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The Baltic Sea circumstances significant for its critical infrastructure networks

Keywords

Baltic Sea, geographic characteristic, abiotic parameter, climate and weather, environment protection, critical infrastructure

Abstract

The paper is an overview of the Baltic Sea and its basin characteristic. The geographical location and climate and weather of the Baltic Sea region according to its zones and seasons were described. Moreover, the abiotic parameters of water such as salinity, oxygen concertation and temperature distribution in the water column were explained. Some of these characteristic parameters has influence on the critical infrastructure networks existed in the Baltic Sea region as well as the critical infrastructure objects activity has significant impact on these parameters changes and consequently the environmentally quality of the region. Finally, the Baltic Sea as the sensitive area is presented.

1. Introduction

The Baltic Sea is a young, epicontinental, non-tidal and small sea on a global scale (it is about 1/900 part of world marine ecosystems) [1], [10], [11]-[12]. It consists of seven sub-basins, from the north: the Bothnian Bay, Bothnian Sea, Gulf of Finland, Gulf of Riga, Baltic Proper, the Sound and Belts, Kattegat (*Figure 1*). The whole area of the Baltic Sea is about 415,000 km². It contains 21,547 km^3 of brackish water. It is important that Baltic Sea has a narrow and shallow entrance (few kilometers in Danish Straits) thus, it can be compared to very big but not very deep lake. The Baltic Sea is the shallower sea in compared to the other world's ones (it is characteristic for epicontinental seas opposite to seas located between continents). It has an average depth of only 53 m while its deepest part is the Baltic Proper with approximately depth of 62 m and maximum depth of 459 m (Landsort Deep).

The water level in the Baltic Sea is higher than Atlantic Ocean because of the Sound and Belts and water cannot easily and quickly pass through these straits with mean depth of only 14 m. It also limits the exchange of water with Atlantic Ocean (there is needed about 33 years to exchange the whole water in the basin).

The drainage basin (also called catchment or watershed) of the Baltic Sea includes all the land areas from which water flows into the sea, either via rivers or as direct run-off.

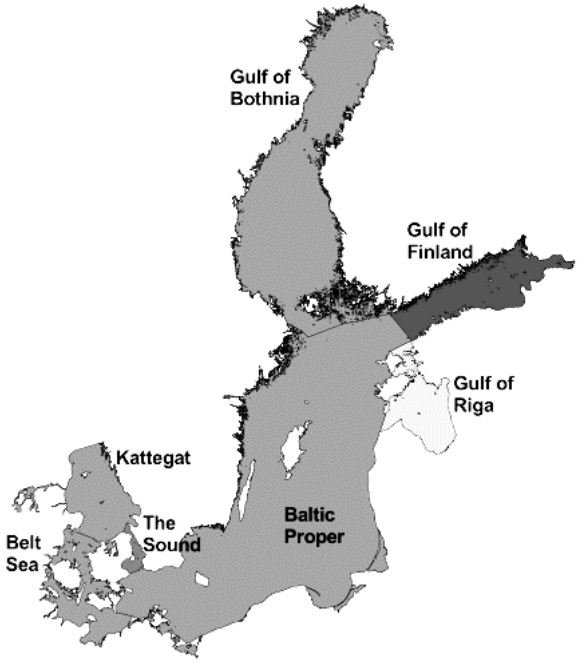

Figure 1. Sub-basins of the Baltic Sea [11]

Accordingly, the Baltic Sea drainage basin consists of the whole or partial territories of 14 countries (*Figure 2*). Nine of them: Poland, Lithuania, Latvia, Estonia, Russian Federation, Finland, Sweden, Denmark have direct access to the coast whereas Czech Republic, Slovakia, Ukraine, Belarus and Norway have not. In total, the Baltic Sea drainage basin covers an area of 1,745,000 km^2. It means that drainage basin is approximately four times larger than the sea. If the Baltic Sea area is added to its drainage basin, the total area is 2,250,000 km^2 – it is about 15% of all Europe.

Figure 2. The Baltic Sea drainage basin (source: http://maps.grida.no/baltic/)

There are 7 coastal types around the Baltic Sea. In the north rocky coasts are dominated, and in the south – sandy ones. The archipelagos prevail at Swedish and Finnish coastline. The archipelago between Sweden and Finland is the largest in the world and contains 25,000 islands. The cliff and klint coast are found in Estonia and on the west coast of Gotland, and lagoons in Gdansk Bay.

2. Abioticparameters of the Baltic Sea water

There are three abiotic important parameters of water that are fundamental for the Baltic Sea marine life: salinity, temperature and oxygen concentration.

