By Stig H. Fonselius

STAGNANT

THE BALTIC SEA is a major shipping highway that serves industrial centers in Northern Europe and the U.S.S.R. Chemical and organic wastes—by-products of industrial, urban, and shipping activities — impede the life-supporting capacity of the Baltic. This threat is heightened by an influx of sewage, much of it untreated, from the millions of persons living along the coast. Modern synthetic detergents and fertilisers have contributed to a sharp rise of phosphate levels in the sea that may strain the critical oxygen balance by feeding algae which then proliferate, die, and cause oxygen depletion during decomposition by bacteria. Overfertilisation may initially increase the number of commercially valuable fish in some areas, but the long-term result may be a reduction of oxygen that is essential to marine life.

Reduced oxygen content of shallower water already has changed the composition of marine plants and animals in some fjords and archipelagos. Sewage sediment off Gothenburg on Sweden's west coast has contributed to a decrease in the diversity of animal species. Pollution of Öresund, the sound off Copenhagen, has been marked by pollution-indicator organisms, and pollution may have impaired reproduction of certain marine species. Viruses and bacteria harmful to man have been reported in some regions.

Other pollution problems plague the 800-mile long sea. Fibers from cellulose industries suffocate bottom life and destroy fish spawning grounds. Ammunition, poison gas containers, and other military cast-offs disposed of during and after World War II foul fishing gear in the central Baltic and threaten the safety of fishermen. Mercury from compounds in pesticides, agricultural products, and paper manufacturing wastes have often built up to dangerous levels in fish and consequently have forced suspension of commercial fishing in many coastal areas. Another potentially hazardous industrial chemical, polychlorinated biphenyl, or PCB, is at high levels in Baltic fish, sea birds, and seals. DDT concentrations in the seals of the Baltic are up to ten times higher than those in their cousins in the North Sea. Local episodes of oil pollution, though so far minor, are a potentially serious threat in the confined waters of the Baltic, particularly in view of the large modern tankers scheduled to carry petroleum products there.

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The pollution threat in the Baltic is similar to that in Lake Erie, although one obvious difference is the scale involved — the Baltic is fifteen times larger than Lake Erie. Another difference is a natural tendency toward stagnation in the Baltic due to heavy influx of salt water, a problem that does not occur in freshwater. This tendency means that this century's sharp decline in dissolved oxygen content in the Baltic must be ascribed to natural as well as to man-made causes. At the same time, the naturally low content of oxygen in the deep

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Nearly twenty million people live along the Baltic coastal areas. Enormous amounts of urban and industrial wastes are discharged into the Baltic. Heavy sewage discharges causing reduced oxygen content of the water followed by changes in marine life have been reported from Stockholm, Sweden, shown above.

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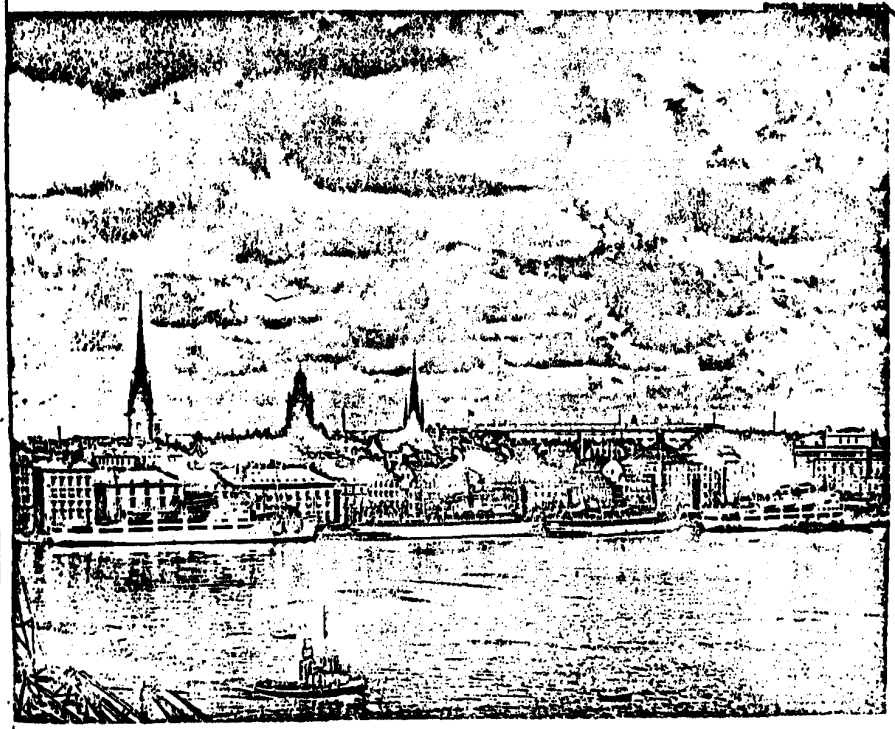
SEA

Stagnation periods are turning the entire deep-water area of the Baltic into a large oceanic desert without any kind of life except anaerobic bacteria.



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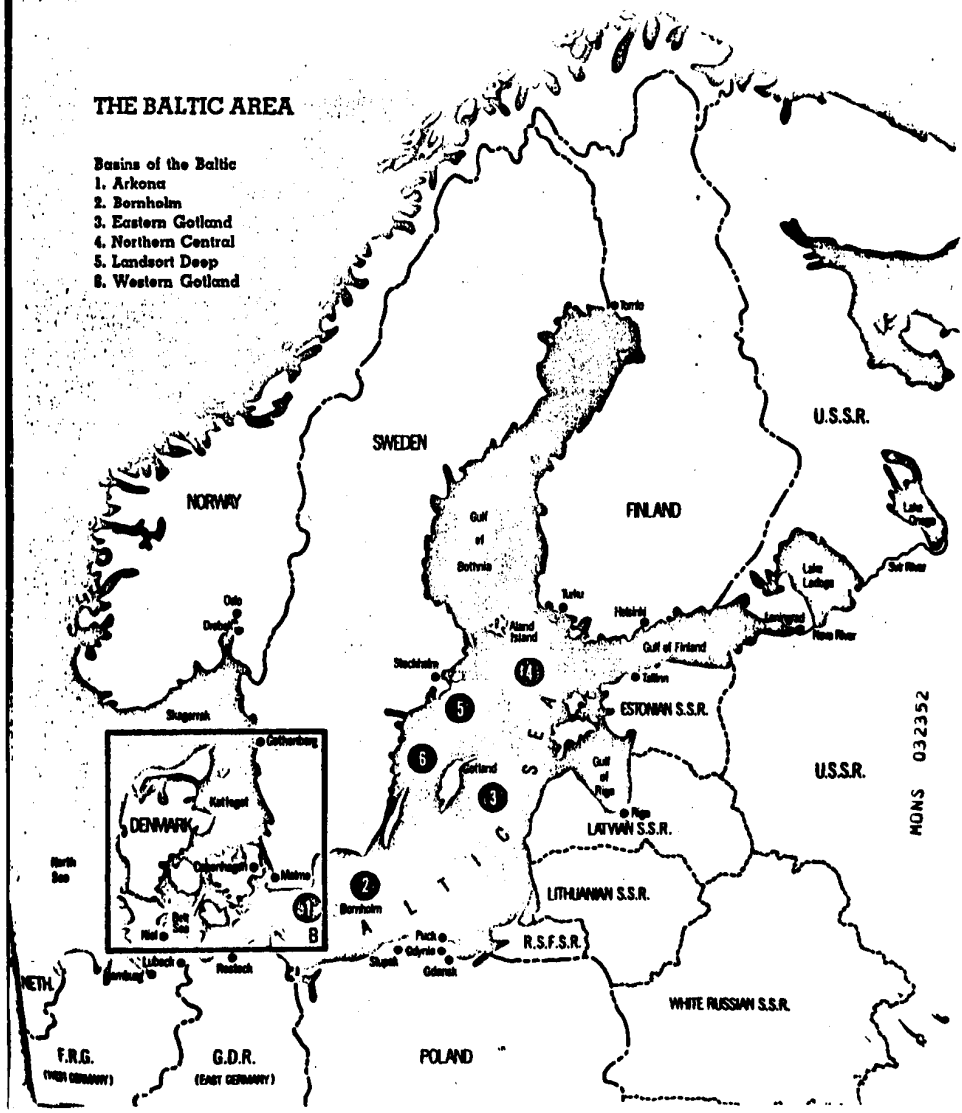
THE BALTIC AREA
Basins of the Baltic
1. Arkona
2. Bornholm
3. Eastern Gotland
4. Northern Central
5. Landsort Deep
6. Western Gotland
NORWAY
SWEDEN
FINLAND
U.S.S.R.
Gulf of Bothnia
Tornio
Turku
Helsinki
Aland Island
Gulf of Finland
Lake Ladoga
Lake Onega
Svir River
Leningrad
Nova River
Oslo
Drobak
Stockholm
Tallinn
ESTONIAN S.S.R.
Skagerrak
Gotland
Gulf of Riga
Riga
LATVIAN S.S.R.
LITHUANIAN S.S.R.
R.S.F.S.R.
WHITE RUSSIAN S.S.R.
Bornholm
Puck
Gdynia
Slupsk
Gdansk
Lubeck
Rostock
Kiel
Bremen
North Sea
Gothenburg
Kattegat
DENMARK
Copenhagen
Malmo
Belt Sea
B
NETH.
F.R.G.
(WEST GERMANY)
G.D.R.
(EAST GERMANY)
POLAND
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Profile of the Baltic

