CROATICA CHEMICA ACTA CCACAA 70 (1) 459–472 (1997)

ISSN–0011-1643
CCA-2432

Opinionated Paper

Environmental Specimen Banking – Marine Monitoring Strategies and Oceanographic Perspectives*

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Received March 20, 1996; accepted January 3, 1997

The establishment of an international marine specimen bank for worldwide collection, preparation and storage of authentical biological and environmental samples for monitoring and retrospective analysis is supported by a number of straightforward arguments. Discharge of radioactive waste, organic and inorganic pollution, various mining activities and ammunition disposal into the seas of the world in enormous quantities gives raise to serious concern about the future integrity of the marine ecosystem. Impact to climatic changes as well as large economic losses could result from marine ecosystem damages. International efforts should therefore be immediately initiated for global monitoring together with banking of authentical materials to enhance our present knowledge about cause/effect relationships and the physico-chemical background of stress to our marine ecosystem.

INTRODUCTION

In the past, not only natural events but also human activities affecting the environment have caused significant and tangible changes in the living conditions on Earth. However, it has only been in the past 20 or 30 years that man-made environmental damage – resulting both from a hitherto un-

* Dedicated to Marko Branica on the occasion of his 65th birthday.

precedented population growth and uncontrolled industrial pollution – has reached such dimensions that this damage jeopardizes both our present living conditions and those of future generations, mainly because of its global scope.

These changes not only have an adverse impact on the general quality of life, but in the long run they also pose a potential threat to the global economic and societal systems. For this reason, measures have been adopted worldwide to protect the environment. The United Nations Conference on Environment and Development (UNCED), held in 1992 in Rio de Janeiro, Brazil, also known as the »Earth Summit«, clearly showed that this process has been initiated. But many of the processes and interactions which underlie the global changes are known to a limited extent only, or not at all. Effective damage prevention and risk containment strategies can , however, only be developed by politicians if they have reliable basic information at their disposal. Therefore, this is a challenge that confronts politicians and scientist alike.

Specimen banking for biological and human tissue has now been well established for about two decades. Environmental samples archived as part of monitoring programs have been found useful in a number of specific studies.[1–4] Yet, these are only scattered efforts restricted to regional or national problems. The German Environmental Specimen Bank with its two branches – the Human Tissue Specimen Bank in Muenster and the Environmental Specimen Bank (ESB) in Juelich[5,6] – is a national archive of specimens for real time monitoring and retrospective analysis. The National Marine Mammal Tissue Bank (NMMTB)[7,8] located at the National Institute of Standards and Technology (NIST) in Gaithersburg, USA, is more devoted to the assessment of the highest links in marine food webs with organic and inorganic pollutants whereas the Environmental Bank at the same institution archives a valuable collection of human livers collected as autopsy samples[9] from various places in the United States in 1981 and 1990. A number of small scale specialized specimen banks exist around the world in different countries (environmental specimen banking programs in the Nordic countries,[10] a fresh water specimen bank in Canada[11]). Though the need for reliable analysis of properly collected marine environmental materials has been emphasized on several occasions (*i.e.* International Symposium on Marine Pollution – Mammals and Toxic Contaminants (ISMAP), Kamogawa, Japan, February 1993; International Conference on Marine Pollution and Ecotoxiclogy, Hong Kong, January 1995) the stringent answer to this scientific problem, namely specialized sampling and storage of authentical tissues by experienced experts for further distribution of such materials to the analysts, has rarely been advanced. However, at the ISMAP meeting, the establishment of an International Environmental Specimen Bank was recommended by 50 scientist from 16 countries, as well as by representatives of UNEP, UNESCO/IOC and the United Nations University.[12]

THE GLOBAL PROBLEM

About three quarters of the Earth's surface is covered by oceans which contain 98 percent of our planets total free water volume. There are still major gaps in our knowledge of this ecosystem, which is the largest of all. Even today, many parts of the oceanic environment are still »white spots« on our knowledge map, although the oceans – along with the atmosphere – play a key role in the Earth's climate and balance of resources. In addition, the oceans are a tremendous source of food and mineral resources.

