phase (1999-2000) is planned to strengthen the newly created functional capacities, complete initiated environmental assessments, and issue recommendations and guidelines for future activities targeting the quality of the Black Sea environment.

Six laboratories — one each from Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine, which play key roles in their countries' marine radioactivity monitoring and assessment programmes — are the main project counterparts. In addition twelve other collaborating institutes contribute to the project's programmes. To date US $700,000 worth of sampling and radiometric equipment, various materials, and laboratory supplies have been provided. Over 50 scientists have been trained in marine sampling, and in radioanalytical and tracer techniques through fellowships, workshops, and courses.

A structure of task groups has been put into place, creating a functional basis for continued regional co-ordination after the project's conclusion. The groups correspond to the main objectives of the core programme: methodologies, quality control, monitoring and assessment, tracer applications, data management, scientific cruises *(see box, page 35)* and project information. Task group activities, supported by expert advice, include the elaboration of methodological guidelines aiming to harmonize sampling and analytical methods, intercomparison exercises for radionuclides in marine samples, a co-ordinated monitoring programme, development of emergency response capabilities and joint database, sampling and analytical work, and publication of reports. Collaboration and exchange of information has been operating well with the Black Sea programmes of the Intergovernmental Oceanographic Commission (IOC) of UNESCO and with the European Commission's European River-Ocean System programme.Ultimately the IAEA's project will contribute, alongside other programmes, to develop in the region the capacities needed to assess, control, and remediate marine pollution.

Strengthening Commitments. The commitment of the governments of Black Sea countries to support the rehabilitation and protection of the marine environment is confirmed by the adoption of a series of documents creating political, legal, and institutional regional frameworks for marine environmental management. They include the Convention on the Protection of the Black Sea against Pollution, 1992; the Odessa Ministerial Declaration, 1993; and the Black Sea Strategic Action Plan, 1996.

These documents were adopted following diplomatic conferences involving Ministers of Environment from all six Black Sea countries. Much of the preparation work was done with support from UN organizations, channeled during the past five years through the Global Environment Facility (including the United Nations Environment Programme, United Nations Development Programme, and the World Bank) and its Black Sea Environmental Programme.

Within the framework of its regional project, the IAEA is convening a Ministerial Meeting of Black Sea countries in

TIMES OF LOSS FOR BLACK SEA COUNTRIES

The Black Sea was traditionally a rich fishing area. Its fisheries once supported a population of some two million people, many of them fishing families. During the late 1980s, the Black Sea fishing industry collapsed. Total catches fell from over 650,000 tons in 1988 to about 100,000 tons in 1992, never to recover since, causing great economic losses and unemployment. This results in estimated annual losses for the fisheries sector alone of at least US$300 million.

Tourism was another important source of revenues for the Black Sea countries. Pollution and unregulated coastal development resulted in closure of beaches and annual losses of over US $400 million.

Credit: BSEP

Monaco, in October 1998, to agree on further co-operation. This meeting will be held during the International Symposium on Marine Pollution, which has a Special Session dedicated to the Black Sea.

A Memorandum of Understanding will be signed following the Ministerial Meeting. Through it, the activities jointly supported by the IAEA and the national authorities in Black Sea countries will be formally integrated in national and regional action plans.

This high-level meeting will provide a new context for the definition of future national and regional strategies specifying the remedial actions required for the rehabilitation of the Black Sea environment.

THE BLACK SEA ENVIRONMENTAL PROGRAMME

The Black Sea Environmental Programme (BSEP) was formally established in September 1993. It was funded by the GEF with additional cost-sharing contributions through programmes of the Commission of the European Communities (PHARE and TACIS), and from Canada, the Netherlands, Switzerland, and France.

The programme's main objectives are to to strengthen and create regional capacities for managing the Black Sea ecosystem; to develop and implement an appropriate policy and legal framework for the assessment, control, and prevention of pollution and the maintenance and enhancement of biodiversity; and to facilitate the preparation of sound environmental investments.

The GEF and its partners invested almost US $2 million in equipment and training. Laboratories in the Black Sea riparian countries were identified to receive support and be properly equipped to measure contaminants.

MEL's Marine Environmental Studies Laboratory (MESL) collaborated with the BSEP and with the laboratories in the region to upgrade monitoring capabilities for non-radioactive contaminants. Workshops were held to train analysts from Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine in Monaco, and again for Ukraine and Russia in their own laboratories.

Also organized were analytical intercomparison exercises to ensure the comparability of data, and a preliminary screening of pollutants was carried out in a few areas of the Black Sea through collaborative work of the national laboratories and MESL. The areas screened include the continental shelf of Ukraine, the coastal sea near Sochi, Russia, and the entrance to the Bosphorus, Turkey. These field surveys were carried out in 1995 and the results were reviewed with scientists from the region in a joint assessment of Black Sea pollution.

From this preliminary screening of pollutants, it seems clear that the main causes for the ecological degradation of the Black Sea are nutrient and sewage discharges. Nutrient discharges cause accelerated eutrophication and oxygen depletion. These discharges are not only traced to the riparian countries; for

THE IAEA'S "RADEUX" BLACK SEA EXPEDITION IN 1998

A major undertaking within IAEA's regional technical co-operation project for Black Sea environmental assessment is a two-week scientific expedition taking place in September 1998. The name of the cruise — the acronym"Radeux" — is derived from one of the names given to the Black Sea by ancient Greeks: Pontus Euxinus, meaning "the hospitable sea" (RADionuclides in Pontus EUXinus, 1998).