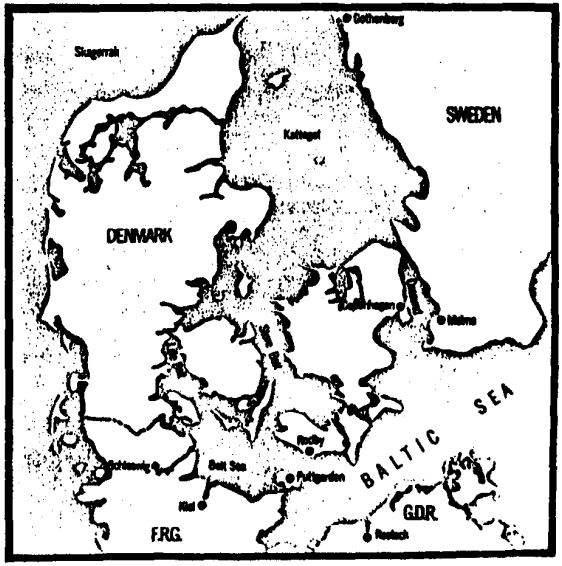
The Baltic separates Scandinavia from the European continent. The entrance to the Baltic is formed by the broad straits of Skagerrak and Kattegat. Skagerrak separates Norway from Denmark. Its continuation, Kattegat, separates Sweden from Denmark. From Kattegat three narrow straits—Lille Belt, Store Belt, and Öresund—lead into the southern end of the Baltic proper. In the northern part of the sea, three large gulfs extend far inland. The Gulf of Bothnia lies between Sweden and Finland; the Gulf of Finland separates Finland from the Estonian Soviet Republic; and the Gulf of Riga thrusts between Estonia and the Latvian Soviet Republic. The distance from the mouth of the Skagerrak at the boundary of the North Sea to the city of Tornio in the northermost part of the Gulf of Bothnia is about 1,500 miles. The surface area of the Baltic is about 374,000 square kilometers, including Skagerrak and Kattegat.

The Baltic proper is surrounded by seven countries: Denmark, Sweden, Finland, the Soviet Union, Poland, The German Democratic Republic (East Germany), and The Federal Republic of Germany (West Germany). Southern Norway borders on the Skagerrak. Large cities are located in the Baltic area. Oslo, the capital of Norway, lies on the Skagerrak. Gothenburg, the largest port of Sweden, is on the Kattegat. Copenhagen, the capital of Denmark, lies on the Öresund. The German cities of Kiel, Lübeck and Rostock are also located in the entrance area to the Baltic. At the shores of the Baltic proper and its large gulfs we find the capitals of Sweden and Finland, Stockholm and Helsinki, Leningrad (with a population of more than four million), Tallinn, Riga, Gdansk, and Gdynia. More than 50 smaller cities are located along the coasts.

Many of the coastal areas are heavily industrialized. The coasts of the Baltic with large archipelagos, river mouths, gulfs and bays make for excellent harbors, and the shipping in the Baltic plays a very important role in the economies of the surrounding countries. Ship traffic in the Danish sounds is among the densest in the world. It has been estimated that nearly twenty million people live around the Baltic in the coastal areas.

The Baltic is basically shaped like a fjord, which is a narrow inlet between steep ridges with a shallow entrance. The main difference is that the Baltic is a shallow sea with an average depth of only 60 meters. Therefore the water volume is only around 22,000 cubic kilometers in spite of the large surface area of 366,000 square kilometers inside the entrance sills (submerged ridges). The average river discharge to the Baltic is 472 cubic kilometers per year, and the average precipitation 200 cubic kilometers per year. The annual evaporation over the surface is estimated to be close to 200 cubic kilometers. This gives a net freshwater supply of nearly 500 cubic kilometers per year. The water of the Baltic is brackish, and therefore there must be a transport of salt water into the Baltic. This inflow has been computed to be also about 500 cubic kilometers per year. In order to keep the water level of the Baltic constant, the annual excess of water, about 1,000 cubic kilometers, must flow out through the Danish sounds. These are narrow and shallow. The sill depth to the Baltic at Darss is only seventeen meters. The outflowing water forms a surface current called the "Baltic Current" which in Kattegat follows the Swedish coast, and in Skagerrak the Norwegian coast. Large amounts of salt water flow into the Baltic below the surface current at Darss. The Baltic therefore has a light surface water layer with a low salinity. The salinity in the central Baltic is about .7 percent by weight, and the thickness of the surface layer is about 60 meters. Below that layer, the deep water of the Baltic has a salinity of between 1.0 and 1.8 percent and a low oxygen concentration. Although the Baltic is nearly a stagnant basin, the small volume of the deep water (3,500 to 4,000 cubic kilometers) makes it possible for the water to be renewed occasionally. The residence time of the water in the Baltic as a whole is about 22 years. The oxygen content of the deep water is, however, constantly low, but generally hydrogen sulfide is not formed there due to the occasional renewals of the deep water. These renewals are caused by unusually large inflows of salt water along the bottom of the Belts over the sill at Darss.

The topography of the Baltic shows a series of basins connected to each other over shallower sills. The main basins are: the Arkona basin, indicated on the map as (1), at the entrance area west of the island of Bornholm (maximum depth 55 meters) and the Bornholm basin (2) east of Bornholm



At left, a map of the Baltic Sea and the countries surrounding it. The Denmark area enclosed in the square is enlarged at right, showing the Belts, the three narrow straits connecting Kattegat with the Baltic Sea.

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(maximum depth 105 meters). The sill connecting them is located between Bornholm and the Swedish coast (sill depth 45 meters). East of the Bornholm basin, the large central basin of the Baltic proper begins. The sill depth at the Slupsk Furrow is 60 meters. The central basin may be divided into three main parts. The eastern Gotland basin (3) extends from the Gdansk Deep between the Baltic coast and the island of Gotland. The maximum depth is 249 meters at the Gotland Deep half way between Ostergarn on Gotland and Ventspils in Latvia. This basin is connected to the northern Central basin (4) over a 115 meter deep sill. The northern Central basin extends from Hoglund in the Gulf of Finland to Landsort at the Swedish coast. There the Landsort Deep (5), the deepest spot of the Baltic, is located (459 meters). South of the Landsort Deep, a 100 meter sill leads into the western Gotland basin (6) (maximum depth 205 meters) located between Gotland and the Swedish coast. Between the southern tip of Gotland and the island of Öland, the water depth decreases to below 50 meters. The Gulf of Bothnia is separated from the Baltic proper through a 40-meter-deep ridge extending between Sweden and the southern part of the Åland archipelago.

When heavy salt water enters over the sill at Darss, it follows the deepest channels along the bottom of the Baltic proper. The Arkona basin is first filled up to the depth of the sill at the Bornholm basin. When the Bornholm basin is filled to the 60 meter level, the salt water may enter the eastern Gotland basin. The deep water thus circulates counter-clockwise around Gotland. The deep water in the western Gotland basin has therefore moved around Gotland and has entered into the basin from the north through the Landsort Deep. No deep water can enter into the Gulf of Bothnia due to the shallow sill at Åland. The deep water is slowly diluted, and the salinity decreases from 1.5 to 1.3 percent in the southern part to 1.0 percent in the western Gotland basin. There the last remains of the inflow are mixed into the surface layer. Due to the great difference in salinity between the surface water and the deep water, a very stable permanent halocline is formed in the Baltic proper. The halocline is a permanent layer that marks the beginning of a sharp, stepwise increase in salinity with depth. It is an impediment to the mixing and effectively isolates the deep water from the surface. Therefore the deep water cannot renew its oxygen content, and the oxygen concentration decreases rapidly and may be close to zero in the bottom water of the Bornholm basin. This is due to the fact that the inflowing water occasionally may be so heavy that it remains for a long time in the basin. The next inflow may consist of water with a lower density. In that case it may float over the heavy bottom water directly to the next basin. If the bottom water stays long enough in the basin, it may completely lose its oxygen and hydrogen sulfide may be formed there. Through diffusion and turbulence in the boundary layer, the density eventually decreases so much that a new inflow may expel the old water from the basin. The hydrogen sulfide disappears and the oxygen concentration increases in the deep basin.