While near-shore marine regions account for only about 10 percent of the total ocean surface area, they are our most important food reservoir – 99 percent of the fish caught worldwide comes from these coastal waters. Moreover, near-shore marine regions are also important habitats and recreational areas – 70 percent of the worlds population lives in the coastal regions. The oceans shorelines are thus affected by a wide variety of natural and anthropogenic factors, which often exposes them to latent or acute threats. In some areas the condition of the ecosystem »ocean« is alarming. While the open seas still seem to be comparatively unaffected, the coastal region and the adjacent seas are already considerably polluted by atmospheric deposition and direct discharges or inflows from rivers. Offshore mining activities producing tremendous turbulence of polluted sediments as well as finely ground discharges from inland mining threaten the marine environment by dispersion of concentrated heavy metal loaded marine dust.[13] In addition, submarine and subseabed waste disposal sites (radioactive waste, chemical warfare ordnance etc.) are becoming a source of acute risks.

Recently, GESAMP – an international group of marine scientists, identified the potential threats to the environmental quality of the ocean system.[14] In an attempt to itemize the growing level of contaminants that could turn into pollutants and endanger the resources of costal zones, the report included nutrients, microbial pathogens, chlorinated hydrocarbons, petroleum components, plastics, heavy metals and radionuclides. So far, however, there has not been an international or large scale national effort to rise to this challenge. One notable exception has been the five year program of the Japanese Fisheries Agency to monitor persistent and toxic chemicals on a world-wide basis.[15]

The oceans have in the past been extensively used as disposal sites for various kinds of waste. Fortunately, the integration of oceans into waste management assessments has become more difficult.[16] Scientific research and the outcry of environmentalists that the ocean can receive no waste without suffering unacceptable degradation has found its place in many national and international policies, such as the London Dumping Convention.

Another example might be the upcoming interest to monitor long-lived radionuclides in environmental samples.[17] Bearing in mind the enormous amounts of disposed high level radioactive waste in the open oceans in the 60's and 70's by nuclear power nations together with some incidents of nuclear submarine submerging it might soon be of major concern to determine radionuclides as ^{129}I, ^{99}Tc or ^{237}Np in archived samples to follow up the trends and to identify the point sources of their release.[18]

The case of plutonium isotope releases (as a consequence of the Manhattan Project and the activities of Los Alamos National Laboratories, New Mexico, USA, but also due to atomic bomb testing at the Nevada Test Site) into the Rio Grande has shown how difficult the differentiation of plutonium from these various sources is.[19] This is partly due to inadequate records of Pu releases in the early years of the Los Alamos site, but also to the unavailability of uncontaminated samples from the Rio Grande system.

After the establishment of the North Atlantic Cooperation Council (NACC) in 1991–1992, cross-border environmental problems were identified as one of four priority areas for cooperation between NATO and the countries of central and eastern Europe. Defense-related radioactive and chemical contamination studies were in the focus of this cooperation. These efforts encompass both risk analysis and mitigation approaches for existing and potential hazards. First results of several pilot studies have recently become available to the public.[20] Until recently, the Soviet Union/Russia routinely dumped liquid radioactive waste in the Arctic Sea. The wastes originated from reactor cooling systems, including those on board submarines, and from cleaning and decontamination operations at shipyards or on board service ships. A further concern are the massive quantities of solid radioactive waste in the form of spent nuclear fuel accumulated from overhauled or dismantled Russian submarines from the Northern Fleet. The Northern Fleet of the Soviet/Russian Navy has been operating attack and ballistic submarines with nuclear propulsion since 1960. According to declassified information, about 170 submarine units have been built for this fleet, of which some 90 are still operational. The Northern Fleet has thus at least 21000 spent nuclear fuel assemblies in storage, partly on land and partly on board ships. This accumulation presents a potentially serious environmental hazard. According to Russian sources, a total of 16 reactors were dumped along the east coast of Novaya Zemlya or in the open Kara Sea. A further potential hazard present the nuclear factories located primarily on rivers (or their tributaries) belonging to the Ob and Yenisey catchment areas – the Mayak reprocessing facility at Ozersk near Chelyabinsk, and the two plutonium production facilities in Seversk near Tomsk, and in Zheleznogorsk near Krasnoyarsk. Due to the large quantities of radioactive materials stored at or near these facilities, an accident scenario would certainly have very serious consequences within a large area.[20,21]