The salinity of surface water varies from 1-2 PSU (PSU – practical salinity unit in average means parts per thousand) in Bothnian Bay, 2-4 PSU in Bothnian Sea to 20 PSU in Kattegat (compared to 35 PSU in common marine ecosystems). Near the mouth of large rivers, salinity falls close to 0 PSU. Moreover deep water are more saline (10-12 PSU on average) than surface water (7-8 PSU on average). Thus, the rapid increase of saline at water depth of about 70-90 m (called halocline) is observed. The halocline limits the vertical mixing of water, consequently the bottom layer of water is more dense than surface one.

The oxygen concentration in the Baltic Sea is also different according to the depth. The surface water is generally well oxygenated (7-9 cm^3/dm^3) whereas the oxygen concentration immediately runs out at 60-70 m water depth, and finally the no oxygen concentration at 140 m water depth is observed (redoxcline). Additionally, the toxic hydrogen sulfide is produced beneath the redoxocline and in general there are no living organisms below 140 m depth in the Baltic Sea. The oxygen concentration has dramatically reduced for two last decades. The oxygen concentration below 3 cm^3/dm^3 causes stress for fish and animals living in the ecosystem.

Temperatures of the Baltic water ranges from -0.5 to +20°C. Moreover, the bottom water temperature is constant independently of the season (about 2-4°C) whereas the wind-mixed surface water temperature is variable according to the season. Thus, the layer between the seasonally changes of water temperature and deeper water with constant temperature at water depth of about 20-70 m (called thermocline) is observed.

3. The climate of the Baltic Sea region

The climate around the Baltic Sea is different in the north and south because of long north-south extension (about 3000 km) of the basin. The mean annual air temperature is 0°C in the north, whereas it is 8-12°C in the south. The surface air temperature has increased since 1871. The changes of temperature are resulting in changes in the season: the length of the warm season has increased, while the length of the cold season has decreased [3].

Both, the salinity and the air temperature have influence on the Baltic Sea annual ice occurrence. The ice impairs shipping as well as has influence on marine wildlife. The ice cover during normal and mild winters occupies 15-50% of the sea area in the north-eastern part of the basin, but may extended to the entire sea during infrequent severe winters. In general the Bothnian Bay is ice-covered every winter, while the Baltic Proper is usually ice-free. The latest winters with the Baltic Sea totally frozen were in 1941/1942 and probably also in 1946/1947 [10]. The first sea ice usually begins to form in November (in the beginning of October at earliest) in the shallow coastal areas in the northernmost

Bothnian Bay. The maximum ice coverage is typically reached in February or March, but sometimes already in January, and finally sea ice remains in the Bothnian Sea usually until mild-May. In the Bothnian Bay, the ice thickness is commonly 65-80 cm, while 10-50 cm in coastal areas of Poland and Germany.

The Baltic is stormy sea (in average 3°B/year) and waves are short and steep. The highest waves are about 10 meters but typically they reach about 5 meters. Prevailing winds come from west, thus air pollutants are usually transported from west to east. On the other hand the Baltic surface water constantly and anti-clockwise circulates thus, the marine pollutants from the south can pass the east and the north coastal areas to return to the south. Moreover winds blowing at a speed of 15 m/s are strong enough to disrupt ferry and other ships, bring down electricity cables and other structural damages as well as whip up large waves at the coast to cause localized flooding. On the other hand strong winds and storms are essential for the ventilation and mixing of the stagnated waters and inflow indispensable salt and oxygen to the Baltic Sea from the North Sea and Atlantic Ocean.

The precipitation in the Baltic Sea region has varied between seasons and regions. The mean annual precipitation equals 750 mm/year for the entire Baltic Sea basin (including both land and sea). The largest precipitation amounts occur in Scandinavia and southern Poland mountain regions, while the lowest amounts occur in the northern and northeastern part of the basin as well as over the central Baltic Sea. Mean monthly precipitation is highest during July and August, with up to 80 mm in August, and lowest from February to April, with less than 45 mm on average.

For much of the Baltic Sea basin, in particular the eastern continental part and also much of the Baltic Sea itself, there is an annual cycle of clouds, with the largest cloud amounts during winter and the smallest ones during summer. However, little to nearly no annual cycle in clouds is observed in parts of the western and northern regions (in particular, mid- and northern Sweden and northern Finland). During summer months, few or no convective clouds form over the Baltic Sea, in contrast to the surrounding land areas.

4. The Baltic Sea as the sensitive sea area

Summing up, due to the Baltic Sea special geographical, climatological and oceanographic characteristic (sheltered inland and shallowed sea with many coastal types, cold climate), the sea is highly sensitive to the environmental impacts of human activities. The Baltic Sea like other seas is an area where maritime transportation, trade, fishing and other industrial activities take place.