The old water from the basin is displaced northward into the area north of Gotland and from there to the Gulf of Finland and the western Gotland basin. If the water contains hydrogen sulfide, it will react with the oxygen of the water it is mixing into. Therefore the oxygen values will decrease in the northern parts of the Baltic. If the hydrogen sulfide concentration of the expelled water is high, all oxygen in the northern Baltic deep water will be used up in the deepest parts and hydrogen sulfide will be found there. If the inflow is great enough to renew the deep water of the whole Baltic proper, the hydrogen sulfide will, of course, eventually disappear through reacting oxygen below the halocline. No hydrogen sulfide will reach the surface layer.

During stagnant conditions nutrients will accumulate in the stagnant water. These nutrients originate from decaying organic matter. A part of these nutrients is deposited into the bottom sediments. When hydrogen sulfide is formed close to the bottom, these nutrients will dissolve in the water, increasing the nutrient concentration of the stagnant water still more.

When the water of the basins is renewed, the nutrients are spread out in the deep water and eventually they are mixed up into the surface water during the winter, when the vertical convection mixes the whole surface layer. This causes an enormous fertilization of the surface water. During the spring, the phytoplankton bloom will increase to a corresponding degree. This again will increase the transport of dead organic matter to the deep water. The oxygen of the deep water will be used up quickly, and hydrogen sulfide will soon be formed close to the bottom. Again nutrients will be accumulated through dissolution from the sediments and mineralization of organic matter in the water. Thus, alternating periods of hydrogen sulfide and oxygen will occur in the deep basins. The hydrogen sulfide periods will become more prolonged until a steady state is reached. This serious development seems to be occurring in the Baltic, at present, as all observations indicate. S.H.F. □

Figure 1

The concentration of oxygen essentia... to marine life has decreased near the bottom of the Northern Central basin of the Baltic from slightly over 3... percent of saturation in 1900 to zero in January 1970, as is shown in this graph. The depiction of oxygen is due to both stagnant conditions and the burden of pollutants

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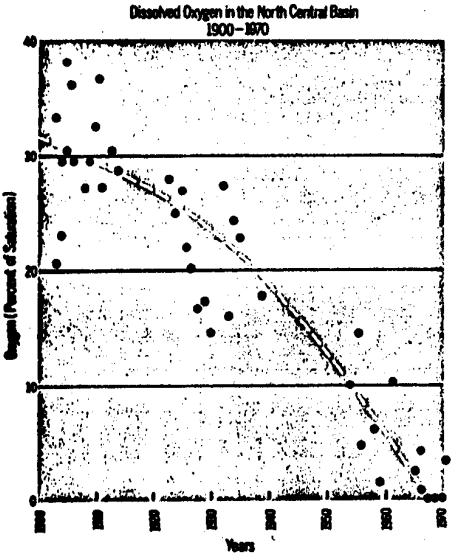

(continued from page 2)

basins of the Baltic makes control of pollution even more crucial to protect its marginal life-supporting capacity.

Last year was designated "Baltic Year" to focus the attention of the scientific community on unresolved questions about the state of the sea. Another major result of such activities was a report published in February 1970 as the cooperative research effort of representatives from the seven countries bordering the Baltic. The report was prepared under the auspices of the International Council for Exploration of the Sea (ICES), an oceanographic organisation with headquarters in Denmark that established a working group in 1967 to assemble scientific data on the pollution threat to the North Sea. That investigation led to a research report that identified major sources of pollution along the coasts of central and northern Europe and England. The research was carried forward by another working group established in 1969 that helped to gather data for the 1970 Report on the Baltic, entitled "Report of the ICES Working Group on Poilution of the Baltic Sea." I will describe major findings of the report in the course of this article.

Stagnant Basins

The Baltic is generally considered to be a stagnant basin, and there has always been an oxygen deficit in the Baltic deep water. The stratification in sediment cores from the Baltic shows dark or black bands, which indicate stagnation periods. These become more frequent towards the top of the core.

A stagnant basin is a semi-enclosed sea area with a restricted oxygen supply to the deep water. This is generally caused by narrow and shallow connections to the ocean and by the occasional or permanent existence of a light surface water layer, which isolates the deep water from oxygen exchange with the atmosphere.

Natural stagnant basins are generally found in areas with a humid climate. In such areas the annual freshwater supply through river discharge and precipitation exceeds the evaporation from the sea surface. The excess of freshwater then forms a brackish layer of light surface water, which impedes the replenishment of oxygen to the deep water by prohibiting the vertical mixing of layers. The existence of a shallow sill (a submerged ridge) in the inlet area restricts the horizontal water exchange. This gives the deep water a long residence time in the basin.

Bacteria utilize oxygen to convert dead organic material to simple inorganic compounds, carbon dioxide, water, phosphate, nitrate, and silicate. If the water exchange in the deep water is very slow and the production of living matter by small plants, or phytoplankton, in the surface layer is relatively high, the dissolved oxygen in the deep water may be completely used up because of the continuous supply of organic matter in the form of dead organisms which sink down from the surface. Then hydrogen sulfide is formed in the deep water through reduction of sulfate by anaerobic bacteria (bacteria that live in the absence of oxygen). In this process, the oxygen from the sulfate ions is used to oxidise organic matter. Ammonia and nitrogen gas are formed during the process. Due to the slow water exchange, inorganic compounds thus formed accumulate in the deep water. Therefore, the concentration of hydrogen sulfide, carbon dioxide, nitrogen, ammonia, phosphate and silicate is extremely high in stagnant basins where the oxygen has been completely exhausted. A stagnant basin thus acts as a kind of nutrient trap. Nutrients are removed from the surface area and accumulate in the stagnant deep water. In spite of the high nutrient concentration in the deep water, the surface water may have a very low nutrient content, often close to zero.

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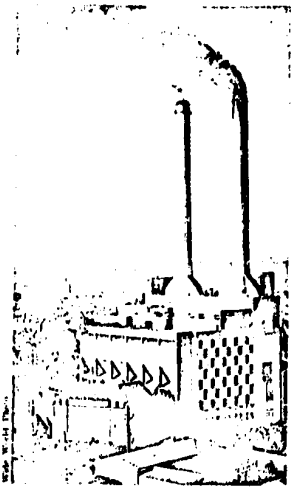

Pollution by heated water from nuclear and fossil fuel power plants on the shores of the Baltic and on inland rivers and lakes may worsen damage from pollution and natural processes. Above, the Aalborg Community power plant in Denmark.



Stagnant basins are not very common in nature, but the lower levels of the Black Sea, several Norwegian fjords, and similar formations in Greenland and Canada are known to be naturally stagnant. The vastly larger Baltic is also a partially stagnant basin. A Norwegian fjord on the Norwegian Sea is shown at right.

The best known stagnant basin is the Black Sea. The largest stagnant area of the world, it contains enormous amounts of hydrogen sulfide and is known to have been stagnant for at least 6,000 years. The volume of the Black Sea is approximately 538,250 cubic kilometers. The Black Sea is characterized by the absence of coastal features and by very deep shores that give it the shape of a large bowl. The maximum depth is 2,200 meters, and the average depth of the basin is 1,271 meters. The average residence time for the water of the whole Black Sea can be calculated to be around 1,350 years, being much longer in the deep water.

Stagnant basins are not very common in nature, but several Norwegian fjords (narrow inlets of the sea between high cliffs or steep slopes with shallow entrances) and similar formations in Greenland and Canada are known to be naturally stagnant. A fjord has generally a narrow and shallow sill at the entrance, a considerable water depth inside the sill, and a supply of freshwater through a river which discharges its water in the innermost part. Some fjords have an annual water exchange due to autumn storms, but there are fjords with constantly stagnant water which contain large amounts of hydrogen sulfide.

