DYNAMIC WATERS OF THE BALTIC SEA

IAEA PROJECTS HELP ASSESS THE SEA'S MARINE ENVIRONMENT

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Environmental protection is a field of growing importance for various IAEA programmes, in particular in the European region. Many countries in the region are suffering from serious degradation of the environment. The share of IAEA technical cooperation projects focusing on environmental issues represents almost 15% of the total programme for Europe.

Based on requests from its Member States, the IAEA has been involved in major projects related to terrestrial, atmospheric and marine environmental assessment as well as restoration and remediation activities in several parts of Europe. They focus on:

- Capacity building;
- Assessment of possible contamination from radionuclides as a priority issue among other pollutants, related to the Chernobyl accident and the risk associated to other nuclear facilities;
- Increased coordination with (and participation in) international environmental projects.

The Baltic Sea area has been no exception and for several years has had the IAEA's attention. This paralleled the growing awareness and concern of Baltic countries about the environmental state of the Baltic Sea, which has become a major issue during the past three decades.

An almost land-locked water basin, draining through a large number of rivers about one fifth of the area of Europe, the Baltic Sea is the largest brackish (low-salinity) water body in the world. The slow water exchange with the North Sea through the shallow and narrow Danish Straits results in a long residence time of water in the Baltic Sea of between 25 to 40 years. This creates favorable conditions for the accumulation of pollutants.

In winter the Baltic is largely covered by ice, further slowing down the weak wind-driven water circulation and decreasing the potential for pollutant dispersion. Particular hydrographic conditions sustained by the limited water exchange with the rest of the world's oceans and the important inflow of fresh water favor the persistence of oxygen-depleted bottom waters, inappropriate for supporting marine life. As opposed to its shallower waters, which are renewed at a slow but continuous rate, the Baltic Sea's deepest waters are renewed only periodically, with a variable frequency determined by complex meteorological processes. In this century, major inflows of North Sea water occurred approximately every 11 years, but this cycle has been known to vary over the last decades. Between these inflows, anoxic conditions may occur in the Baltic's near-bottom water, leading to the formation of hydrogen sulphide, which is toxic to organisms. Thus, areas of "dead bottom", devoid of all forms of benthic or higher life forms, may develop, sometimes covering one-third of the entire area of the sea floor.

Overimposed on this natural fragility, anthropogenic influences led to further environmental change and degradation. Over 16 million people live on the coast and about 80 million in the sea's catchment area. The coastline is shared between nine countries: Denmark, Estonia, Finland,

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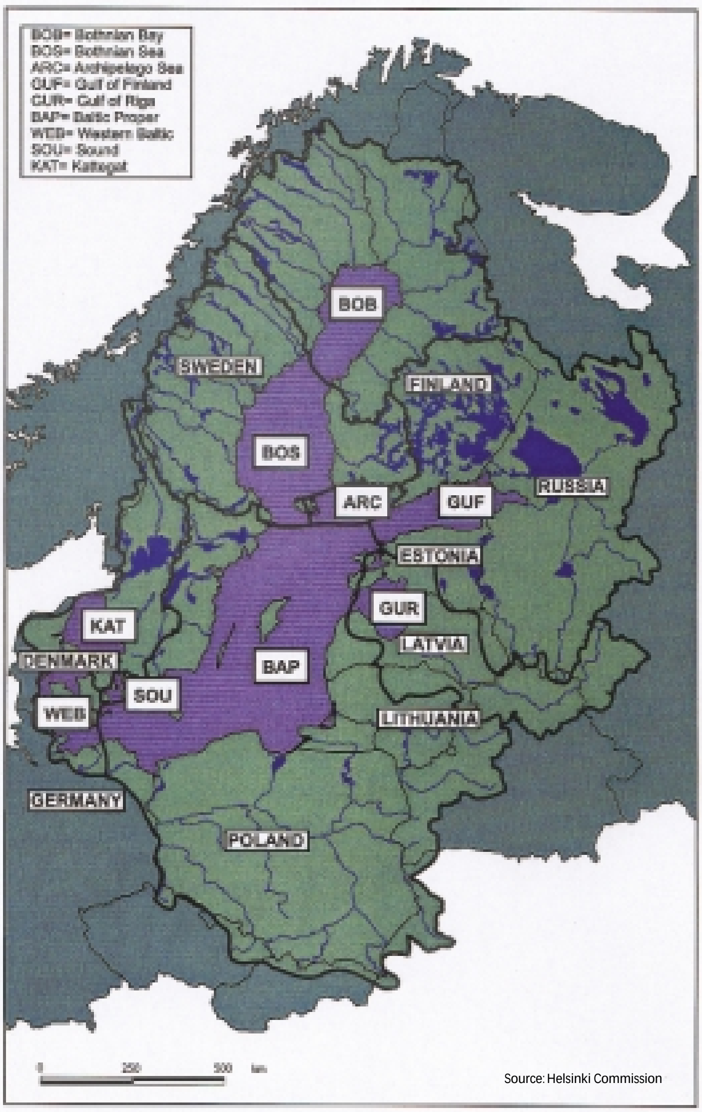
THE BALTIC SEA & CATCHMENT AREA

