Environmental pollution of the Black Sea: A search for answers

As part of larger efforts, the IAEA is supporting research to help countries assess pollution problems in the Black Sea region

by V. Fabry, K. Fröhlich, and I. Osvath

Many countries around the world increasingly are concerned with the protection of their coastal regions and estuaries against pollution and other harmful effects of human activities. A case in point is the Black Sea region, where governments have initiated a regional approach to the management and protection of the marine environment that is supported by research at national and international levels.

Environmental problems in the Black Sea are serious. The Sea's shallow, mixed surface waters receive river discharges which are heavily loaded with nutrients containing nitrogen and phosphorus and contaminated with industrial and mining wastes. In addition, coastal industries appear to discharge wastes directly into the sea with little or no treatment. Thus the water quality of the life-supporting surface layer has seriously deteriorated. Eutrophication (an enrichment in nutrients) presently prevails in many parts of the Black Sea. It has dramatically changed the marine food chain, thus contributing to the demise of the Black Sea fishery and, especially in the northwestern region, to its diminished amenity value.

Other factors also are at work, including changes in the hydrological balance, overfishing, and chemical pollution. *(See tables, next page.)* Taken together, they have contributed to catastrophic changes in the Black Sea environment. For example, the run-off to the Black Sea has substantially decreased due to the construction of dams on major rivers for irrigation. As a result, there may be an alteration in the water exchange through the Bosphorus and a decrease in the water exchange through the Kerch straits. Additionally, the reduction in the flow of the Don and Kuban rivers has caused a net increase in salinity in the nearby Azov Sea. This consequently has led to a dwindling of the fisheries' production in that region.

Following the Chernobyl accident in 1986, riparian countries further identified radioactive pollution as having a high priority. Public concern recently has been increased by reports of safety deficiencies at some nuclear facilities located in the Black Sea basin and possible problems related to waste storage. To date, none of the admittedly limited radionuclide measurements from the Black Sea suggests that there is a significant radiological exposure either collectively or to critical groups. Nevertheless, a more detailed dose assessment is still required.

This article looks at major aspects of the state of the Black Sea's environment, and outlines the potential of, and first results derived from, the use of isotope tracers in Black Sea studies. It further discusses IAEA initiatives to join concerted international actions directed towards rehabilitation of the Black Sea environment.

Isotopes in studies of the Black Sea

In recent years, isotope techniques have significantly contributed to the advancement of oceanographic and marine environmental studies. Research in these fields is directed towards a better understanding of fundamental oceanographic processes and phenomena, the protection and management of the marine environment including the adequate use of marine resources, and the reconstruction of past, and prediction of future, global changes.

In the Black Sea region, further studies of the transport and redistribution of radioisotopes recently introduced into the Sea's surface waters are needed, particularly in response to health concerns. Studies additionally are needed for a