No less serious has been the dumping of large quantities of chemical warfare agents and weapons (containing mostly very toxic nerve gases such as Tabun, Lewisite, Phosgene, Chloractophenone, Clark 1 and 2 *etc.*) into the North Sea and Baltic Sea. About 40 German cargo ships were filled with chemical ordnance and sunk either at 700 meters depth ca 20 n miles east of the Norwegian town of Arendal, or at 400 meters outside the Swedish town of Fiskebackskill, north of Gothenburg. In the Baltic Sea, chemical weapons, often deposited at depths less than 120 meters, were mainly dumped east of Bornholm and southwest of Gotland. Some of the dumping occurred near commercial fishing sites, and this has led to several incidents in which fishermen have been contaminated. The United Kingdom, the United States and the former East Germany dumped chemical warfare munitions at great depths in the Atlantic Ocean.[22]

However, even contemporary activities present potential environmental hazards to the oceans and their resources. The recent resumption of French nuclear test in the Pacific, near the Mururoa and Fangataufa atolls has triggered severe international disputes over the environmental aspects of these test, especially trans-border pollution.[23] The low but constant releases of radionuclides from nuclear reprocessing plants, located preferentially near the shore (*e.g.* La Hague, France; Sellafield, U.K.) gradually enhances the total inventory of long lived artificial radionuclides in the open oceans.

Although the use of marine resources has so far been limited to comparatively few products, it still involves risks, in some cases producing adverse effects on the marine environment (*e.g.* overfishing, oil spillage, marine mammal deaths due to drift nets, whale killings). An anticipated more intensive use of marine resources could therefore lead to further adverse effects, unless the risks are assessed beforehand and new environmentally sound methods are developed. To this day, however, reliable predictions about the effects of extracting and using additional marine resources have been largely impossible due to the extremely complex interdependencies involved. Understanding the biological, chemical, physical and geological processes in the oceans, as well as their mutual interactions, is a prerequisite to estimating the effects of perturbations in these systems. The ability to asses these effects and the possibility of developing countermeasures will become a vital necessity for large segments of the worlds population.

One of the great challenges, perhaps the greatest one, for a successful exploitation and management of coastal waters involves accidents and unexpected events that can have severe consequences. The »Exxon Valdez« oil spill along the Alaskan coastline, or the recent »Sea Empress« spill off the south-western coast of England are examples of such episodes that cannot be predicted.

One other major threat arising from man made environmental contamination from our present day knowledge arises from the mass input of polycyclic aromatic hydrocarbons (PAH) and persistent organochlorines into the water bodies. Due to their lipophilic solubility these compounds are strongly accumulated in the food webs of the oceans and Arctic waters seem to act as a sink for persistent contaminants.[24,25] As such compounds are still produced in enormous quantities as agrochemicals, solutes or technical byproducts, concentrations of such substances are steadily increasing in marine biota. In this respect we are already far behind the goal to preserve pristine samples for trend monitoring and retrospective analysis.

MARINE SPECIMEN BANKING CONCEPTS

The world ocean – being the final sink for many natural and anthropogenic substances – is a »labile« ecosystem which is and has for a long time been the focal point of extensive interdisciplinary research. Measurements of heavy metals and a suite of various chemical compounds in the marine environment has mostly been carried out on limited scales, within national (or regional at best) monitoring programs (*i.e.* the Mussel Watch program in the USA, or the North Sea or Baltic survey by the Northern European countries). Most of these actions were restricted to coastal waters and estuaries which are more severely impacted by pollution than the open ocean. A long term systematic investigation of human impact on the oceans of the world (along the global currents, the Gulf stream or El Niño and verging on the main shipping trails) would ideally require a central survey station accompanied by an extensive banking facility, capable of handling a large volume of various marine samples.

Natural banks preserving valuable long term environmental information are existing as unperturbed marine sediments or as ice sheets of the poles. Marine sediments are an important repository of information on oceanic and climatic change. Obtaining sediment sequences from climate-sensitive areas is thus an important aspect of paleooceanographic and paleoclimate research. Recently, more than 7000 m of sediment core have been recovered in the Mediterranean by the Ocean Drilling Program (ODP) Legs 160 and 161. Unfortunately, no drilling or sample recovery has been done in the Adriatic Sea. These sediments reach back to the Miocene/Pliocene boundary (age *ca.* 5 million years). Since the Mediterranean is a land locked, semi-enclosed basin with very limited open ocean water exchange, the composition of these sediments is particularly sensitive to natural variation, and environmental signals are preserved in great detail. The discovery of sapropels in the western Mediterranean, which have in the eastern section been traditionally attributed to episodes of bottom water anoxia, is linked to new conceptual models[26] which correlate sapropel formation with periods of minima in the Earth's orbital precession cycle. During such events the northern hemisphere receives stronger summer insulation, leading to more intense summer monsoons throughout Asia and Africa and enhanced moisture transport to the Mediterranean catchment area. Changes in the evaporation/precipitation ratio stabilize the water column structure, and the combined effects of biological production and anoxia may have lead to sapropel formation.[27]