The Baltic Sea is a shallow semi-enclosed sea with an area of 415,000 square kilometers, and a maximum depth of 460 meters. The catchment area extends over 1.7 million square kilometers and an average of 480 cubic kilometers of freshwater is discharged into the sea every year. Almost half of this inflow drains through the seven largest rivers: Neva, Vistula, Daugava, Nemunas, Kemijoki, Oder and Göta älv.



Source: Helsinki Commission

Germany, Latvia, Lithuania, Poland, Russia and Sweden. The catchment area, however, also extends over parts of Belarus, the Czech Republic, Norway, the Slovak Republic and Ukraine. Discharges of industrial and agricultural wastes and poorly treated or even untreated wastewater from communities through the tributary rivers or directly into the sea have caused a serious deterioration of the environmental situation in many parts of the Baltic Sea.

Pollution from ships and ship accidents, practices related to fishing and fish farming and, more important, atmospheric inputs of pollutants also contributed to further disturbing the ecological balance. Harmful or toxic and persistent substances (e.g. PCBs, DDT, PAHs, polychlorinated compounds, pesticides, mercury), nutrients (phosphorus and nitrogen compounds causing eutrophication), heavy metals, radionuclides and hydrocarbons have been the main causes of concern.

The type and amount of pollutants reaching the Baltic Sea, as well as the scale of the impacted areas, varied in time. But in the early 1990s, experts appreciated that the Sea's pollution had become a threat to its living resources and ultimately to the health and well-being of the human population depending on its resources.

REGIONAL COLLABORATION

In the wake of the 1972 UN Conference on the Human Environment, in 1974 the governments of the littoral States of the Baltic Sea signed the Baltic Marine Environmental Protection Convention, known as the Helsinki Convention, which entered into force in 1980. The steering agency for the Convention is the Helsinki Commission – Baltic Marine Environment Protection Commission (HELCOM). The Contracting Parties to the Convention include the nine countries sharing the Baltic coastline and the European Community.

The Baltic Sea Declaration -- establishing the long-term objective of ensuring the ecological restoration of the Baltic Sea and the preservation of its ecological balance -- was adopted at the level of Prime Ministers at the Baltic Sea Environment Conference in Ronneby (Sweden), in 1990. Two years later the Diplomatic Conference on the Protection of the Marine Environment of the Baltic Sea Area adopted the Baltic Sea Environmental Declaration. It endorsed the strategic approach and principles of the Baltic Sea Joint Comprehensive Action Programme.

Many international organizations, among them the IAEA, and financial institutions were invited, as observers, to attend this key Diplomatic Conference in 1992. The same occasion also saw the signing of the new Helsinki Convention, which entered into force at the beginning of the year 2000 after ratification by all Contracting Parties. The Convention was expanded to include the internal waters of the Contracting Parties and the concepts of the Precautionary Principle, Best Environmental Practice, and Best Available Technology. It states the firm determination of the Contracting Parties to assure the ecological restoration of the Baltic Sea. It recognizes that the protection and enhancement of the marine environment of the Baltic Sea Area are tasks that cannot effectively be accomplished by national efforts alone but by close regional cooperation.