The Baltic is one of the most investigated seas of the world and has been the subject of an extremely

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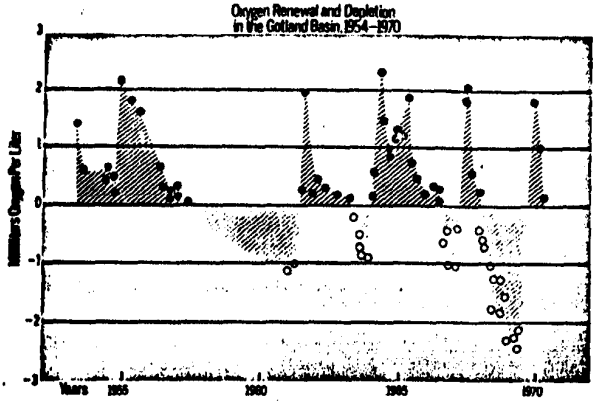
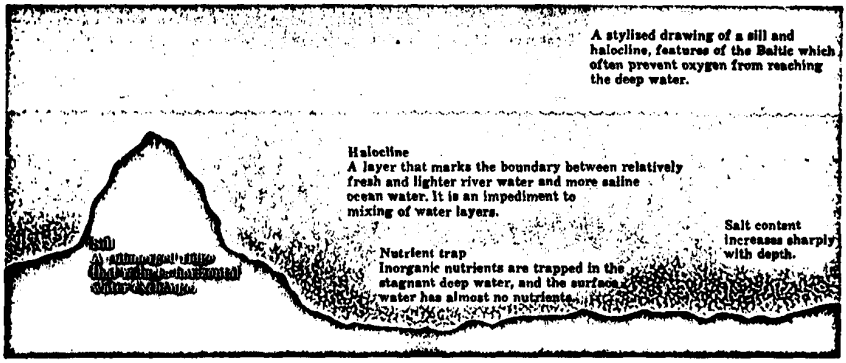


Figure 2

Under normal conditions bodies of water maintain sufficient dissolved oxygen to support ecological cycles. The Baltic, however, undergoes periods of oxygen depletion. The cycle of alternating water (and oxygen) renewal and stagnation periods in the Gotland basin from 1954 to 1970 is shown in this graph. The water renewals are expressed as oxygen increases and are indicated by the black dots and black diagonal lines. The stagnation periods are expressed as oxygen decreases followed by hydrogen sulfide formation; the hydrogen sulfide values are expressed as "negative oxygen" and are indicated on the graph by the circles and white diagonal lines. The most recent measurements show that the oxygen values in the basin's deep water are decreasing fast and have already dropped to zero in some areas. It seems that the stagnation periods are becoming more frequent and that the amount of hydrogen sulfide produced at the depth of the cycle is increasing.



long series of observations. Hydrographic measurements have been carried out rather regularly since the beginning of the present century. The first oxygen measurements in the deep basins of the Baltic were made during the 1890s, and from 1904 regular oxygen analyses have been carried out using the Winkler method. The work was interrupted only during the two world wars. A compilation of the results from some main stations during this period shows that the oxygen concentration of the deep water in the northern part of the Baltic proper has decreased from around three milliliters oxygen per liter of water in the beginning of the century to zero in 1969 (Fig. 1). During 1969 hydrogen sulfide was found in all the main deep basins of the Baltic proper. Hydrogen sulfide formation had earlier been observed only occasionally in a few places. The first formation occurred in the large Gotland basin (see map on p. 4) in 1932. The water was renewed the following year, and no new hydrogen sulfide formation was observed until after World War II. In December 1951 there occurred an unusually large inflow of salt water through the Belts (the three narrow straits leading into the Baltic). In only a few weeks, more than 200 cubic kilometers of salt water penetrated into the Baltic. This caused a long stagnation period in the Gotland basin, where the water was renewed ten years later, in 1961. The old

MONS 032357

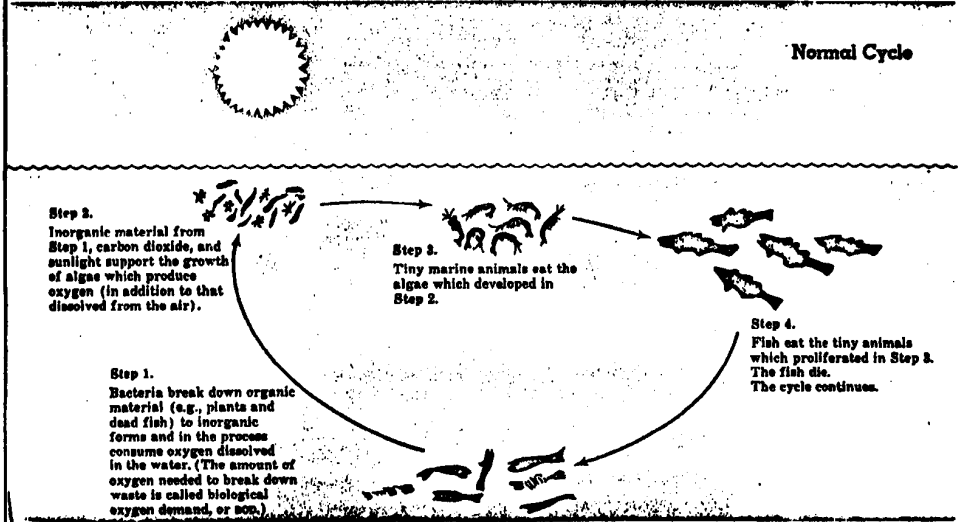
stagnant water was spread into the deep water north of the Gotland basin, causing unusually low oxygen values in the water there. Since then, six different inflows have occurred, and some of them have been large enough to cause hydrogen sulfide formation in the Gotland basin and in others.

These stagnation periods are turning the entire deep-water area into a large oceanic desert without any kind of life except anaerobic bacteria.

The last stagnation period observed began in the middle of 1966. In 1968, all the deep basins of the Baltic proper contained hydrogen sulfide. Such an enormous hydrogen sulfide poisoning of the Baltic has never been observed in historical time, even though stagnation periods have occurred earlier in geological time in the Baltic. The water of the Baltic was again renewed during 1969 through an inflow of water from Kattegat which began in November 1968 and January 1969. In January 1970 there were only traces of hydrogen sulfide left in some of the deep basins in the northern part of the Baltic proper. The most recent measurements show that the oxygen values in the deep water of the Gotland basin are fast decreasing and that all oxygen will be used up in the near future. A new hydrogen sulfide period will then begin. It seems that the stagnation periods get more and more frequent and that the amount of hydrogen sulfide formed increases each time (see Fig. 2). A cycle of alternating stagnation periods and fertilizations has started, and it seems to be very difficult for nature to restore the normal conditions.

Complex Causes

One may, of course, ask the reason for this development. It is known that the salinity of the Baltic has increased during the present century. This increase is a natural phenomenon and is caused by changes in the water balance of the Baltic. This may have increased the stability of the water stratification and thus decreased the water exchange through the halocline (a permanent layer which marks the beginning of an increase in salinity and which isolates deep water from the surface). It is also known that the temperature of the deep water has increased more than one degree centigrade during the same period. This has increased the oxidation rate of organic matter. It has been shown in freshwater research that a ten-degree increase of the water temperature will double the oxidation rate. Then it may be assumed that a one-degree increase in the Baltic has increased the oxidation rate by some 10 percent. The increased oxidation rate will, of course, increase the oxygen utilization in the deep water. The reason for the increased temperature is probably the observed increase of the surface temperature in the North Atlantic during the cen-



MONS 032358

tury. This increase is of climatological origin.

These two natural factors may well have caused the observed oxygen deficit in the Baltic deep water. Another phenomenon which is connected with the increased salinity is the fact that in the central Baltic the halocline during the century has risen from 80 meters below the water surface to 60 meters, increasing the volume of the deepwater body by some 200 cubic kilometers. It has also been observed that during the last fifteen years the concentration of dissolved phosphate has increased nearly three times in the deep water. This may be ascribed to the dissolution of phosphate from the sediments during reducing (oxygen consuming) conditions and to mineralization of organic phosphorus from large amounts of dead organisms sinking down from the productive layer. Fertilization and greater growth of algae caused both by natural processes and by sewage and industrial wastes in the surface layer have obviously increased the transport downward of dead matter.

The Pollution Problem

There are, however, other important factors which may have played a role in the eutrophication processes in the Baltic. The water exchange is slow both vertically and horizontally. One has to recall that some twenty million people live around the Baltic. The living standard is generally high, and the area is heavily industrialized. Enormous amounts of urban and industrial wastes are discharged into the Baltic.

The working group of the International Council for Exploration of the Sea made a thorough investigation of the pollution state of the Baltic as discussed above. Members of the working group were from Denmark, Finland, Poland, the Soviet Union, Sweden, and the Federal Republic of Germany. The German Democratic Republic, which is not a member of the ICES, participated as representative from the "Baltic Oceanographers." Most countries have their own methods and rules for pollution control, and it was not easy to find a commonly acceptable way to express pollution values from different countries in a comparable way. It was finally agreed to express the results as biological oxygen demand [the oxygen used by bacteria to convert organic material to inorganic substances] during five days (BOD_5). BOD_5 figures, as a rule, give only part of the real organic load carried by waste waters, and the value of BOD_5 estimations has been discussed many times. Nevertheless, these estimations are considered to give a hint of the pollution load imposed on the oxygen supply of a body of water.