Continuing studies of the Leg 160 and 161 sediment cores are expected to focus on three goals. First, the determination of Mediterranean paleoceanography by establishing temporal relationships between sapropel formation in the eastern and western sections of the Mediterranean basin. The second aim is to document the hydrography of inflowing Atlantic waters and their potential links to marine environmental changes in the western Mediterranean from the Miocene/Pliocene boundary onwards. Thirdly, it is hoped that gradients for physical, chemical and biological properties during sapropel formation in the entire Mediterranean Sea will be established. It is more than obvious that such an extensive sampling and research campaign would benefit from a regional sampling storage facility.[27]

Greenland ice cores can be dated as far back as 5700 years BC. After the extremely difficult task of contamination free sampling became available, such samples have so far been analyzed for a couple of heavy metals and their species. It is evident that *e.g.* Pb had been introduced already some 3000 years from now by roman mining activities and a rapid increase of lead concentrations, mainly in the form of alkyl-lead, took place from 1930 until the late 1960s (~ 200 times the natural values) and then declined rapidly from the early 70s to present.[28,29] Such investigations confirm that ice sheets can be used to monitor long term trends for some selected contaminants if the extremely demanding task of reliable sampling and ultra trace analysis can be handled.

Natural »banks« of specimens such as deep sea sediments or the ice sheets of the poles are very difficult to probe if trace elements or other micro-contaminants are considered. As biological specimens seem to be perhaps the most suitable for collection and processing for analysis, one of the aims of a Marine Environmental Specimen Bank (MESB) should be to focus on such samples. Biological indicator organisms integrate over their life span from the surrounding media the bioavailable portion only and this, however, is the most interesting part of all xenobiotics if environmental provisions are examined for human protection.

Starting from the sampling and storage strategies already developed at some existing Environmental Specimen Banks (ESBs), a Marine Environmental Specimen Bank (MESB) needs a specialized sampling team, state of the art sampling vessels and large cryogenic storage containers. After appropriate Standard Operating Procedures (SOPs) have been developed for the various matrices (sediment, plankton, algae, bivalves, crustaceans, different type of fish, mammals *etc.*) sampling and analysis of individual specimen need to be carried out to evaluate such basic features as seasonal variation, biological variability, regional distribution etc. Close multidisciplinary cooperation between biologists, ecologists, chemists and oceanographers is mandatory to elucidate the most straightforward collection and handling procedures. A representative sample reflecting a particular situation in time and space should be composed of a considerable number of individuals of an identical generus.

Contamination free sampling is an art that has to be developed and cultivated. Using a diesel-engine driven, strongly painted, multi-metal, large volume vessel is definitely not the best choice for careful and uncontaminated sampling of marine biological and environmental materials. The extent of contamination of a sample is detected in most cases only in the laboratory after a large amount of money for inappropriate sampling has already been wasted.[30]

Further processing of the sample pool can be carried out by cryogenic milling for homogenization or just by aliquoting (sediment, plankton...) into a large number of sub-samples. These should be freshly stored in the vapor phase of liquid nitrogen without drying. Avoiding further treatment as far as possible enables the use of this materials for scientific investigations in a very broad sense, *e.g.* for speciation analysis.[31]

Storage of authentical materials is not only valuable for real time monitoring and basic research activities but it opens the possibility for long term trend evaluation through retrospective analysis of well characterized samples taken according to stringent sampling protocols. In addition, general awareness of pollution threats as well as our abilities to detect substances accurately changes considerably in time. As an example, the reported concentration of lead in sea water decreased from results determined in 1940 to 1970 by several orders of magnitude, not because the environmental situation improved during this time span so dramatically but because of enhanced analytical capabilities and growing awareness of contamination problems during sampling and analysis.[32]

The need for specimen banks is particularly obvious when the biases of existing and potential data banks are taken into account.