The Convention sets the framework for the adoption of legislative, administrative and other relevant measures to prevent and eliminate pollution in order to restore and promote the ecological balance of the Baltic Sea Area. The Action Programme addresses these issues by identifying problems and priority actions in all countries within the Baltic Sea catchment area. The Programme encompasses both preventive actions to promote sustainable use of the Baltic Sea environment and curative actions to remediate the existing environmental degradation due to pollution from point and diffuse sources. The strategy is based on development of appropriate environmental policies and legislation, implementation of regulatory reforms, promotion of economic incentives to encourage environmentally sound technologies, strengthening of institutional capacity and human resources and increasing local capacities to finance environmental measures. The Programme includes elements to support applied research and environmental awareness and education.

Environmental monitoring and assessment play an important role in the regional collaboration. It provides HELCOM with reliable data allowing the commission to develop its environmental policy and to assess the effectiveness of measures to abate the pollution. An extensive programme of monitoring and assessment was initiated early on. Periodically HELCOM publishes comprehensive reports on the Baltic Sea's marine environment and pollution load compilations. The "4th Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1994-1998" has been finalized and will be published shortly.

In a press release in March 2001, HELCOM reported on this latest study's findings. It said the study shows that the actions taken by the Baltic Sea countries to protect the marine environment are going in the right direction, but that the efforts need to be continued and intensified, with particular attention to sustainable economic growth.

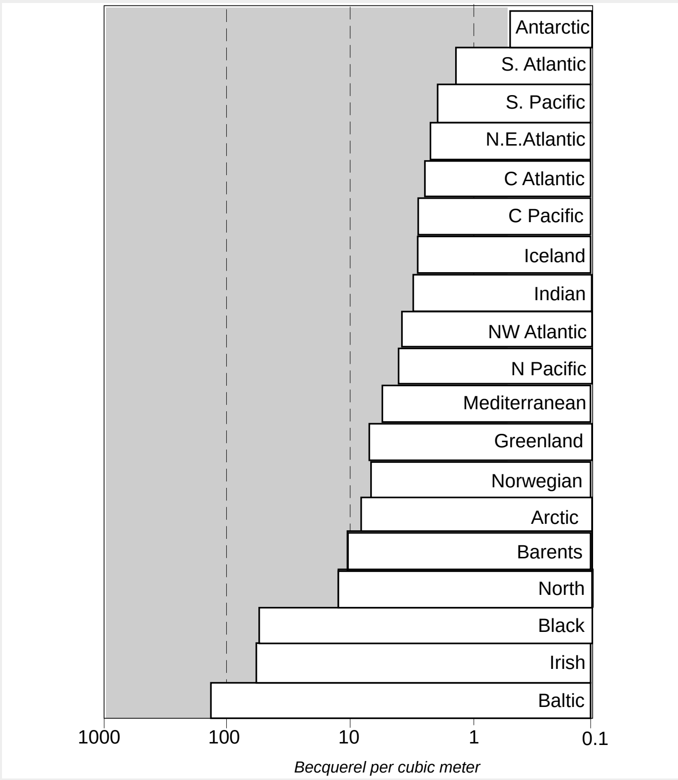
STUDIES OF RADIOACTIVITY IN THE BALTIC SEA

The main sources of anthropogenic radionuclides to the Baltic Sea are global fallout from nuclear weapons testing, releases from reprocessing plants at Sellafield (UK) and Cap de La Hague (France) and the fallout which came from the Chernobyl nuclear power plant accident in 1986.