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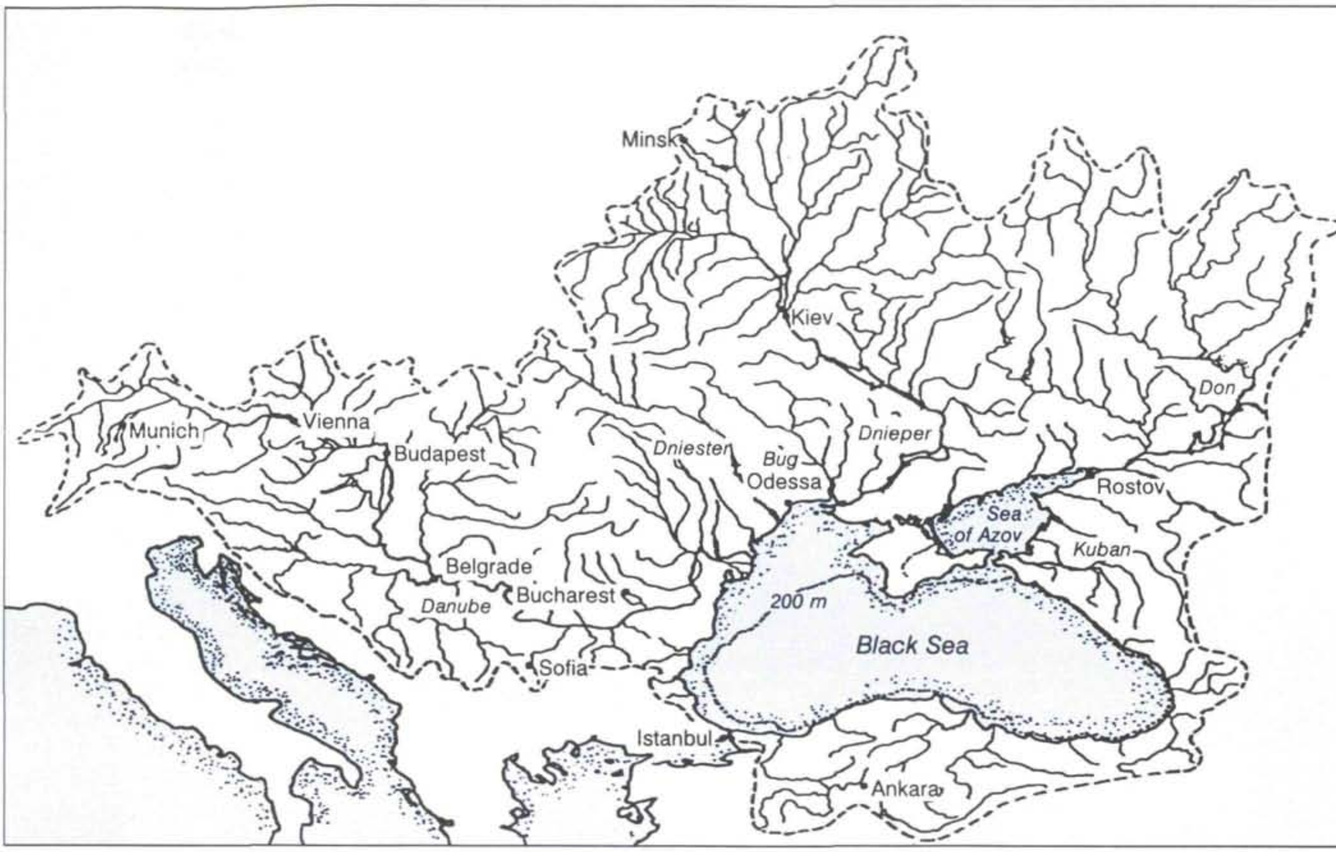


Map: The Black Sea — with an area of 461 000 square kilometers and volume of 540 000 cubic kilometers — is a unique, virtually enclosed and fairly deep (maximum depth of 2212 meters) water body shared between Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine. Its shallow, mixed surface layer has a relatively low salinity, maintained by a large influx of fresh water from two of Europe's largest rivers, the Danube and the Dnieper, as well as from the Dniester, Don, Kuban and a number of smaller rivers. The total drainage area extends more than 2 200 000 square kilometers. The total influx of fresh water is estimated to be 350 cubic kilometers per year. A slightly smaller amount (230 cubic kilometers per year) is derived from precipitation falling over the Black Sea area. The Mediterranean waters entering into the Black Sea through the Bosphorus Strait in Turkey rapidly mix with cold waters on the continental shelf and sink to intermediate depth (500 meters), forming a series of cold intrusions spreading horizontally into the interior of the basin. Unlike any other sea, the Black Sea is permanently anoxic (deficient in oxygen) below a depth of 150-200 meters. Its deep water chemistry is thus controlled by entirely different chemical and biological processes than the rest of the world's oceans. *Source:* Map adapted from L.D. Mee, *Ambio*, 21, 4 (1992).

Reduction in annual discharge of some rivers into the Black Sea

River	Natural flow (cubic km/yr)	Percent reduction during		
		1971-75	1981-85	1991-2000 (projected)
Don	27.9	19	27	43
Kuban	13.4	39	49	65
Dnieper	53.5	24	52	71
Dniester	9.3	20	40	62

Source: Adapted from L.D. Mee, Ambio 21 (4) 278-286 (1992).

Nutrients and pollutants discharged by the Danube river into the Black Sea

Substance	Amount (tonnes/year)
Phosphorus	60 000
Nitrogen	340 000
Zinc	6 000
Lead	4 500
Chromium	1 000
Copper	900
Mercury	60
Oil	50 000

Source: Adapted from L.D. Mee, Ambio 21 (4) 278-286 (1992).

better understanding of processes which will be critical to improved regional environmental management.

