Sustainability and Impact Aspects of Exploitation of Marine Salt, Magnesium and Bromine

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ABSTRACT


Among the minerals dissolved in seawater some occur in quite high concentrations. Such is for instance the case for salt (NaCl), magnesium (Mg) and bromine (Br), but also for sulphur (S), calcium (Ca), potassium (K), boron (B) and—although in lesser quantities—for iodine (I). Salt, magnesium and bromine from marine origin have been exploited on a large scale; salt from times immemorial, the others since numerous decades. In 2000 close to 15 million ton of salt were extracted from the sea, representing 7% of worldwide total salt production. In the same year marine magnesium production amounted to 1.8 million ton or 53% of total magnesium production. Even better, marine bromine production was 380,000 ton or 70% of total world production. But to what extent are those mineral exploitations sustainable and for how long can such operations continue? In view of the industry’s demand for these minerals and the very large share of marine origin the question is both pertinent and answers are urgent. The military demands for these minerals, during World War II, contributed largely to the development of “mining” operations while the expansion of the car industry and the need for a no-knock-gasoline spurred the production of bromine. Equally pressing is the question of the impacts such exploitations exert on the environment, both offshore and in the coastal zone. Last but not least, is the use of those minerals not harmful for the environment in general?

ADDITIONAL INDEX WORDS: Black Sea, ecosystem, erosion, minerals, concentration.

MINERALS DISSOLVED IN SEAWATER

Minerals present in seawater result mostly from erosion. Wind, rain and rivers carry them to the oceans. Marine currents spread them in nearly equal concentrations over the oceans. It was long thought that the concentration of chemical components was gradually increasing as an effect of the continual supply of continental minerals. Wallace S. Broecker, professor at the Lamont-Doherty Earth Observatory of Columbia University in New York, has however proposed another thesis: oceans are not the end-destination of erosion material, but only an intermediate step. The continental minerals that are eroded by wind and water are getting together with silt and sand into the oceans. In a first stage they are kept in suspension, but eventually they sink because of their specific gravity and contribute to the formation of the sediment layer. After a given period those layers are lifted above sea level as an effect of the plate tectonic and the whole cycle can start over again.

The terms salt and salinity do not only designate sodium chloride (NaCl) but cover all mineral elements dissolved in seawater. Table 1 provides an overview of most important components and their respective proportions.

Those mentioned salts occur in nearly all seas worldwide in reciprocal similar concentrations. Commonly used standards for percentages:

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine</td>
<td>2.0 parts per million</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.4 parts per million</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.05 parts per million</td>
</tr>
</tbody>
</table>

The equation establishing the link between the two standards is:

\[ \text{salinity} = 1.805 \text{ chloride} + 0.03^2 \]

In the ocean the salinity varies mostly between 3.4% en 3.7%. High values can be found in subtropical regions, with low rainfall and high evaporation heat caused. The Mediterranean Sea reaches in many places a salinity exceeding 3.8% and values of 4.1% in the Red Sea are quite normal. Low values are found close to the equator (because of the high rainfall), in higher latitudes (because of the temperature) and near river-mouths. The Baltic Sea has a salinity varying from 0.5% to 1%, a result of the many rivers discharging into this sea and the low water temperature (Figure 1).

Salt

Sodium chloride (NaCl) has played an important role in most old cultures. Salt was indeed for a long time one of the very few methods to preserve food and even today it is still an indispensable element in our alimentation. Already 2200 years BC Chinese extracted salt from seawater.

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\(^2\) For instance: A salinity of 34.33 = 1.805 (chlorinity) x 19.00 + 0.03
In general salt is produced using three basic technologies: —conventional shaft mining for rock salt: those deposits come most probably from ancient evaporated seas. As a result of tectonic plate shifting those deposits were lifted and are now mainly located on the continental shelf. Important deposits can be found in Europe in Germany (Stassfurt), Switzerland (Bex), Poland (Wieliczka), England (Cheshire, Cleveland), Spain (Cardona) and Russia (south-western Urals). On the other hand Belgium, Italy and Scandinavia are quite poor in salt deposits. —brine, vacuum pan, open pan: is nearly everywhere in the world the most used process for salt production. Water is squirted into rock salt deposits and pumped back to the surface as a brine (concentration of about 30% sodium chloride). In a further phase the brine is purified and can be fed to large evaporators where it crystallizes into granulated salt. —solar salt: is produced in large open ponds. The seawater is evaporating using the solar heat and (marine) winds.