By comparison, inputs from the nine nuclear power plants and from the research centres, hospitals and other facilities in the sea's catchment area are extremely low. A former coastal open dumping ground in Sillamäe (Estonia) -- used for disposing of mineral processing residues containing uranium and thorium, and later expanded to a waste depository -- has been assessed as having negligible radiological impact. Other relatively insignificant or potential sources of releases include reported small-scale past dumping by Sweden

AVERAGE CONCENTRATION OF CAESIUM-137 IN SURFACE OCEAN WATERS

(LOGARITHMIC SCALE, 1990)



Source: Estimates from the IAEA's Coordinated Research Programme on "Sources of radioactivity in the marine environment and their relative contributions to overall doses from marine radioactivity - MARDOS". Results published in IAEA-TECDOC-838 (1995).

(IAEA-TECDOC-1105, 1999) and the former Soviet Union (Yablokov Report, 1993), as well as authorized liquid discharges from decommissioning of a former USSR Navy training base in Paldiski (Estonia).

By far the most important source of contamination of the Baltic Sea with anthropogenic radionuclides was the Chernobyl accident in 1986. The most significant contributions came from caesium-137 and caesium-134, which were relatively easy to quantify and trace due to their well-established initial isotopic ratio of around 2:1 in the Chernobyl fallout. Following the accident, the caesium-137 inventory in water increased from 325 TBq in 1985 to 4300-5000 TBq in 1986.

Other short-lived radionuclides were detected in the marine environment during the days and months following contamination. However, neither these nor strontium-90 or long-lived isotopes of plutonium were considered significant for the marine environment, either because of their fast decay or the very small increase in their levels.

The distribution of caesium-137 on the Baltic Sea's surface was uneven. This was attributed to the direct deposition of Chernobyl's fallout as the radioactive plume crossed the Sea in the early days following the accident and to run-off from rivers on adjacent contaminated land. In May-June 1986 its concentrations in water ranged over two orders of magnitude, from below 50 Bq per cubic meter in the south to over 5000 Bq per cubic meter in the Gulf of Finland.

Surveys carried out in 1989 and 1994 show that maximum values were still measured in surface water. But contamination had penetrated significantly into the deep layers and an important fraction of the inventory had been transferred to the sediments. The surveys identify the Bothnian Sea and the Northern Baltic Proper as the areas with highest concentrations, though levels had decreased to below 140 Bq per cubic meter eight years after the accident. Although these levels do not pose radiological problems, in relative terms the Baltic Sea remains the marine environment with the highest caesium-137 contamination in the world. *(See graph.)*

The measurement and assessment of Baltic Sea radioactivity has been an issue of interest for the region, and it has been the subject of many national and international research programmes. Already back in 1980 the IAEA initiated a Coordinated Research Programme (CRP) for the "Study of Radioactive Materials in the Baltic Sea". This programme aimed to evaluate the long-term behavior of radionuclides entering the Baltic Sea, including their transfer to humans. It was carried out in 1981-84 with the participation of scientists from all the countries surrounding the Baltic Sea and from IAEA's Marine Environment Laboratory in Monaco (known at that time as the International Laboratory of Marine Radioactivity). The CRP resulted in valuable data on the levels and fate of anthropogenic radionuclides in the Baltic Sea and provided a key baseline assessment prior to the Chernobyl accident.

Beginning in 1985, HELCOM decided to continue the work initiated by the IAEA and established a Group of Experts on Monitoring of Radioactive Substances in the Baltic Sea (MORS). The IAEA continued to participate in this work by providing an intensive quality assurance programme. MORS has published comprehensive reports on the levels and trends of anthropogenic radionuclides in seawater, sediment and biota, inventories of radionuclides in sea water, discharges from nuclear installations in the catchment area, modelling of radionuclide transport and assessment of radiological doses to humans from marine exposure pathways.

These issues were also evaluated in great detail through the European Commission's MARINA BALT project (1996-98). It focused on estimating the radiological exposure of the population of the European Community to radioactivity in the Baltic Sea.