The BOD_5 figures were calculated on the basic assumption that the organic load of discharged sewage

(continued on page 40)

The Baltic

If there is poor water circulation, as there often is in the Baltic, most of the oxygen remains in the surface layer, while dead plants and animals from steps 1, 2, 3, and 4 sink to the bottom.

Stagnant Water (high salt content)

The organic material is converted by oxygen-requiring bacteria into inorganic nutrients, quickly depleting oxygen in the deep water; the surface water has almost no nutrients. The cycle is broken. In the deep water, bacteria which do not need oxygen and which produces hydrogen sulfide, ammonia, and [illegible] nitrogen, predominate. At those times when the deep water *does* mix with the surface water, the large quantities of inorganic nutrients, augmented by sewage input, support algae which proliferate, die, and cause depletion of the oxygen essential to marine life.

MONS 032359

Input

But About That Pipeline. . . .

[*Editor's Note:* In the May 1970 issue Spectrum noted that of 23 million Alaskan acres set aside for study by former Interior Secretary Udall, less than half had been designated a scenic area; the Trans-Alaskan oil pipeline route lies through the remaining land.]

The first item of Spectrum in your May 1970 issue of *Environment* deals with the [Interior] Department's proposal for the 10.5 million-acre Wrangell Mountains Natural Scenic Area. I would like to explain its relationship to the Department's classification in 1969 of the 23 million acre Copper River area, which included the Wrangell Mountains. These two actions have been taken under the Classification and Multiple Use Act of 1964 and the regulations issued pursuant to that Act. . . .

We are involved here with what is essentially a five-step program.

1. Reconnaissance inventory of the resources of an area of public lands.
2. Classification of lands in the area for multiple use management, after analysis of the inventory, publication of a proposal to classify, and public hearings and other meetings.
3. Detailed inventory of the resources in the classified area.
4. Designation of all or parts of the classified area to indicate the general objectives of future management, after analysis of the detailed inventory and public discussion of the proposal to designate.
5. Detailed planning for management of the designated area.

For the Copper River-Wrangell Mountains Area, the first two steps were completed by January 1969. A total of 23 million acres were classified for multiple-use management. Studies since then have led the Department to an initial proposal that the Wrangell Mountains and Chitina River Valley portions of the classified area should be managed primarily for retention of their natural values. This intention was announced as the proposal to designate this portion of the classified area as the Wrangell Mountains Natural Scenic Area. Studies of the remaining area will be made to determine the best management in the public interest. . . .

JOHN MATTOON
Chief, Office of Information
Bureau of Land Management

Stagnant Sea

(continued from page 11)

person per year. The organic load was estimated for each country as directly and indirectly (by rivers, for instance) discharged sewage. The phosphorus load of the waste water was estimated in the same way. The phosphorus content was calculated from the basic assumption that the discharge is equivalent to one kilogram per person per year.

In many cases the BOD_n and phosphorus figures were "corrected" in relation to the degree of sewage treatment or other local circumstances known to be important for the estimations. It has to be stressed that the figures are rough approximations. This is especially true for those figures which refer to indirect discharge. The members of the committee discussed the difficulties of expressing pollution conditions in more exact ways and decided to use the figures in the report as they were. Sewage pollution and industrial pollution were estimated separately in the report.

Sewage Pollution

Table 1 shows the sewage BOD_n and phosphorus content figures for the different countries summarized for the different areas of the Baltic as indirect and direct sewage discharge.

TABLE 1

	No. of Inhabitants (in millions)		BOD_n Tons/Year		Phos. Tons/Year	
area	on shore	on river systems	from shore	from river systems	from shore	from river systems
Bothnian Bay	.220	.167	5,500	4,500	220	220
Bothnian Sea	.865	.495	13,650	12,200	780	600
Gulf of Finland	4.868	.797	121,450	19,200	5,050	870
Baltic Proper	3.335	2.065	60,900	38,000	2,850	2,270
Baltic Sea	8.990	3.524	201,500	65,900	9,700	4,000
Belt Sea	1.195	2.800	40,100	21,000	1,240	2,000
Öresund	1.770	.310	40,000	2,000	1,900	350
Kattegat	.525	.360	16,000	5,000	890	400
Total	12.588	6.794	298,300	94,500	13,859	7,610

As can be seen, the quantities of sewage discharged into the Bothnian Bay and the Bothnian Sea are small; those released into the Baltic proper, the Belt Sea, and the Kattegat are moderate. Those de-

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posited into the Gulf of Finland and the Öresund are, however, large, due to the dense population, especially in the Leningrad and the Copenhagen-Malmö regions.

Most of the directly discharged sewage is not treated at all or undergoes only primary treatment —separation of liquids and solids. There are some biological treatment plants, but at present no treatment plants for chemical precipitation of phosphorus compounds have been built. In all countries much greater efforts have been made hitherto to avoid pollution of the inland waters.

In some countries pipelines extending out some distance from the shore have been constructed or are planned in order to protect nearshore areas from sewage pollution. The working group agreed that this is generally not a good way to dispose of sewage or industrial wastes unless they are sufficiently treated beforehand. The heavy load of nutrients carried out by pipelines can eventually influence the conditions so much that they may be harmful to fisheries in areas with restricted water exchange. A number of coastal areas were found to be more or less influenced by sewage discharges, often in combination with local industrial wastes.

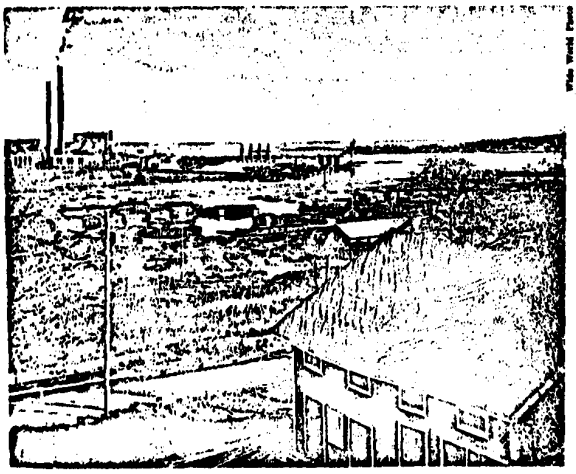
Heavy organic loads causing, among other things, reduced oxygen content of the water followed by changes in the marine flora or fauna, have been reported from the fjords of Schleswig-Holstein and the Bay of Lübeck in Germany, the archipelagos of Stockholm in Sweden, and Turku and Helsinki in Finland.

Even if no remarkable oxygen decrease is observed, sewage pollution may contribute to changes in the distribution of some organisms. In the heavily polluted archipelago off Gothenburg there is a good oxygen supply, but a thick sediment layer contributes to a decreased number of hard-bottom animals and the water turbidity seems to prevent the distribution of some fish species. In the same area the number of soft-bottom species has decreased, but the number of individual fish has increased.

Changes in the bottom fauna caused by pollution have been observed in many parts of the Öresund. The increase of some pollution indicator organisms, sludge worms for example, has been established. It has not been possible to show that fish, except perhaps herring, avoid the waters of Öresund, but some scientists consider the reproduction ability of some species to be reduced. The fish population, however, seems to be replenished, mainly from Kattegat.

Heavy blooms of marine algae, caused by eutrophication through pollution, have occurred in some of the coastal areas, including the archipelagos of Stockholm and Helsinki.

Viruses and bacteria harmful to man have been reported from some places. A case of an epidemic caused by an adeno virus from Stockholm sewage has been described in the scientific literature. Different microorganisms which cause epidemics—the *salmonella* species, for example, found in the Öresund area—have been shown to survive for a considerable time in the water. *Salmonella* and viruses have also been shown to be present in the water in rather large quantities in the Puck and Gdansk



The discharge of wastes from industries located on inland lakes and rivers has severely polluted inland waters and contributed to the Baltic pollution. Shown above, a wood-processing plant on a river system in central Sweden.

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areas. All countries monitor the content of coliform bacteria in bathing waters.

An anaerobic bacterium, *Clostridium botulinum*, which may be common in sewage and which may render fish products toxic, has been found in both bottom sediments and fish of the Oresund.

Industrial Pollution

Table 2 shows the industrial pollution of the Baltic expressed as BOD_n values.