In 2000 about 214 million ton of salt were produced worldwide. The biggest producers are the United States with 45.6 million ton. Other important producers are China (31.3 million ton), Germany (15.7 million ton), India (14.5 million ton) and Canada (11.9 million ton).

The United States, which are quite representative for salt production, consumed 52% of the salt under the form of brine, 31% was coming from rock salt, 10% vacuum pan salt and 7% solar salt. In 2000 nearly 42% of the produced salt was used in the chemical industry, especially for the making of soda, 36% was used for de-icing roads during the winter, 6% in other industries, 4% in agriculture, 3% in food production and 1% for water treatment.

It should be emphasized that using salt for de-icing roads has negative effects on the environment. A five-year scientific assessment ordered by the Canadian Government declared road salts toxic to the environment. Under the Canadian Environmental Protection Act (CEPA), the Canadian government has two years in which to develop management measures that will reduce the environmental impact of salt. Problem is that there are no reasonable alternative de-icing products. Calcium chloride, calcium-magnesium acetate, hydrogen chloride (HCl) and potassium chloride can be used, but they are more expensive. Besides, a study carried out in the United States by the National Conference of State Legislatures has shown that those alternative de-icing products are also harmful to the environment and that they are strongly damaging the road infrastructure.

Salt reserves are nearly limitless. Not only because of the fact that many countries do have important salt deposits on the continental shelf, but mainly due to the salt dissolved in seawater. Those marine reserves can be estimated at

Table 1. Proportions of dissolved substances in seawater.1

<table>
<thead>
<tr>
<th>Substance</th>
<th>Grams per kg seawater</th>
<th>Proportion w.r.t. total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride (Cl(^{-}))</td>
<td>18.980</td>
<td>55.051</td>
</tr>
<tr>
<td>Sodium (Na(^{+}))</td>
<td>10.556</td>
<td>30.618</td>
</tr>
<tr>
<td>Sulphate (SO(_{4}))</td>
<td>2.649</td>
<td>7.863</td>
</tr>
<tr>
<td>Magnesium (Mg(^{2+}))</td>
<td>1.272</td>
<td>3.869</td>
</tr>
<tr>
<td>Calcium (Ca(^{2+}))</td>
<td>0.400</td>
<td>3.869</td>
</tr>
<tr>
<td>Potassium (K(^{+}))</td>
<td>0.380</td>
<td>1.102</td>
</tr>
<tr>
<td>Hydrogen carbonate (HCO(_{3}))</td>
<td>0.140</td>
<td>0.406</td>
</tr>
<tr>
<td>Bromide (Br(^{-}))</td>
<td>0.065</td>
<td>0.189</td>
</tr>
<tr>
<td>Boric acid (H(<em>{3})BO(</em>{3}))</td>
<td>0.026</td>
<td>0.075</td>
</tr>
<tr>
<td>Strontium (Sr(^{2+}))</td>
<td>0.008</td>
<td>0.023</td>
</tr>
<tr>
<td>Fluoride (F(^{-}))</td>
<td>0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>Total</td>
<td>34.477</td>
<td>100%</td>
</tr>
</tbody>
</table>

39,000,000 billion ton (39 x 10^{15} ton). Of course not the entire amount of salt can be extracted from the oceans. The lower the percentage of salt in seawater, the more difficult and the more expensive extraction will be. This is true for all minerals dissolved in seawater. But as already mentioned most of the minerals will flow back to the oceans by way of sewage, brooks and rivers.

Marine salt is mainly collected in regions where the sun is strong enough to allow a natural evaporation. This is the case for the Mediterranean region (France, Spain, Portugal, Italy, Turkey, Tunisia) and for California, Texas and Mexico. Other locations are Central America, the Antilles (Bahamas, Bonaire), Senegal, Namibia, India, Thailand and Indonesia. Salt production also can be a by-activity of desalination plants. The collected salt can be sold and will decrease the exploitation cost of the desalination plant.