IAEA TECHNICAL COOPERATION

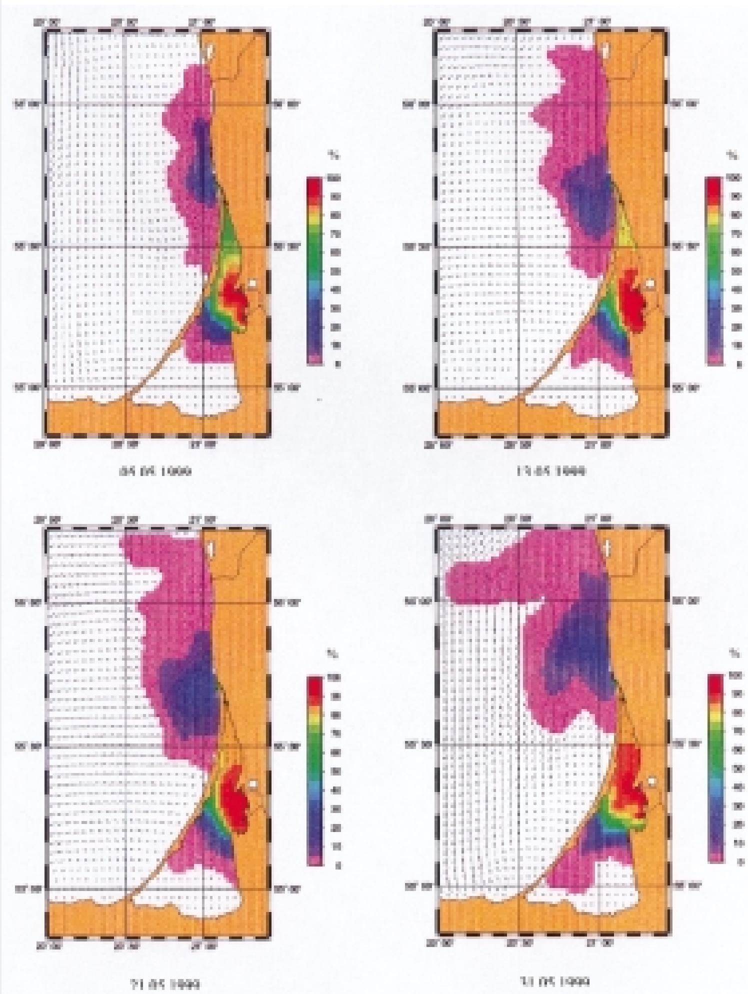
In 1998, the Lithuanian Government requested the IAEA's support to develop the capabilities required for assessing radioactivity in the Lithuanian part of the Baltic Sea. In particular, the interest was in understanding the dynamics of radionuclide concentrations in the marine environment in relation to input sources and to key oceanographic processes specific to that area of the Baltic. The final goals were the optimization of the monitoring programme and the development of a reliable predictive capacity based on validated models. This involved development and implementation of high-resolution 3-D hydrodynamic models of circulation, validated dispersion models, and validated models for dose calculations.

A technical cooperation project with a budget of $360,000 was designed in 1999. It aims to develop a model, supported by site monitoring, for assessing radionuclide dispersal in the Lithuanian part of the Baltic Sea, the tributary waters of the Nemunas River and the Curonian Lagoon. The project has a strong government commitment and has been

Photo: View of the Klaipeda Strait, connecting the Curronian Lagoon and the Baltic Sea. *(Credit: Valkunas/Lithuania)*

TRACKING RIVER FLOWS TO THE BALTIC SEA

The sequence of plots illustrates the model-simulated time evolution of concentrations of a conservative tracer released continuously at a constant rate at the mouths of the Nemunas River, which is of special interest in studies of transboundary pollution affecting the Baltic Sea. The numerical experiment was conducted over the period from 1 April to 1 June 1999. The dated "snap shots" show the tracer's path and indicate the direction and speed of current. *(Credit: L. Davuliene)*



declared as a national priority for IAEA assistance in the framework of the 2001-02 technical cooperation programme.

The project is well coordinated with other national and international programmes on the Baltic Sea. Work is carried out in collaboration with four Lithuanian institutions: the Institute of Physics, the Vilnius Gediminas Technical University, laboratories of the Ministry of Environment and the Institute of Geography. In addition, the project involves staff from the Radiation Protection Centre of Lithuania's Ministry of Health.