Tracer studies based on different radioisotopes essentially give different types of information on oceanographic and biogeochemical processes. Since any information that can be provided is of great importance for developing a better understanding of the Black Sea, continued measurements of various tracer substances have been encouraged. *(See table, page 24.)* For example, the anthropogenic radionuclides caesium-137 and strontium-90 can yield valuable information on decadal time scales. In this context, radionuclides released by the Chernobyl accident in 1986 to Black Sea surface waters are of particular interest. This pulse-like input of tracers can be used to follow physical mixing of the surface oxic waters, labelled with the Chernobyl tracers, and the deeper anoxic waters, which were initially free of the Chernobyl components. *(See graphs, next page.)*

Other particle-reactive elements, such as thorium and plutonium, can be used to define the time scale for the removal of particles from the surface layer and shelf regions. The use of radionuclides such as carbon-14, lead-21, thorium isotopes, caesium-137, and plutonium isotopes for bottom sediments can provide chronologies up to tens of thousands of years. Additionally, in parallel with other relevant parameters, they can be used to record rates of climatic change and eutrophication processes. Information on the ages of certain biomarkers in the sediments also can be obtained. For example, it has been found recently that sedimentation rates determined by carbon-14 are lower than those determined by lead-210, suggesting some long-term decrease in overall sedimentation rates. Using this newly established deposition information, accurate records over the past 3000 years can be established for any variety of ancillary elements and biomarkers in the Black Sea.

Stable isotope ratios can yield information on the role of river inflows and effects from the Bosphorus Strait. They further can give information on the sources of organics and nutrients, and the chronological fluctuations of the plankton population of the surface waters.

IAEA co-ordinated research programme

For more than three decades, the IAEA Department of Research and Isotopes has initiated and supported the use of isotope tracer techniques in hydrological and marine environmental studies through activities conducted by the Isotope Hydrology Section of the Division of Physical and Chemical Sciences and the IAEA Marine Environment Laboratory (IAEA-MEL) in Monaco.

In view of the present environmental crisis in the Black Sea, a consultants' meeting, jointly organized by IAEA-MEL and the Isotope Hydrology Section, was held in the summer of 1992 in Monaco. The meeting, attended by experts from eight countries, provided guidelines for further research and defined the scope and objectives of a co-ordinated research programme (CRP) on the application of tracer techniques in the study of processes and pollution in the Black Sea.

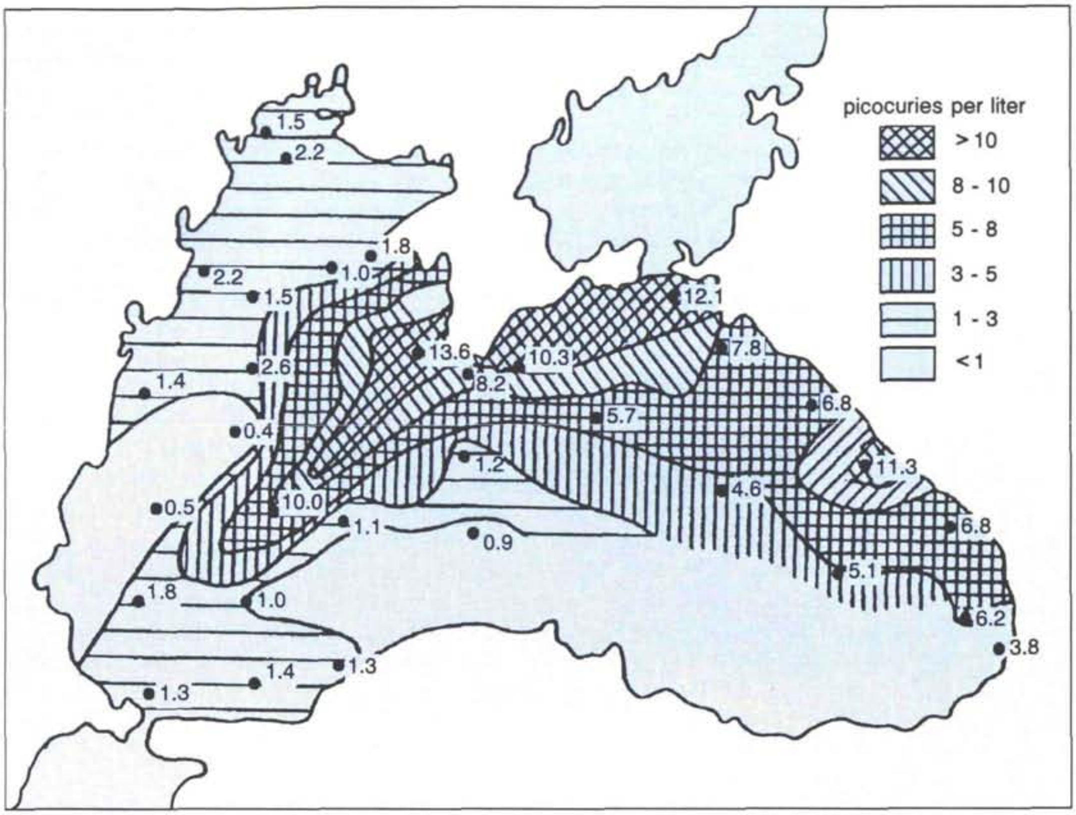
The experts recommended the use of natural and anthropogenic radionuclides and environmental isotopes in assessing the inventory of radionuclides in the Black Sea; evaluating future trends of radioactive pollution; and studying physical circulation and eutrophication processes in the Black Sea. The programme is meant to be implemented by institutes of riparian countries. However, other laboratories having long-term experience in the use of these techniques in marine environment research also will be involved.