France is among the most important marine salt producers with its system of "marais salants" (Figure 2). The "marais salants" of Aigues-Mortes belong to the oldest in the Mediterranean region and are producing yearly 500,000 ton of sea salt. This quantity covers more than one third of the total consumption of people and animals in France. Even bigger is the area of the Salin de Giraud with a yearly production of 900,000 ton. Also located on the French Mediterranean coast, the region of Port La Nouvelle, La Palme and Gruissan has a production of 100,000 ton per year, while the region of Berre in de Bouches-du-Rhône is producing 50,000 ton per year. The Spanish Union Salinera de España (UNION SAL) produces yearly 940,000 ton of salt in the region of Torrevieja, Cadiz, Almeria and El Pinet. Tunisia produces yearly 500,000 ton of salt in the regions of Bizerte, Souss and Gabès. The Société Nouvelle des Salins du Sine Saloum in Kaolack (Senegal) has a yearly production of 160,000 ton. In America the most important exploitations of marine salt are located on the west coast of Mexico. Guerrero Negro, the largest salt-complex in the world, is administrated by Exportadora de Sal, S.A. (ESSA), producing 7 million ton of salt each year. Other Mexican exploitations are located in Cuidad Obregon, Navojoa, La Mochis, Angostura, Culiacan and Mazatlán. On the east coast of Mexico, in the region of Las Coloradas, the plant Salinera de Yucatan reaches a yearly production of 500,000 ton.

In 2001 some new projects to extract salt from the sea were developed in Venezuela and Vietnam, a long-time artisanal producer. On the other hand projects such as Exportadora de Sal S.A. in Laguna San Ignacio (Baja, Mexico), were rejected by the Mexican Government because environmentalists were worried about the harmful consequences such an exploitation can have on the marine environment—especially on whales and turtles. The project was quite huge with a capacity twice as large as Guerrero Negro. Besides the project was located in the natural reserve of Vizzcaino Desert Biosphere. Thus new roads, a railway-line and a harbour would have been built in the lagoon area. Once finished the plant would have pumped between 450 and 800 million ton of water a year from the bay into the evaporation basins with a total surface of 150 km². There is no doubt that the pumping of such quantities would have harmed marine sea-life. In a first phase a change in salinity and temperature of the water in the lagoon would have occurred. After a few months this activity would have had an impact on the whole ecosystem: from plankton and fish to birds and cetaceans.

**Magnesium**

Magnesium has a small specific gravity, even lower than aluminium*. The earth’s crust is composed for nearly 2.09% of magnesium, but because of its high reactivity with other elements it never occurs in pure shape. It occurs as carbonates, chlorides, silicates and sulphates. Although magnesium is present in more than 60 minerals, only dolomite, magnesite, carnallite, brucite and olivine do have an economical importance.

Seawater also contains considerable quantities of dissolved magnesium, mostly under the form of magnesium chloride (MgCl₂), magnesium sulphate (MgSO₄) and magnesium bromide (MgBr₂). After chlorine and sodium, magnesium is the third most occurring mineral in seawater and represents 3.68% of all elements dissolved in seawater. The United States already started with the extraction of marine magnesium in the 1930s. The magnesium is obtained by the chemical reaction of lime and magnesium resulting in the precipitation of insoluble magnesium hydroxide. This is the reason why most magnesium plants are located in regions rich in limestone, like the coasts of Louisiana, Texas and California, in Burgas (Bulgaria) and in England. In a further phase, when adding hydrochloric acid, the obtained magnesium hydroxide can be transformed in magnesium chloride (MgCl₂). Finally the magnesium metal can be extracted from the magnesium chloride by electrolysis. This process has the big inconvenience of using a lot of electricity. In 2000, 63% of the magnesium production in the United States was extracted from seawater, mainly in California, Delaware and Florida. The total American production in that year amounted to 370,000 ton. Globally 51% of the magnesium production is from marine origin.