The scientific community, including marine researchers, is currently in the midst of what is commonly called the »information explosion«. The exponential growth of the Internet and World Wide Web (WWW or Web) resources is partly due to the ease of use and popularity of browsing applications for documents written in the hypertext markup language (HTML). This situation has already improved many facets of marine research operations, providing efficient and effective means of communication and information distribution. Environmental data are deposited in computerized data storage and retrieval systems, both on national and international scales. National agencies and numerous international programs accumulate information from a wide variety of sources, including both valid and invalid data. Upon subsequent retrieval it may be difficult if not impossible to distinguish between these two categories. As pointed out by Goldberg and Taylor[33] such data are essentially useless, except for bibliographic or historical purposes. They therefore rightfully advocate data validation mechanisms, especially in the field of environmental sciences where much of this information is used by decision makers in various environmental mitigation issues. Since there are no straightforward mechanisms for data validation obligatory for everybody today, storage of proof samples for re-evaluation is the only way out of this dilemma.

The storage of all kinds of marine specimens (from water to sediment, fish and algae, plankton *etc.*) in a central MESB, as a complement to environmental monitoring[34] is necessary to provide future investigators with authentic materials which will facilitate an assessment of and source identification of environmental stress on various marine ecosystems. Stringent sampling procedures have to be developed and only specialized teams can assure that the quality standard of every sampling campaign is maintained. It is clear to day that the accuracy of an analytical result in the first place is a direct function of the sampling procedure. Data interpretation should therefore always start with a critical discussion of the various steps of the sampling procedure. Regional marine specimen banks could serve as models for an appropriate sample storage facility (SSF) on a large (global) scale, and would serve the purpose of gathering requisite experiences on various logistic aspects of such a project – ranging from site-location, accessibility to transportation routes and infrastructure, training of staff, operations etc. It is envisaged that a feasibility study for a regional Adriatic and/or Mediterranean Marine Specimen Bank located on the Croatian Adriatic coast will be undertaken in due course.[35,36]

THE ROAD AHEAD

In view of the scope and complexity of the challenges ahead of us, there is a need for global coordination of environmental research. Global problems can only be effectively tackled in the framework of broadly based international efforts, which should form the basis for national and regional research strategies. In the next few years, we will have to start by closing the current gaps in our basic understanding of the marine ecosystem and the interdependencies between the oceans and climate. Once they have been identified, it will, however, be important to develop concrete solutions for environmental problems, and to draw up concepts for environmentally sound ways of producing and using natural resources. Because of this, together with the need to develop effective pollution mitigation strategies on a world-wide scale, marine research should not be limited to basic research only. Instead, it must include impact analysis and recommendations for action. Oceanographic research is thus closely linked to technology impact research and technology assessment, and this is true not only for basic marine sciences and research investigating *i.e.* »the role of the oceans as an ecosystem and a source of resources« but even more for applied problems addressing »the oceans as a sink for waste«. In view of their global dimensions, as well as their scientific complexity and financial scope, the problems we are confronted with today can only be approached by means of joint international efforts. In terms of specific research priorities and financing, these multidisciplinary master programs will have to be sufficiently flexible over relatively long periods of implementation, to enable both scientists as well as fund providers to adapt to new developments as new findings are made.

The international scientific community has become more aware of the relativisation of scientific knowledge, particularly since the recent nuclear tests in the southern Pacific. However just and precise, science cannot predict the future and decide upon the future consequences of a persistently dangerous matter whose long-term effects cannot be known. Too many parameters are involved for one to be able to give a reasonable answer to such a prospective analysis. Precedents add grist to the deep conviction of certain opponents of nuclear tests – indeed, from the end of the 1940s until the sixties, the United States, like the Soviet Union, conducted scientific tests under the aegis of the most eminent institutions on the effects of radioactivity on human beings. These facts, now well-known thanks to the declassification of many documents in the two countries, clearly show how ignorance of certain consequences of radioactive matter can lead to serious problems for humans. Given the state of their knowledge at that time, eminent research workers were convinced that they could master the consequences of their acts. Even though any human activity involves an element of risk, a critical mind and the possibility to retrieve any pre-event samples should accompany scientist when making certain affirmations.

In the light of these expected trends in international marine research programs, the needs and prospects for a Marine Environmental Specimen Bank, as a complementary facility to data banks, are clearly evident. If the various aspects of marine research are well poised for the 21st century, a storage facility with samples from the past will strengthen its position in the concert of natural sciences aimed at a better understanding and prediction of environmental processes. Climatic changes – today a topic of prime concern – will only be an episode if one day the environmental collapse of the oceans should be encountered. To prevent such catastrophes, early trend monitoring and careful assessments should be started on the basis of long term observations.