The recommendations of the meeting include the establishment of a detailed database which can then serve to define the baseline activities for radionuclide studies in general and for pollution and dose assessment questions in particular. It was noted that the IAEA-MEL, as part of an existing project, will provide a detailed database for the region.

Experts further noted that, except for the gamma-spectrometric systems which are up-to-date, other equipment in countries bordering the Black Sea is inadequate for meeting their requirements of the low-level analyses needed in the application of tracer techniques to marine research. Equipment for stable isotope analyses is generally not available at the laboratories directly involved in marine research. Therefore, it was considered necessary that low-level radiometric equipment and some radiochemical processing facilities should be made available to selected regional laboratories participating in the programme.

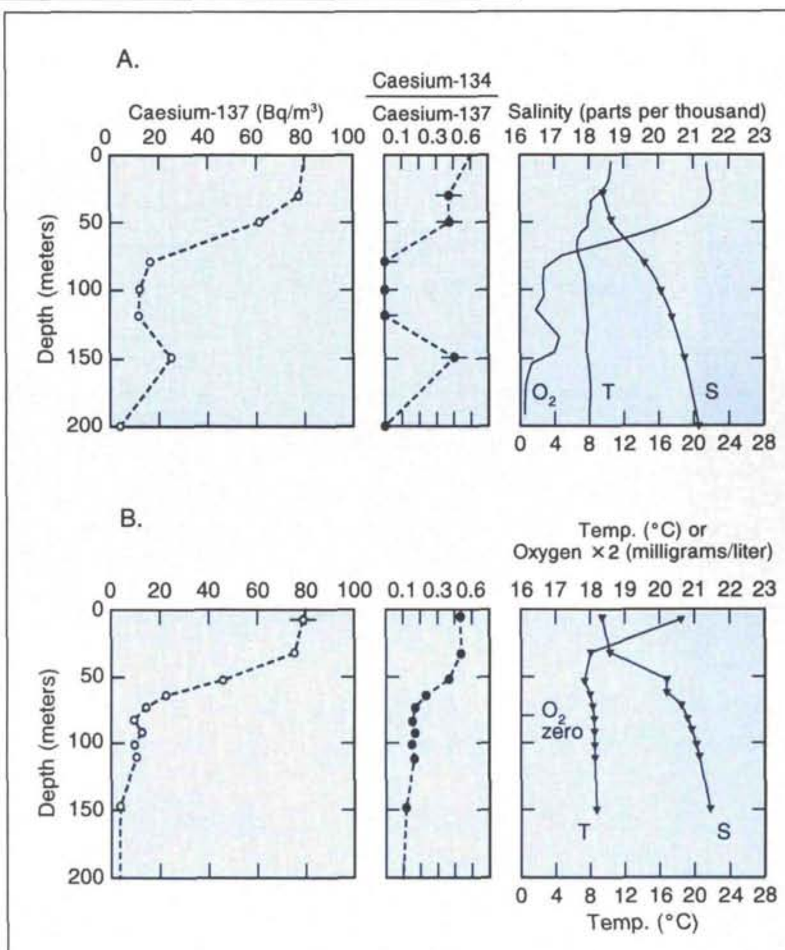
Moreover, the meeting strongly recommended the regular participation of the concerned laboratories in the IAEA intercomparison exercises organized through its Analytical Quality Control Services (AQCS) programme. The exercise should include both high-level and low-level activity samples. In addition, it was recommended that intercomparison runs be organized using Black Sea sediment and water samples.

Discussions on existing expertise in the riparian countries led to the conclusion that train-



Map: The Chernobyl accident in April 1986 dispersed caesium-137 over surface waters of the Black Sea. During an observation period from 12 June to 6 July 1986, measurements showed that the eastern part of the sea was more contaminated because of higher fallout levels in this area. Before the accident, the caesium content of the surface waters (about 0.5 picocuries per liter, or 18 becquerels per cubic meter) was uniform over the sea. The maximum concentration level recorded in June-July 1986 (14 picocuries per liter, or 520 becquerels per cubic meter) was almost 30 times this pre-accident value, but still about three orders of magnitude below the maximum permissible concentration. Source: Adapted from A.I. Nikitin, *Atomnaya Energiya* 65, 2 (1988).