Magnesium production already had glorious times during wars. The metal was of strategic importance for the manufacture of incendiary bombs and for the production of light military material for the troops and of course for building airplanes. Nazi-Germany did not possess aluminium reserves but disposed of huge quantities of magnesite in Austria. Therefore they performed extensive research on possible applications from that light metal.

Today magnesium is mainly used for more pacific purposes under the form of magnesium oxides. Nearly 70% of the magnesium compounds consumed in the United States were used for the production of miscellaneous fireproof accessories (refractories). Although lighter than aluminium, magnesium has the disadvantage of having less resistance against corrosion and requires better protection (paint coating). Magnesium is also not as strong as aluminium and cannot be flattened, drawn out or rolled. Because of this magnesium accessories are mostly used under the form of aluminium or

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* Magnesium has a specific gravity of 1.74 while aluminium has one of 2.69. In comparison iron has a specific gravity of 7.87 and lead of 11.34.

zinc alloys. In 2000, nearly 45% of the produced magnesium in Western countries was used in the aluminium industry. Zircon alloys are used in building airplanes. More expensive zircon alloys are characterised by their solidity.

The manufacture of modern cars requires ever more use of those lighter materials. They are not only less sensitive to corrosion, but also consume less fuel because of their smaller weight. A very important point at present when production of carbon dioxide responsible for the greenhouse effect must be reduced by all means. Worth mentioning is the fact that during the last decennia ever more magnesium products were recycled under the cover of striving towards "sustainable development". In 1969 not even 10% of the total production came from recycled magnesium. In 2000 this share rose to 25%. Magnesium is also used in the manufacture of fireworks, underwater welding, glass production, for soft drink cans, wastewater treatment and in the pharmaceutical industry and bio-industry.

In 2000, the total production of magnesium compounds from continental and marine origin amounted almost to 3.5 million ton. The leading producing countries were China and Turkey, both dredging 700,000 ton. Next came the United States with 370,000 ton and North Korea with 300,000 ton. The Russian Federation and Slovakia produced each 250,000 ton.

Total known reserves of magnesium are estimated at nearly 3.4 billion ton. One billion ton thereof is thought to be located in China. Other important reserves are located in North-Korea (750,000 ton) and Russia (730,000). These concern of course exclusively continental reserves. Marine reserves are almost inexhaustible. Indeed, without taking into account magnesium minerals (like magnetite) located under the sea floor, the quantity of magnesium dissolved in seawater amounts to nearly 1,800,000 billion ton (1.8 x 10¹⁶ ton).

Extracting magnesium from seawater is rather expensive. Nevertheless countries like the United States are ready in invest in such processes so as to be less dependent upon import. In 2001 the United States consumed almost 590,000 ton of magnesium compounds. From the 360,000 ton that were produced in the United States, nearly 225,000 ton (or 62.5%) were extracted from the sea. American import sources were China (65%), Canada (8%) and Australia (8%).

A current problem is the drop in magnesium price on international markets due to lower consumption and higher stocks. While the price for one ounce (28.3 gram) of magnesium metal was $2.09 in 1995, it dropped to $1.30 per ounce in January 2001 and even to $1.10 in September 2001. This low price makes the use of magnesium more attractive, but on the other hand it is a restraining factor for further investments in new exploitation projects.

Striking is the fact that increased investments in new projects are directly financed by the car-manufacturing industry: Volkswagen became a partner in the Dead Sea Magnesium Ltd and Ford has done considerable investments in an Australian magnesium plant in Queensland.

A second important factor in favour of the exploitation of marine magnesium by the United States is the relative small continental reserves the county is disposing of (15 million ton). If the actual consumption remains at the same level, the continental reserves will be exhausted by 2060. Australia is carrying out a similar policy. At the end of 2004 a new

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Figure 2. Traditional system of "marais salants" on the "Tile de Ré" on the Atlantic Coast (France). Source: La Charente-Maritime: un patrimoine naturel.
plant in the state of Western Australia will start extracting marine magnesium at a yearly rate of 50,000 ton. Although the country actually exports magnesium, an increasing demand is forecast due to ever-increasing needs of the non-ferro industry.