Thirty scientists from the countries bordering the Black Sea will take part in this cruise. The great majority come from laboratories involved in the IAEA's technical co-operation project. In addition, on the basis of reciprocity, scientists involved in IOC/UNESCO's Black Sea programmes were invited to join. The area of investigation covers the Western Basin of the Black Sea, with a special focus on the north-western shelf and the estuaries of the Danube and Dnieper rivers, which are regions of primary concern in terms of pollution. Samples will also be taken from the deep basin and the area of the Bosphorus.

The expedition's goals are to:

■ ***Establish proficiency in marine environmental radionuclide measurements***. As part of a quality assurance/quality control programme, groups from various institutes participating in the cruise will intercompare methodologies of sampling and sample preparation on-board ship. Later on in the lab, using the collected samples of water, sediment and biota, the intercomparison will be extended to cover all analytical and data interpretation steps involved in obtaining values of radionuclide concentrations in marine samples and in certain key radiotracer applications.

■ ***Use radionuclides to study natural and anthropogenic processes significant for oceanography and pollution in the Black Sea.*** These processes include sedimentation, water mixing and bioaccumulation. Inventories of radionuclides in water and sediment will be estimated. Priority is being given to addressing gaps in information, for instance to obtaining data on concentrations of transuranics and polonium-210 in fish. They are required, alongside the commonly measured caesium-137, for assessing radiological doses to human populations and comparing anthropogenic versus natural contributions.

■ ***Provide new inputs to the radioactivity database and integrate time series measurements.*** The aim is to contribute to completing a database which can be used to produce comprehensive environmental and radiological assessments and to validate Black Sea circulation and dispersion models.

■ ***Interpret radioactivity and ancillary data; publish results in reports and scientific papers.*** The results will be published in IAEA reports and the open scientific literature.

The samples collected during the cruise will be shared for analysis between the participating laboratories. Besides the natural and anthropogenic radionuclides, ancillary measurements required for the interpretation of the radioactivity data will be carried out on-board and in laboratory.

Photo: Scientists aboard the "Radeux" cruise will collect a range of samples for analysis. Shown here is a scene from a 1996 training exercise for scientists participating in the IAEA's Black Sea regional project. *(Credit: Osvath/IAEA)*

example, 66% of the discharges of dissolved phosphorus into the Black Sea come from the Danube basin.

Pollution by oil in the Black Sea seems to be in nearly equal amounts from coastal sources and from Danube discharges. Concentrations of oil in sediments are high near some sea ports and in the waters at the Danube mouth, where contamination levels were about ten times higher than in the western Mediterranean.

Concentrations of pesticides and polychlorinated biphenyls (PCBs) were generally quite low. Some slightly elevated concentrations of lindane were found near the Danube discharge, but most samples were comparable with the Mediterranean. However, a full survey of these compounds along the Black Sea is not yet done.

A large volume of reliable data has been gathered on the concentration of heavy metals in the Black Sea. Analysis has shown that, in general, heavy metal concentrations in the sea are virtually indistinguishable from natural levels. However, there are some areas with higher levels of contamination (near industrial "hot spots") and a more detailed survey of coastal sites is needed.

There is little quantitative information on litter in the Black Sea. Some municipalities in the south and southeast of the sea are known to be discharging municipal garbage to beaches, the sea, or to the banks of tributary rivers. As a consequence, beaches are highly littered. The situation below the water line is unknown.

Implementing appropriate environmental monitoring of chemical contaminants and environmental management in the Black Sea region requires a coordinated monitoring programme and established analytical capabilities. Thanks to the BSEP and associated projects, these capabilities exist now in several Black Sea riparian countries.

Collaborative efforts and support have to be maintained. The willingness of the Black Sea countries to continue this effort was recently confirmed through the establishment of a Program Implementation Unit as an acting body of the Istanbul Commission.

As part of its continued support, MESL organized a training course in 1997 for laboratory managers on the design of marine monitoring programmes with emphasis on data quality assurance. Two analytical training courses on trace metals in Bulgaria and on organic contaminants in Romania are being implemented in 1998, for the regional analysts. Furthermore, a new screening project is planned in collaboration with the regional laboratories to assess the contamination by petroleum hydrocarbons and pesticides along the Black Sea coasts.

SCOPE FOR ACTION

There is certainly scope for further co-ordination of efforts at the regional level.

As one step, laboratories involved in the IAEA's technical cooperation programme and the BSEP can develop joint activities. Coordinated monitoring programmes are planned for radioactive and non-radioactive contaminants in a widespread bio-indicator organism, the mussel *Mytillus sp.*

Excellent collaboration continues between the IAEA and IOC/UNESCO through joint training courses, field work, and tracer studies. Additionally, the IAEA has assisted with sampling equipment for several Black Sea research cruises organized by laboratories in the region and western European institutions, and radioanalytical work was performed by participants in the Agency's regional technical coperation project on samples collected during these cruises.

Thus, strengthened regional capabilities already are paying off. The continuation of radioactivity studies is supported by national authorities, as well as by recommendations of independent expert groups. They include experts assembled in 1997 by the Food and Agriculture Organization's General Fisheries Council for the Mediterranean, and the GEF's advisory body for Global International Water Assessments. Developments initiated through the IAEA's Black Sea activities are consistent with and supportive of the Global Programme of Action for Protection of the Marine Environment from Land-Based Activities, the major emerging UN programme of the decade.

Importantly, international coordinated efforts now are leading toward a more reliable and comprehensive assessment of marine pollution and its different impacts in the Black Sea region. A concerted approach is needed for protecting the Sea's environment, and for managing marine resources upon which its neighbouring countries so critically depend. ❐