The Baltic is one of the most contaminated sea around the world because of living about 85 million people in 14 countries within the basin, multiple-using of coastal areas, intensive agriculture, building of a new cities, growing industry and other man activities in the surrounding drainage basin leading to the pollution dangerous for this region. This was the reason to create so-called HELCOM (Baltic Marine Environment Protection Commission – Helsinki Commission) for monitoring the pollution and other dangerous impacts of human activity on the Baltic Sea environment. The role of HELCOM is also the consolidation of international cooperation for the protection of the Baltic Sea environment, supervising and coordinating the implementation of the 1992 Baltic Sea Convention (so-called Helsinki Convention) [13] and binding decisions in order to further the objectives of the convention, giving recommendations on measures, defining pollution criteria and quality objectives and promoting researches.

In *Figure 3*, the countries that are the HELCOM members are highlighted. The European Union (EU) is also HELCOM member and is strongly interested in Baltic Sea region protection.

Figure 3. HELCOM member states
(source: *https://en.wikipedia.org/wiki/HELCOM*)

According to the United Nations Convention on the Law of the Sea (UNCLOS 1982), the Baltic Sea was

divided into the co-called exclusive economic zones (EEZ). The borders of EEZ at the Baltic Sea, claimed by each state are presented in *Figure 4*. In the EEZ eachstatehas special rights regarding the exploration and use ofmarine resources, including energy production from water and wind. Moreover, eachstate is obliged toprotection and preservation of its EEZ marine environment.

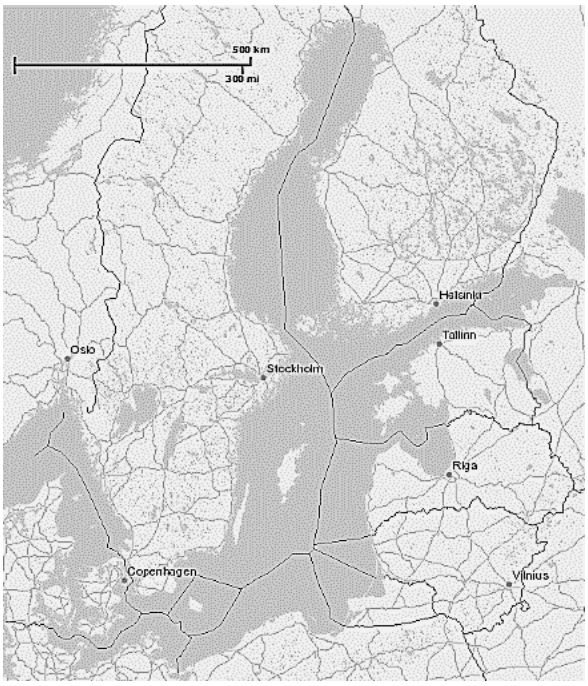

Figure 4. Exclusive economic zones at the Baltic Sea (source: http://maps.helcom.fi/)

A very important role in the Baltic Sea region (BSR) protection plays the EU and EEZ states policy concerned with the safety and security of operating in this region so called critical infrastructures, critical infrastructure networks and interconnected and interacting complex networks of critical infrastructure networks. The strengthening the critical infrastructures resilience to climate and weather changes in this region also is one of the most important aspects of this EU and EEZ states policy.
The designation of the Baltic Sea as a Particularly Sensitive Sea Area (PSSA) by the International Maritime Organization is the another attempt to try to stop the environmental degradation of the sea and its region. The Baltic Sea PSSA was created by IMO Resolution MEPC.136(53) in 2005. PSSA status means that the Baltic Sea area is particularly sensitive (because of its ecological, economic, cultural or scientific significance) and under threat from human activities related to shipping and other maritime activities. Moreover, it means that specific measures can be used to control the maritime activities in the area.

5. Conclusion

The Baltic Searegion economic activity is very intensive last decades. There are 8 Baltic critical infrastructure networks for various existing in this region industrial installations. These critical infrastructure networks were defined and particularly analysed in [2]-[6], [9], [14]-[15]. Additionally, 1 network of 3 most natural and typical for Baltic Sea region closely interacting critical infrastructure networks was defined and its operation process was primarily modelled [8]. Moreover, in [7], an effort was made in order to create a global network of all considered in this report critical infrastructures within the Baltic Sea region in the form of Baltic critical infrastructure "network of networks" called the Global Baltic Network of Critical Infrastructure Networks (GBNCIN). The objects of these critical infrastructures are vulnerable to damage, caused by external factors, occur threats of other critical infrastructures and their networks, finally caused the environment degradation.
Then, the climate-weather changes influence on the mentioned critical infrastructure networks will be examined by modelling, identification, prediction and optimization its processes.

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