Bromine

Bromine (Br) is a foul smelling corrosive liquid7. Bromide represents only one millionth of the earth’s crust and the concentrations in which it is found are never important since it combines with nearly all other chemical elements8. Hence nearly 99% of the total bromine present on earth can be found in the seas and oceans under the form of different combinations8. In seawater it is mostly present in the form of a bromide-ion (Br-). This is the case for such salts as NaBr, KBr, MgBr2, and CaBr2. Bromine can also be found on the continental shelf, mostly in salt deposits. Such locations can be found in Germany (Stassfurt) and in the United States (Arkansas9, Michigan, Ohio and West Virginia).

Bromine is playing an important role in modern society:
—40% of the produced bromine is used as fire-retardant to decrease the inflammability of products mainly used in the building industry. The most used bromine additives are polybromine biphenyl (PBB) and tetra bromine biphenol A (TBBA). Furthermore, several microprocessors are protected by a plastic layer containing a quantity of TBBA.
—Bromine under the form of ethylene dibromide is used as “seawenger” in the car industry to avoid the deposition of lead in the motor. Although this use has strongly decreased in the Western countries, it still represents 15% of the total consumption of bromine in the world.
—Another 15% of the produced bromine is used in agriculture as brominated pesticides. Methyl bromide is a very strong soil disinfectant and protects bulbs and sensitive hothouse plants from diseases.
—Additionally the pharmaceutical industry is a very common user of bromine—bromine methane (CH3Br)—as disinfectant or as bleach.

The two most important bromine-producing countries, during 2000, were the United States with a supply of 229,000 ton (45% of the total world production) and Israel with a supply of 185,000 ton (35% of the total world production). Smaller bromine producing countries are China (45,000 ton), the United Kingdom (30,000 ton) and Japan (20,000 ton). All other bromine-extracting countries have a bromine production below 3,000 ton. By the end of 2002, Jordan should become a main producing country. The opening of a new bromine complex in Safi, on the shore of the Dead Sea, is expected to produce an extra 50,000 ton per year.

The total world bromine production amounted in 2000 to 542,000 ton. Of this amount 64% were produced by three concerns. The largest is the Dead Sea Bromine Group (DSBG) located on the Dead Sea in Israel. Approximately 90% of the Israeli production is exported and represents some 80% of the bromine world trade. The two other big concerns, the Great Lakes Chemical Corporation and the Albemarle Corporation, are both located in the United States. Although the two plants delivered 94% of the American production, the United States needed to import 10,000 ton additional, mainly from Israel.

The total continental bromine reserves are quite small and estimated at 16 million ton. The known reserves of the United States amount to 11 million ton. France has 1.6 million ton and Spain 1.4 million ton. On the other hand the marine reserves are mostly unlimited since the total quantity of bromine dissolved in seawater amounts to mostly 86,000 billion ton. The Dead Sea is estimated to contain 1 billion ton of bromine. Also underground water can contain bromine. The university of Warsaw estimated the quantity of bromine contained in the Polish underground waters at 36 million ton.

Bromine can be extracted from seawater by conducting chlorine gas through the water. This results in the substitution of bromine by chlorine and the gathering of the bromine gasses. An other way is the use of chlorine gas and carbon disulfide (CS2). In this second method the bromine precipitates with the sulphur once the chorine has substituted for it. The first problem is that only 60% of the present bromine can be extracted. A second problem is the high cost of this process since it requires quite pure seawater. In comparison nearly 90% of the present magnesium can be extracted from seawater and there is no need to first purify the seawater.

The ever-increasing use of bromides, especially in agriculture is however a real threat for the environment. They pollute the surface waters, rivers and seas. By way of the food chain they enter the organism of animals and in a further phase the organism of man. High concentrations in the human body can cause dizziness, tiredness, muscle problems and even psychological trigger problems. In case of extreme intoxication, lungs and the nervous system can be badly damaged. Since two decades industrialized countries are very much aware of this problem and are attempting to reduce the use of bromide in agriculture, but most countries, including countries boarding the Black Sea, are still using it on a large scale. Next, research led by the World Meteorological Organization11, has demonstrated that methyl bromides do play an important role in the destruction of the ozone layer. Not only developing countries, but also Eastern Europe, are making use of methyl bromides on a very large scale. Under the Montreal Protocol, the United States will phase out methyl bromide as a crop pesticide over the 2001–2005 period. Problem is that agricultural products grown and treated with methyl bromide in Mexico will still be imported and sold on the American markets12. The same can be said about Eastern European agricultural products sold in Western Europe.