TABLE 2

Areas	BOD_n tons/year (from shore and river systems)
Bothnian Bay	160,000
Bothnian Sea	385,000
Gulf of Finland	115,000
Baltic Proper	110,000
Baltic Sea	760,000
Belt Sea	10,000
Öresund	10,000
Kattegat	20,000
Total	800,000

The coastal waters of all countries around the Baltic area are contaminated with industrial wastes, often in combination with sewage. The worst problems seem to occur on the coasts of Sweden and some of the Finnish coastal areas. This is to a great extent due to the large paper and pulp industries in these countries. The location of a large part of the Finnish paper industry in inland areas has caused severe problems for the inland waters. Plans for discharging the waste water from these industries into the Baltic through a big tunnel or through an open channel have been discussed. The paper and pulp industry along the Baltic coast in the Soviet Union is not of great importance, but it has to be remembered that large amounts of wastes from such industry are discharged into Lake Onega and Lake Ladoga. The Onega discharges into Ladoga through the Svir River, then to the Neva River, and finally to the Gulf of Finland. A great part of the Finnish paper industry discharges its wastes into the Saima water system which also discharges into Lake Ladoga. Opinions differ as to how much waste is broken down in the lakes and how much reaches the Baltic.

Liquors from pulp industries can be toxic and can also taint the flesh of fish. Furthermore, the chemicals may interfere with the assimilation process of phytoplankton. The oxygen content of the water may also be affected since sulfite liquors may contain half of the original content of wood in solution. The breakdown of this amounts to 200 to 500 kilograms BOD_n per ton of pulp.

Fibers from different kinds of cellulose industries



Cover Courtesy from National Audubon Society

Baltic sealife contains eight to ten times higher concentrations of DDT and polychlorinated biphenyl (PCB) than organisms from the Swedish west coast or from England or Canada. These chemicals are brought to the Baltic in river water and through fallout from the air. The photographs show grey seals and a white-tailed eagle, which were among the animals studied for levels of DDT and PCB.

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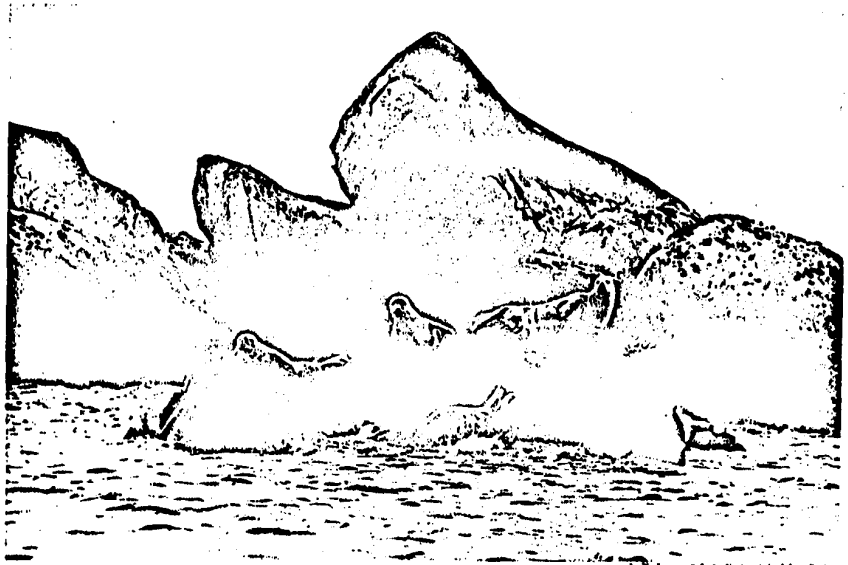

A. V. Longmoir from National Audubon Society

are often discharged in great quantities. They accumulate on the bottom, suffocating the bottom life and destroying spawning grounds for fish. The breakdown of the fibers also contributes to the decrease of the oxygen content of the water. Several examples of this are known from the Swedish coast.

Other toxic substances from industries, such as heavy metals, cyanides, arsenic, and phenols, may be dangerous even though they are discharged in small amounts. This is especially true for almost indestructible compounds such as PCB (polychlorinated biphenyls) [see *Environment*, January-February, 1970] used, for example, in paints.

Industrial wastes have been dumped into the Baltic, but this is now avoided, especially inside territorial waters. It is known that several thousand tons of raw arsenic mixed with concrete have been dumped into the Gulf of Bothnia. Waste products containing mercury have also been dumped there. Sulfuric and hydrochloric acid and chromium compounds are also known to have been dumped into the Baltic. Furthermore, phosphorus compounds, chlorinated hydrocarbons, and heavy metals like mercury are carried through the air from industrial centers in Europe and may fall into the Baltic as dust or with rain or snow. It is believed that part of the PCB found in different offshore organisms in the Baltic is brought there through the air.

Eutrophication through Pollution

The direct effect of pollution on the oxygen conditions in the Baltic probably is significant only in semi-enclosed bays and in the archipelagos. A more severe threat is the eutrophication of the surface waters by nutrients discharged in the wastes. The surface water has a very low nutrient content, and it is generally considered that phosphate is the limiting nutrient for the primary production (growth of algae) in the Baltic.

Most of the phosphorus compounds discharged into the Baltic derive from sewage. A minor part comes from industrial wastes. A rough estimation, according to some Finnish figures, suggests that the amount is a maximum of 30 percent. Therefore, most of the phosphorus is discharged in areas with a high population density.

The phosphorus figures given in Table 1 were, as was mentioned above, calculated from the basic assumption that the personal equivalent is one kilogram of phosphorus per year. The figures may be higher for some countries, and for all countries they may be increasing. In Sweden it has been estimated that sewage from communities some ten to fifteen years ago contained about 1.5 grams phosphorus per person per day and that the amount now has in-

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creased to about 4 grams per person per day. This increase is believed to depend on the increasing use of synthetic detergents, especially washing powders. These may contain up to 30 percent phosphates. The same trend has been observed in other countries. The use of phosphate-containing fertilizers in agriculture has also increased in some countries.

From Table 1 it can be seen that the total phosphorus supply from sewage and industry (excluding the Belt Sea, the Öresund, and the Kattegat) is estimated to be around 14,000 tons per year. To this amount must be added the natural amount of phosphorus in the river water (about 3,400 tons per year), the airborne phosphorus (this has been measured to be about 3,000 tons per year, a surprisingly high value), and the phosphorus brought in from Kattegat with the inflowing saline water (estimated by the author to be 6,100 tons per year). The total supply of phosphorus to the Baltic will then be 26,500 tons per year. About 8,000 to 10,000 tons are carried out from the Baltic with the outgoing surface current through the sounds. This leaves a surplus of 16,000 to 18,000 tons per year. Most of this phosphorus is taken in by organisms or is deposited directly in the neighborhood of the discharge point. In shallow areas most of the dead organic matter is included in the sediments and thus removed from the biological life cycle. Very small amounts reach the open sea areas. The effect of such eutrophication has, however, been observed in the vicinities of the large cities on the shores of the Baltic.

The increased primary production caused by this fertilization of the surface waters will be beneficial for the fisheries, as has been observed, for example, in the Gulf of Riga. It will, however, influence the deep waters in a negative way by increasing the amount of organic matter there. This may be one of the reasons for the observed increasing oxygen deficit of the deep water. The phosphorus balance of the Baltic is at present not well understood, but the very extensive data from the "Baltic Year" reports may give us a better basis for understanding.

Of the total BOD_5 load of about 1,200,000 tons per year discharged into the Baltic, 580,000 tons enter the Gulf of Bothnia. Here also many of the worst polluted coastal areas are found, especially on the Swedish side. The open parts of the Gulf of Bothnia have a generally good water circulation, and this reduces the pollution effects in the open sea. The small phosphorus supply to this area seems to be unimportant.

The BOD_5 load of the Gulf of Finland is higher than that of the Baltic proper, and in both areas the phosphorus supply has a considerable influence in the coastal areas. The open sea may also be influenced to some degree. In the Belt area and the Öresund, the phosphorus values are higher than in the open sea. It has been shown that the phosphate values of the deep water of the Öresund have increased during the last decades; and a *slightly* increasing oxygen deficit has been observed there. There are also some signs of the same trend in the Kattegat, but the observations are too few to allow any direct conclusions.

There are a few biological waste-treatment plants around the Baltic, and several are planned. There are, however, no chemical precipitation plants for removing nutrients from the waste water being built or planned. Attempts have been made to replace the phosphate in washing powders by other substances such as nitrilo-tri-acetic acid (NTA). It is, however, not known if NTA may have unknown harmful effects. Extensive research is being carried out on that problem in the Federal Republic of Germany and in Sweden.

Pesticides

Pesticides are used in agriculture, horticulture, forestry, and the textile industry. In the paper and pulp industry, pesticides are used as slimicides and preservatives. DDT probably is still the most used pesticide in the world, despite increased restrictions. DDT is found in the air and in the thin surface film on natural waters which consists of fats produced by planktonic organisms. Through turbulence it is spread downward. It may affect primary production by inhibiting the photosynthetic assimilation process of phytoplankton.