The counterparts collaborated with the IAEA to design the project and to define the work plan. Since the project's initiation, advice has been provided through expert missions involving specialists from the Risø National Laboratory (Denmark) and the Federal Maritime and Hydrographic Agency - FMHA (Germany). These institutes, with long-standing involvement in Baltic radioactivity studies and the MORS programme, have also hosted eight fellowships and scientific visits of Lithuanian scientists. Training mainly targeted enhancement of radioanalytical and modelling skills. The subject of management for quality assurance in environmental applications of nuclear analytical techniques was also addressed through an IAEA training course hosted by the Centre for Advanced Technological and Environmental Training in Karlsruhe, Germany. The project implementation has been further supported through provision of sampling and radiometric equipment and assistance for organization of scientific cruises.

During the project's first phase, a detailed study of the impact of the Nemunas River on the Lithuanian part of the Baltic Sea was initiated. The Nemunas is the third largest tributary river, flowing into the Baltic Sea through the Curronian Lagoon and the Klaipeda Strait. *(See photo.)*

This river is of particular interest for Lithuania in the context of assessing transboundary pollution, as the river's upper reaches and almost 60% of its catchment area lie outside its territory. It is equally of a wider interest for the Baltic countries, since over 45% of the river's catchment area lie outside the HELCOM zone, and therefore are not subject to the Commission's environmental policy.

Many polluting industries were developed in the basin (food processing, textile and tannery, oil refineries, chemical plants, pulp and paper mills) and concern is related to wastewater treatment facilities and to discharges of industrial load to municipal sewage systems.

Since the river drains the run-off coming from Belarus, the inflow of fallout radionuclides from the Chernobyl accident also has been of interest. The fresh-saline water mixing zone in the area of the Curronian Lagoon is host to a series of transformations for the contaminants entering the Baltic Sea. In conjunction with hydrological, hydrochemical and geochemical measurements, data on environmental radionuclides can be used to trace these processes and to verify or validate transport and transfer models.

Two sampling cruises and several field campaigns in the coastal regions and the Curronian Lagoon were carried out in collaboration by the Lithuanian institutes involved in the Model Project. Water and sediment samples were collected and returned to the laboratories for analytical work. Sampling, sample processing and radioanalytical methods were subject to evaluation and harmonization. Intercomparisons were carried out between the institutes to assure the comparability of the final data.

Starting from the FMHA basin-scale operational circulation model, a high-resolution (one nautical mile grid size) model was developed for the Lithuanian part of the Baltic Sea and the Curronian Lagoon. The model was subjected to sensitivity studies, tested in diagnostic mode with real input data and verified using measurement results corresponding to the respective periods of time. Various scenarios were simulated for input of a conservative tracer through the Nemunas River and its dispersion over periods of several months was studied. *(See graphs, page 14.)*

Project plans and results were presented at MORS and HIROMB (High Resolution Operational Model for the Baltic Sea) groups meetings. They receive much interest from the Lithuanian authorities as well, in view of the potential multiple applications of a predictive model for dispersal of pollutants.

Work is continuing through further development of the circulation model and expansion of the area of study to include one more major river inflow (the Daugava) and the atmospheric input. The IAEA project's second phase targets interrelated topics. They include the investigation of the Nemunas River mouths, the fan offshore Klaipeda Strait, the shallow waters of the Curronian lagoon, the development of skills to analyze additional radionuclides, the development of a dispersion model, simulations for dispersal of caesium-137 and strontium-90, and assessment of doses.

Through the evaluation of radionuclide dispersal and transfer and the development of prognostic models for normal and accident conditions, it is expected that this project will contribute to a comprehensive assessment of the Baltic Sea environment. By supporting ongoing national and international programmes, it is further expected that the project will yield reliable data and information that can contribute to a sound basis for Baltic Sea environmental management decisions in Lithuania, promoting environmental quality, health and safety in the region. ❒