Recent research has shown that ethylene dibromide (EDB),

7 bromine (Greek) = stench.
8 With exception of the elements of the noble gas group: helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn).
9 Frenchman Antoine Jérôme Balard identified, in 1826, for the first time bromine in seawater.
10 Arkansas is the most important bromine producing state of the US.

11 In cooperation with the (U.S.) National Oceanic and Atmospheric Administration and the (U.S.) National Aeronautics and Space Administration.
12 Mexico is not expected to phase out methyl bromide before 2015.
getting into the atmosphere by way of exhaust-gases from cars, not only have carcinogenic properties but also are mutagenic\textsuperscript{13}. On the other hand polybromine biphenyls (PBB) could be affecting the immune system. In Germany law already forbids use of brominated scavengers. Although the further use of bromine and the use of new applications of bromine must be accompanied with a lot of care, in a near future very strict rules or even a total ban on some applications may be imposed by international conventions. In a few chemical reactions bromine is already replaced by chlorine and iodine. Aniline, ethanol or methanol can replace ethylene dibromide and lead in gasoline for cars.

**THE CASE OF THE BLACK SEA COASTAL REGION**

Looking at the impact of the exploitation and use of salt, magnesium and bromine upon the environment in general, some extrapolations may be made on the effects those minerals can have on the specific biotope and environment of the Black Sea region.

The surface water of the Black Sea has a characteristic salinity varying between 1.5% and 1.8% (compared to the 3.8% of the Aegean Sea). This results from the important quantities of fresh water brought into the Black Sea by large rivers such as the Danube, with a yearly discharge of 203.4 km$^3$ per year, the Dnjestr (52.3 km$^3$ per year) and the Don (29.3 km$^3$ per year). Other discharging rivers are the Dnjestrj, the Bug and the Kuban. A second reason is the fact that the Black Sea has a quite low evaporation rate due to its relatively northern location. Furthermore the Black Sea is a nearly closed sea only connected to the Mediterranean by two narrow straits: the Bosphorus and the Dardanelles.

However, a second specific phenomenon is taking place at those two straits: an important upper-stream of slightly salty water is leaving the Black Sea at the surface, while a small salty under-stream is entering the Black Sea at the bottom of the straits. This salty water gathers in the deeper parts of the Black Sea Basin. Because of the relative fresh and thus lighter surface water, the upbuilding of the mass of water in the Black Sea is quite stable and there is nearly no vertical water movement, leaving the deepest parts of the sea deprived of oxygen.

Assuming that Wallace S. Broecker's thesis—proposing that oceans are not the final resting place of erosion material, but only an intermediate step—is correct, care should be exercised as to what extend this thesis can be applied. Since the theory of plate tectonics is implied, a single cycle from ocean back to ocean spreads over several million of years. However modern transportation and use of large quantities of sodium chloride, magnesium, bromine and other minerals have drastically increased the velocity at which the oceanic sediment layers are lifted above sea level and eroded back into the ocean. In a first phase this results in a high pollution level of rivers. Further, if the river is discharging into an open sea or into an ocean, the effects on the environment will be relatively small. However, discharging into a closed sea, like the Black Sea, could mean a real threat for the entire environment.