Chlorinated hydrocarbons such as DDT are soluble in fat and are only slowly destroyed through oxidation. Therefore, they tend to accumulate in tissues of living organisms, especially in the fat.

In Sweden, Dr. S. Jensen and his co-workers in 1966 found a formerly undetected chlorinated hydrocarbon by analyzing trace substances in biological material. This hydrocarbon was a form of polychlorinated biphenyl (PCB). It was found together with DDT, but it seems to be even more persistent than DDT. Analysis of tissues of marine organisms, mussels, herring, plaice, picked dogfish, cod, salmon, grey seal, common seal, ringed seal, guillemot, whitetailed eagle, and heron have shown that organisms from the Baltic contain eight to ten times higher concentrations of PCB and DDT than organisms from the Swedish west coast (Kattegat) or from England or Canada. The eagles (all found dead) contained concentrations 100 times higher than those found in eagles caught in northern Sweden (Lappland). The eagles in the Lappland area generally build their nests on the Norwegian north coast.

The investigation of the Baltic shows that the concentration of DDT and PCB increases along the food chain and that the animals on the top of the food chain therefore have the highest concentrations. Since many of the animals investigated were

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caught in the open sea, there must be a transport of pesticides and other toxic substances from land to the open sea. The concentration of chlorinated hydrocarbons seems to be ten times higher in the Baltic water than in the waters of Kattegat and Skagerrak. The reason for this certainly is the restricted water exchange through the Danish sounds. The chlorinated hydrocarbons are brought to the Baltic in river water and through direct fallout from the air.

Mercury compounds have shown the same tendency to accumulate in the food chain. Such compounds have been used as pesticides in the agriculture of some countries. In Sweden and Finland they have also been widely used as slimicides and fungicides in the paper and pulp industry. Wastes containing mercury also derive from many industries, from the burning of household wastes, and from other processes. Some of the mercury wastes themselves are toxic to living organisms. Others may be transformed by organisms into more toxic forms.

Considerable amounts of mercury have already accumulated in nature. In many Swedish inland waters and coastal areas the concentrations in fish are so high that these areas have been closed to fishing. Fish caught from such areas may not be sold or given to other persons as gifts. The fishermen themselves are, however, allowed to eat the fish at their own risk. The threshold value lies at one milligram mercury per kilogram of wet fish weight. About a dozen of the prohibited areas lie in the coastal zones.

It seems that mercury pollution is more restricted to coastal areas than DDT and PCB pollution. German investigations of cod from the open Baltic do not show unusually high concentrations. The use of mercury compounds is now to a great extent forbidden in Finland and Sweden. New substances have therefore been introduced in the paper and pulp industry. At least one of them (pentachlor phenol) has been shown to have adverse effects on fish, however.

Oil Pollution

The oil pollution problem is becoming serious in the Baltic. The oil tanker traffic increases every year, and the tankers are bigger. The seventeen-meter sill of the Baltic limits the size of the tankers to a little more than 100,000 tons, but plans have been discussed to deepen the sill area in order to admit bigger tankers. Most tanker routes go to Danish, Finnish, and Swedish ports. Accidents involving oil tankers have been rare, but the damages of such accidents may be disastrous in narrow waterways. However, illegal flushing of tanks in the open sea and dumping of oil from smaller ships are the main sources of oil pollution in the Baltic. Some oil prospecting has been carried out in the Baltic area, but without success. Some small oil pollution problems exist around areas where oil shale ("burning stone") is exploited in Estonia. Sweden has several refineries in the Baltic area, but most of the other Baltic countries have none.

Reduced oxygen content of shallower water already has changed the relative numbers of different marine plants and animals in some fjords and archipelagos.

As an example of the problem from chronic oil pollution, 125 oil discharges from ships are known to have occurred during 1968 along the coasts of Sweden. These originated both from tankers and cargo ships. Even if most of them were rather small, they caused considerable damage to beaches, fishing gear, and marine life. It has been shown that marine algae are very sensitive to oil and oil products, which may cause death of the algae or retardation of cell division.

Radioactive Pollution

Radioactive wastes have been dumped into the Baltic, but nowdays the control is rigorous and no dumping seems to occur. The Baltic has, of course, been polluted by radioactive fallout. A slight increase of some radioactive compounds has been reported by Finnish scientists.

The construction of nuclear power plants going on or planned in the Baltic area will cause the release of small additional amounts of radioactive matter. Control measures will, of course, be very stringent, but it has to be remembered that leakages may accidentally occur even if authorities do not admit to such possibilities. Nuclear ships, both submarines and surface vessels, may be a potential danger. If a large leakage occurs in the Baltic, marine life may be damaged for several decades.

Pollution by cooling water from nuclear power plants or from power plants using fossil fuels may cause unpredictable damages. The cooling water will be warmed about 10 degrees C. In Sweden some ten nuclear plants are planned during the next 25 years. Every plant will be using 89,600 gallons of

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water per second. If it is assumed that the other countries build altogether at least ten plants during the same period, the amount of cooling water will be equal to 20 percent of the freshwater supply from the rivers. The effect on the temperature of the Baltic as a whole will be negligible, but in the vicinities of the plants, the warm water will increase the oxidation rate of organic matter. This may cause oxygen deficits in these areas.

Pollution through Wars

During the world wars hundreds of thousands of mines were laid out by the fighting powers and the neutral states. The mines from World War II, especially the magnetic mines, are still a great danger for shipping outside the swept channels. Mine accidents are still known to happen occasionally in the entrance to the Baltic. Drifting mines are not uncommon in Kattegat. More than a hundred ships have been destroyed by mines in the southern Baltic, the Belts, and Kattegat since the war. During the summer of 1969, five mines were found on the Swedish west coast. A Danish fishing vessel was destroyed by a mine almost in sight of the ferries between Rödby and Puttgarden in August 1969. Another problem is that oil leaking from the German cruiser Blücher, sunk in the Oslo fjord, is now a threat to the shores in the Dröbak area.

After World War II ammunition and war gas containers and other kinds of German war material were dumped into the Bornholm basin and other places in the southern Baltic by the Allied occupation forces. Fishermen who have caught corroded mustard gas containers in their trawls have been severely injured. Several such accidents happened during 1969, and one occurred this year. The containers are dragged by the trawls, and when they are discovered, they are generally dumped on the spot where they are found. Other fishermen may then drag them farther away, spreading them over large areas. It has been estimated that around 20,000 tons of mustard gas have been dumped into the Baltic.

Pollution by Ships

The ship traffic among the Baltic countries is considerable. The traffic in the Danish waters and in the Öresund is especially heavy. Other areas with concentrated traffic are the ferry routes between Gothenburg and Frederikshavn in Kattegat and between Sweden and Finland in the Åland Sea. It is estimated that more than twenty million passengers travel across the Öresund every year. During the summer season some 500 passenger ships cruise in the Baltic area yielding between 250 to 400 cubic meters of waste per day. Dumping of garbage from the regular ferry boats is forbidden, but in spite of this I have personally seen it happen several times. Garbage is, of course, also dumped from cargo ships and from all kinds of smaller vessels such as fishing boats, motor boats, and sailing yachts.

Control of Water Pollution

In all Baltic countries there are laws against water pollution. The control is exercised by special national or regional authorities. As a rule the general trend in all countries is to try to prevent the pollution from damaging the environment too seriously. For the most part, however, there is either no or only primary treatment of the sewage and industrial wastes which are discharged into the sea. All of the countries are trying to strengthen the control of coastal pollution. Dumping of wastes from ships, except mud dumping from harbors and treatment plants, is forbidden or at least not recommended within the territorial waters of any of the countries.

The discharge of wastes harmful to the open sea is prohibited from Finnish territory or Finnish ships in accordance with the 1958 Geneva Convention (approved by the U.N. Conference on the Law of the Sea). This convention will probably be ratified in Denmark and the Federal Republic of Germany in the near future. In Germany the discharge of wastes outside territorial waters is now subject only to voluntary control.

All countries except the U.S.S.R. and the German Democratic Republic have ratified the London Oil Pollution Convention. The U.S.S.R. has some special rules for avoiding oil pollution within 50 miles from the coast. The German Democratic Republic uses rules similar to those of the convention.

International Research Collaboration

Pollution research is carried out in all the countries. International collaboration in the hydrographical and biological field is carried out through different international organizations, such as the Interna-

Most of the sewage directly discharged into the Baltic is not treated at all or undergoes only primary treatment, or separation of liquids and solids.