Marine specimen banking facilities will thus become part of regional and global marine research and monitoring programs such as ZISCH (Zirkulation und Schadstoffumsatz in der Nordsee – Circulation and Pollutant Cycles in the North Sea), the World Ocean Circulation Experiment (WOCE), the Ocean Drilling Program (ODP), the JGOFS (Joint Global Ocean Flux Study), the European River-Ocean Systems (EROS) and the planned Global Ocean Observation System (GOOS). Specimen storage facilities will, perhaps, become even more instrumental in regional cooperative endeavors, particularly within Europe. After the political opening of Eastern Europe, the Mediterranean, Baltic and Black Seas will become fully accessible for international research. First advances, encompassing mainly the management of natural resources, are coming from the European Union (EU) and the North Atlantic Treaty Organization (NATO) through initiatives such as the Conference on Security and Cooperation in the Mediterranean and the Mediterranean Forum.[37,38]

Nevertheless, it is important to distinguish between real and perceived problems of marine environmental degradation, recognizing that the assessment of an issue by the scientific community (or part of it) may differ from that of the general public. While public perceptions, even when insufficiently substantial, must be taken seriously and provided with proper political backup, efforts are required that the public is well informed about the current knowledge on specific environmental problems. In particular, this concerns the possibility of the subtle effects of persistent low levels of contamination. These issues have been well recognized by transregional environmental initiatives in Europe, which, being the second smallest continent comprises little more than 7% of the Earths land area. However, it is surrounded by nine major seas, including the worlds two largest land-locked seas – the Caspian and the Black Sea. The major problems, as recognised in the recently published detailed account on Europes environment,[39] are: lack of effective catchment management, coastal zone pollution, eutrophication, conflict of uses in the coastal zone, introduction of non-indigenous species, lack of control of offshore activities, over-exploitation of resources and sea-level rise as a result of global warming. The report stressed that no pan-European marine water quality database exists. Therefore, another recent document of the European Environment Agency (EEA)[40] identifies among the priority issues and actions of the European environmental policy the question as to what are the trends and prospects in our progress towards sustainable development, and what information – basic and aggregated – is worth pooling and disseminating. Thus, media oriented monitoring, as one of the principal programmes covered by the EEA multiannual work programme (MAWP), is expected to »promote consistency between the monitoring activities in the member states and assure the compiling of EU wide thematic data bases (air quality, water quality *etc.*) thus achieving feasible, efficient and economic creation of comparable information«. It is here where associated initiatives, such as the marine specimen banking concept developed in this paper, are expected to provide essential input to preventive environmental policies, in Europe and beyond.

Apart from the significance of marine specimen banks for future research endeavors, perhaps the most important aspect of MESB will be the strong scientific impetus it will certainly have in meeting the challenges of the political process of protecting the marine environment and its resources. Pollution prevention of our environment is, after all, a win-win strategy.

Acknowledgements. – M.R. acknowledges the financial support by the BMU, Bonn, and the German Environmental Agency UBA, Berlin. G.K. acknowledges research support through a fellowship of the Alexander von Humboldt Foundation of Bonn, Germany. Part of this research was done within the framework of the bilateral research project »Environmental Research in Aquatic Systems« supported by the International Bureau of KFA Juelich.

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SAŽETAK

Sustav pohrane uzorka iz okoliša – strategije monitoringa mora i perspektive za oceanografiju

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Postoji više argumenata koji jasno govore u prilog uspostave međunarodne banke morskih uzoraka, s pratećim djelatnostima kao što su prikupljanje, obradba i pohrana izvornih uzoraka iz okoliša. Ispuštanje radioaktivnog otpada, organskih i anorganskih zagađivala, rudarenje u priobalnim područjima, ispitivanje i odlaganje nuklearnih i kemijskih vojno-tehničkih sredstava postaju razlogom za ozbiljnu zabrinutost za očuvanje i održavanje integriteta morskih ekosustava. Oštećenja morskih ekosustava negativno će se ispoljiti u nepredvidivim klimatskim promjenama, a mogu imati za posljedicu i ozbiljne gospodarstvene gubitke. Stoga su potrebna nastojanja u međunarodnim okvirima, kako u smjeru globalnog nadzora (monitoringa) tako i uspostave banaka uzoraka iz morskih i drugih okoliša, što će pridonijeti boljem poznavanju fizikalnih i biogeokemijskih elemenata te uzročno posljedičnih odnosa stresa kojemu je izložen morski ekosustav.