This fragile equilibrium in salinity and water layers must be protected from changes due to human activities. One of the most important characteristics of the Black Sea is the lack of pollution. An important contribution of wastewater containing salts, acids, alkalis, heavy metals or other minerals by rivers discharging into the sea could result in more or less drastic changes in the ecosystem. It is thus very important that not only the countries surrounding the Black Sea, but also countries upstream take appropriate measures to protect the water quality of those rivers. Salt content in wastewater should be reduced to a level corresponding to their concentration in natural water. In comparison, in the years 1970 the water of the Rhine River was so salty due to the activities of the French salt industry in Alsace, that a photograph could be developed with Rhine water in locations downstream. After agreements between Switzerland, Germany, France and The Netherlands, and strong control of the wastewater, salt content was reduced to a normal level. Happily most of the states boarding the Black Sea are aware of the problem and some projects were started to decrease the discharge of harmful wastewater into the Black Sea.

One of the projects, "Development of an ecologically friendly membrane technology"\textsuperscript{14}, was launched in the framework of the Black Sea Economic Cooperation and is of interest to Turkey, Bulgaria, Georgia, Ukraine and Greece. The project stipulates:

- the development of the improved electro-membrane technology for the de-ionized water production at three enterprises of food, medical and microelectronic profiles of the Black Sea Economic Cooperation;
- the creation of water recycling at one of galvanic enterprises;
- the dissemination of the new technology to all interested enterprises of the countries belonging to the Black Sea Economic Cooperation.

On a wider scale a "Convention on the protection of the Black Sea against pollution" was drawn up in April 1992. In this Convention the contracting parties are determined to act with a view to achieve progress in the protection of the marine environment of the Black Sea and in the conservation of its living resources. The parties are conscious of the importance of the economic, social and health values of the marine environment of the Black Sea and convinced that the natural resources and amenities of the Black Sea can be preserved primarily through joint efforts of the Black Sea countries. Article VII of the Convention handles "pollution from land-based sources"; the contracting parties are requested to prevent, reduce and control pollution of the marine environment of the Black Sea from land-based sources. The problem of this convention—but this can be said of most conventions—is the control of all countries through which the rivers are passing. The "good will" attitude of those states is required. If the

\textsuperscript{13} Source: Ibiblio; Chapel Hill, North Carolina, USA, 2000.

\textsuperscript{14} Source: New proposals of Russia for international cooperation within the Black Sea Economic cooperation organization; Black Sea Economic Cooperation, Kuban State University, 1998. See annex page 15.
concerned countries do so, it will only be to the benefit of the entire Black Sea region.

ANNEX

Development of an Ecologically Friendly Membrane Technology of Water Treatment for the Black Sea Region Enterprises with the Purpose of Decreasing Harmful Wastewaters into the Black Sea

Project

Goal of the Project: Conversion of the food, medical, microelectronics, galvanic and other industries to the ecologically friendly water treatment technology excluding generation of wastewaters containing acids, alkalies and heavy metals and reducing salt content in the wastewaters to a level corresponding to their concentration in natural water reservoirs.

Summary of the Project: For today, either ion-exchange technology or distillation have been applied for the production of pure and deionized water (food industry, microelectronics) as well as for the production of water for medical purposes (drugstores, hospitals, resorts). In the first case, the production of pure water is accompanied by formation of acid and (or) alkaline wastewaters; in the second case, excessive electric power is consumed which is indirectly connected with the environment pollution. Electromembrane technology for obtaining the pure and deionized water and the water for medical purposes is developed at the Kuban State University and applied in certain industries. The new technology is characterized by low power consumption and low demand of chemical reagents, and due to this fact, the salt concentration in wastewaters does not exceed the salt concentration in natural water reservoirs. The new technology is protected by five patents and thirty investors certificates of the Russian Federation. The project stipulates:

(1) the development of the improved electromembrane technology for the deionized water production at three enterprises of food, medical and microelectronic profiles of the Black Sea Economic Cooperation;
(2) the creation of water recycling at one of galvanic enterprises;
(3) the dissemination of the new technology to all interested enterprises of the countries of the Black Sea Economic Cooperation.

Results expected: Improvement of the Black Sea region ecological situation by reducing a concentration of polluting matters in wastewaters of industrial enterprises situated in a littoral zone; a 20–50 times reduction of the power consumption for the water treatment.

Draft Economic Estimate: Investments required: US $600000 Potential sales volume: US $1200000 Term of the project recoupment: 4 years Period of the project fulfilment: 2 years from the date of financing