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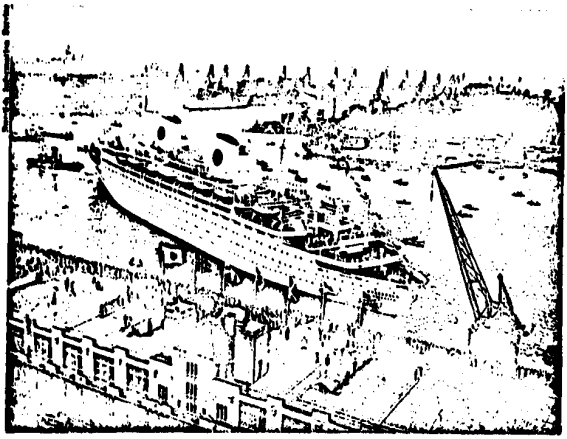
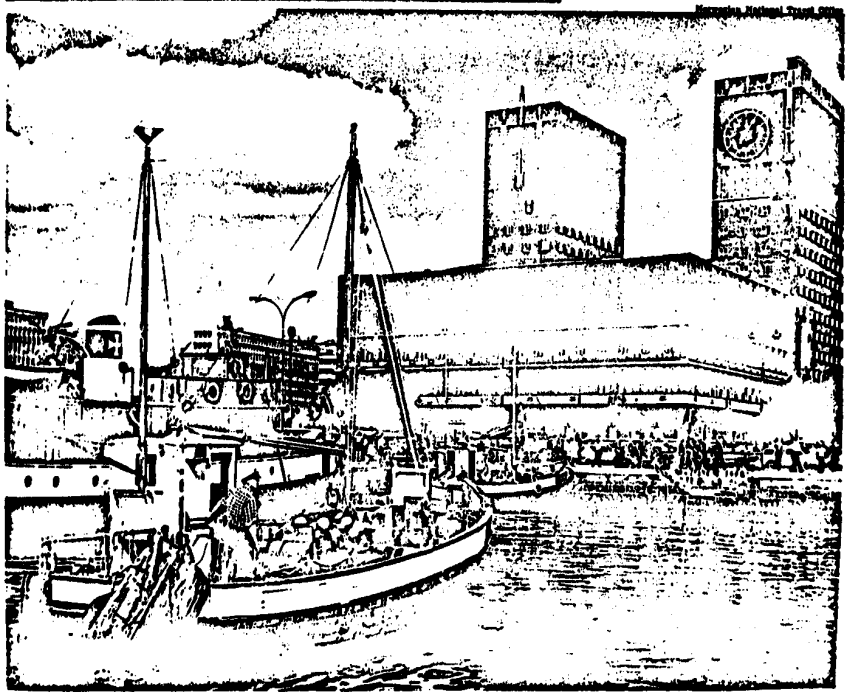


At left, the harbor of Gothenburg, Sweden's second largest city and her greatest port. Below, fishermen sell shrimp from their boats in front of the City Hall of Oslo, Norway's capital. Pollution from industry, shipping, and sewage on the shores of the Baltic may endanger its fisheries.



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tional Council for Exploration of the Sea, the Intergovernmental Oceanographic Commission, the Intergovernmental Maritime Consultative Organization, the International Atomic Energy Commission, and others. Important local organizations also carry out pollution research. In the hydrographical field the "Baltic Oceanographers" have worked since 1957. The "Baltic Biologists" was established some years ago. There are also several more local organizations: the Committee on Pollution of the Öresund (Denmark and Sweden), the Committee on Pollution of the Gulf of Finland (Finland and U.S.S.R.), and others.

It is realized that the pollution problems of the Baltic cannot be solved by one country alone. All countries must cooperate in an effort to stop the contamination.

There have been some more or less fanciful suggestions in newspapers about the pollution problems, especially on how to improve the water circulation. It has been suggested that deepening the sills in the entrance area, by using nuclear power, for example, would give a better water exchange through the sounds. The sill area at Darss is very large, and the difficulties would be enormous. It is not at all certain that such an enterprise would improve the conditions. There is a possibility that the salinity of the deep water would increase, thereby increasing the vertical stratification. Another idea is to close the sounds by locks, transforming the whole Baltic to a freshwater lake. This lake could then be used as a freshwater reservoir for Europe. Since the shipping in the sounds is among the densest in the world, however, locks would cause enormous delays for ship traffic. Freshwater freezes more easily than salt water, and freshwater ice is much harder than the porous seawater ice. This may shorten the sailing period and make the ice more compact, causing enormous costs to the shipping industry. There are, of course, also political aspects of such a project. For example, limitations on free and uncontrolled passage through the sound by warships certainly will not be accepted by all countries.

All countries are aware of the pollution problem, and all agree that something has to be done. It is, however, not easy for the scientists to give recommendations which can be accepted by all of the governments. It is not possible to stop all contamination; the costs for communities and industries would be too high. Much can be done, but we do not know enough about the water exchange through the Danish sounds to be able to tell if the oxygen situation in the deep water really will improve if the organic load and the fertilization are diminished. What proportion of the present situation in the deep water is caused by human activity and what part by natural processes? We hope to be able to answer this important question in the near future. □

NOTES

p. 6. "*. . . inflow . . . 500 cubic kilometers. . . .*"
Brosmun, W., "Eine Revision des Wasserhaushaltes der Ostsee," Kieler Meeresforschungen IX, 1., 1953.

p. 6. "*. . . 40 meter-deep ridge . . . Åland archipelago.*"
Ibid.

"*. . . sill at Darss.*"
Fonselius, S. H., "Hydrography of the Baltic Deep Basins III," Fishery Board of Sweden, Series Hydrography, nr. 23, 1969.

"*. . . hydrogen sulfide is formed close to the bottom . . . increasing the nutrient concentration. . . .*"
Ibid.

"*. . . hydrogen sulfide periods . . . steady state is reached.*"
"On the Stagnant Conditions in the Baltic," Abstract of Gothenburg Dissertations in Science, nr. 14, 1969.

p. 7. "*. . . the concentration of hydrogen sulfide . . . oxygen has become completely exhausted.*"
Richards, F. A., "Anoxic Basins and Fjords," Chemical Oceanography, J. P. Riley and G. Skirrow, ed., Academic Press, London and New York, 1965.

p. 8. "*. . . Black Sea . . . naturally stagnant basin.*"
Caspers, H., "The Black Sea," Treatise on Marine Ecology and Paleoecology, J. W. Hedgpeth, ed., Geol. Soc. America, Memoir 67, 1957.

p. 10. "*. . . water was renewed ten years later, in 1961.*"
"Hydrography of the Baltic Deep Basins I," Fishery Board of Sweden, Series Hydrography, nr. 13, 1968.

"*. . . January 1970 . . . only traces of hydrogen sulfide. . . .*"
"On the Stagnation and Recent Turnover of the Water in the Baltic," Tellus, 1970 (In press).

"*. . . alternating stagnation periods and fertilizations has started. . . .*"
Fonselius, "On the Stagnant Conditions in the Baltic," loc. cit.

p. 11. "*. . . one-degree increase . . . has increased the oxidation rate some 10 percent.*"
Kullenberg, G., "On the Oxygen Deficit in the Baltic Deep Water," 7th Conference of the Baltic Oceanographers, Helsinki, May 11-18th, 1970.

"*. . . increased the transport downward of dead matter.*"
Fonselius, "Hydrography of the Baltic Deep Basins III," loc. cit.

"*. . . . representative from the 'Baltic Oceanographers.'*"
International Council for Exploration of the Sea (ICES), "Report of the ICES Working Group on Pollution of the Baltic Sea," Cooperative Research Report, Series A, 5. Oyborn, ed., no. 16, 1970.

p. 40. "*Table 1. . . .*"
Ibid.

p. 42. "*Table 2. . . .*"
Ibid.

p. 43. "*. . . phosphate is the limiting nutrient for the primary production. . . .*"
Fonselius, "Hydrography of the Baltic Deep Basins III," loc. cit.

p. 44. "*The total supply of phosphorus . . . 56,500 tons per year. . . .*"
Ibid.

"*. . . increased primary production . . . Gulf of Riga.*"
Lichev, M. N., "Stocks of Baltic Herring in the Gulf of Riga and Prospects for their Utilization 1963-1967," Fish. Res. in the Baltic Coll. 1, Riga, 1968. (In Russian).

"*. . . signs of the same trend in the Kattegat. . . .*"
Carlin, C., S. H. Fonselius and A. Svansson, "On the Oxygen and Phosphate Conditions in the Kattegat and Öresund 1966-1968," Meddel. Havsfiskelaboratoriet, Lysekil, nr. 62, 1969.

"*. . . Jensen and his co-workers. . . .*"
Jensen, S., A. G. Johnels, M. Olsson and G. Otterlind, "DDT and PCB in Marine Environment," Fauna och Flora 4, 1969. (In Swedish).

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