Graphs: The graphs show caesium isotope and ancillary data versus depth at the mouth of the Bosphorus Strait (a) and at the interior of the southwestern Black Sea (b) in May 1987 and June 1988, respectively. The profiles manifest a rapid penetration of caesium from the Chernobyl accident below the oxic/anoxic interface that cannot be explained by vertical mixing processes alone. The data suggest that the outflowing surface waters are entrained in a return flow by the inflowing Mediterranean waters. This forms plumes of water with intermediate densities which are then laterally transported into the basin along density gradients. The lateral propagation provides a rapid and effective mechanism for ventilating intermediate depths of the Black Sea. One major implication of this process is that biological and geochemical water column data should be interpreted in terms of a lateral, rather than a one-dimensional vertical transport. Therefore, features in vertical profiles may be related to margin sources and sinks and to *in situ* processes. Source: Adapted from K.O. Buesseler et al, *Deep Sea Research*, Vol. 38, Supplement 2 (1991).



ing is required as soon as possible in the CRP's implementation. In particular, the need was cited for a regional training course on sampling, sample preparation, analytical methods, and data processing covering marine environmental radioactivity and stable isotope analyses, as well as artificial tracer techniques. The course is being organized by IAEA-MEL in co-operation with the IAEA Isotope Hydrology Laboratory.

International co-operative projects

The Black Sea crisis calls for a concerted international approach. Assistance to set up a 3-year programme on "Environmental Management and Protection of the Black Sea" has been requested by the riparian governments. This project —under auspices of the Global Environment Facility initiated in 1992 by the World Bank, United Nations Environment Programme (UNEP), and United Nations Development Programme (UNDP)— should provide the framework for urgently needed support of environmental assessment, among other activities, and for improving the capabilitites of institutions. It also will provide basic data for the very large investments required for controlling pollution and for supporting initiatives to rehabilitate the Black Sea that are presently planned or under way in the region.

Potential use of stable and radioactive isotopes in tracing the Black Sea's environment

Process	Medium	Isotopes
Circulation, ventilation	Water	strontium-90, caesium-137, hydrogen-3, carbon-14
River inflow, Bosphorus effect	Fresh water	oxygen-18, hydrogen 2
Vertical mixing of deep water, air-sea interactions	Water	radon-222
Scavenging	Suspended matter	thorium isotopes
Particle removal, biological processes	Trap sediment	plutonium, americium, and radium isotopes
Sedimentation	Sediment cores	lead-210, plutonium and caesium isotopes, carbon-14
Pollution	Water, sediment, biota	All
Biogeochemical cycling	Water, sediment, biota	carbon-14, hydrogen-3, sulphur-35, nitrogen-15, phosphorus-32, stable isotopes of carbon, nitrogen, sulphur

The European River Ocean System (EROS), funded by the Commission of the European Communities (CEC) since 1988, is a long-term research project on biogeochemical processes in the European coastal environment. Thus far, EROS has focused on the Mediterranean Sea. Recently a proposal to extend EROS to the Black Sea has been submitted to CEC for funding. It has been envisaged to investigate the significance of the Black Sea as a source for greenhouse gases; the consequences of river input; eutrophication processes; and source levels and fate of key pollutants in the Black Sea.

The Bathy-Black project of the United Kingdom focuses on a regional survey of the Black Sea to assess resources and environmental hazards. The objectives of the 2-year project include, among other things, a survey of the seabed gamma radioactivity in areas at risk from artificial radionuclide contamination. The Institute of the Biology of the Southern Seas (Sevastopol) would serve as host and provide survey vessels. The United Kingdom would provide side-scan sonar, high resolution sonar, and a towed seabed gamma-ray spectrometer. Scientists from Russia, Ukraine, Bulgaria, Romania, and Turkey will participate.

The Co-operative Marine Science Programme for the Black Sea (CoMSBlack) was formed in 1991 as a non-governmental organization to help co-ordinate the marine science and monitoring efforts in the Black Sea. CoMSBlack will serve as an advisory body to the national, multinational, and international governments and agencies who have an interest in the Black Sea environmental status. The programme includes all the Black Sea riparian countries, and will operate through a Steering Committee in which two institutes of the United States also are represented. The role of this programme will be to provide the highest quality of integrated and co-ordinated scientific studies and results, as well as appropriate monitoring programmes, to assure that the management and policy decisions are based on the best possible science.

In summary, it is critical for the future of the Black Sea that various programmes addressing the Black Sea's environmental problems be co-ordinated to work together. In this context, the IAEA's co-ordinated research programme can be considered as a timely and important contribution to support national and international efforts towards improved environmental management in the Black Sea region. ❑