TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 16
Number 1
March 2022

DOI: 10.12716/1001.16.01.20

The Impact of Transport on the Quality of Water in the Port of Gdynia

M. Popek, A. Dereszewska, G. Dembska & G. Pazikowska-Sapota
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: Currently, pollution of the sea by refuse, sewage and emission from transport has become one of the most important environmental problem. Environmental sustainability in seaport is an issue of timely importance in Baltic ports given the rapid increase in ports traffic and their location. The Port of Gdynia is an universal modern port specializing in handling general cargo, mainly unitized cargo transported in containers and in a ro-ro system. Ships traffic in the Port of Gdynia has increased in recent years. Many of ships carry cargo that could severally impact costal ecosystems if accidentally released. The common substance is likely oil because it is present in ships as both cargo and fuel. Sheltered harbour waters favour the accumulation of a fine fraction of bottom sediments in which pollutants such as heavy metals and organic compounds accumulate. This paper discusses the situation in the Gdynia Port and its challenges in terms of environmental aspects and current pollution situation. It is based on data on collected during the period 2012 to 2019.The water contamination measurement in the docks is performed for reference substances and parameters, according to the reference methodologies.

1 INTRODUCTION

Intensification of human activities regarding new technologies, especially new substances, progress in industry and the extension of needs in progressing civilization, results in increasing anthropogenic pressure on the oceans and seas environment. Chemical pollution is one of the most critical threats to human populations and aquatic ecosystems. Many substances from industrial activities are released into natural waters without knowledge of the potential environmental risk [26, 28].

The Baltic Sea is an inland sea with an area of 374,000 km^2, the drainage for which is about four times greater. The Baltic sea is almost totally surrounded by land and therefore more endangered by pollution than other marine areas. As enclosed and shallow sea, is particularly vulnerable to toxic pollutants, because it is a cold-water body with complete renewal time of about ten years [9]. The residence time of water in central Baltic is 25-30 years. This is because the Baltic is an almost landlocked subsidiary sea to the Atlantic Ocean. Only narrow straits connect it to the North Sea and exchange of water between the two is therefore restricted. As one the most sensitive marine ecosystems, the Baltic Sea has been classified as Particularly Sensitive Sea Area by the Marine Environment Protection Committee of the International Maritime Organization.

All the Baltic countries have a very limited area in marine environment to realize their economic needs [5]. Ships traffic in the Baltic increases every year. There are about 2000 ships in the Baltic at any one time. In the recent years, the transport of environmentally hazardous cargo has increased in the Baltic Sea area. Currently, pollution of the sea by refuse, sewage and emission from transport has become one of the most important environmental problem [11]. Many of the ships carry dangerous cargo that could impact coastal ecosystems if accidentally released. The most common substance is oil, because it is present in ships as both cargo and fuel [12]. The Baltic sea is an exposed to petroleum hydrocarbons due to intense shipping covering as much as 15 % of the world transport. It is estimated that annually from 21 to 55 thousand tons of these contaminants reaches the Baltic Sea [22].

Chemicals are also discharged into the water as wastes of the industrial towns located on the cost. One of the most polluted areas along the Baltic coast is the Gulf of Gdansk. It is affected by chemical pollution and by eutrophication. High concentration of the detergents, pesticides, polycyclic aromatic hydrocarbons and heavy metals have been found. The biochemical oxygen demand in the coastal of the Gulf of Gdansk is higher than in the water of the Baltic Sea. Environmental sustainability in sea ports is an issue of timely importance in many countries given the rapid increase in port-to-port traffic and port capacity. The possible reduction of current ports impact on living environment should be huge due to the fact that the port is a place where the transport and logistic intersect and constitute industrial estates. In port areas, together with own and external use and activities developed in its surroundings, the conditions favour the intensification of sedimentary processes and the gradual contamination of their bottom. Toxic and persistent pollutants can accumulate in sediment particles and, under certain circumstances, be absorbed by aquatic organisms or plants. Several researches showed that concentrations of heavy metals in sediment are far higher than the concentration of dissolved metals in the water bodies. Marine sediment acts as both sink and source for heavy metals [7]. Ship moving in the port can lead to sediment displacement, release of chemicals and secondary pollution of seawater. Additionally, coal dust contamination in marine sediments has high binding affinity for particle-reactive contaminants. Walker, et al. (2013) reported, that sediments sampled near the coal loading facilities in Sydney Harbour (Canada), had significantly higher contaminant concentrations compared with other harbour sediments. Such a phenomenon may lead to changes in the status of sea waters, e.g. near the port channels [25].

To reduce pollution and improve the situation in the Baltic sea, surrounding countries organized the Convention on the Protection of the Marine Environment of the Baltic Sea Area, known as Helsinki Convention, which come into force in 1980. The Helsinki Commission (HELCOM) founded in 1974 acts as coordinator and is responsible for the enforcement of the Baltic monitoring program and international research project. The HELCOM Baltic Sea Action Plan is an example of voluntary initiative of countries wishing to have a healthy sea back [20]. The activities of HELCOM have led to the reduction of dangerous pollutants which in turn has caused the regeneration of flora and fauna in some areas. Furthermore, the Action Plan distinguishes between measures that can be implemented at regional or national level, and measures that require implementation at EU or international level [2].

The European Union Marine Strategy Framework Directive (MSFD) aims to establish effective protection of the EU marine waters by putting in place a common framework for marine policy, which corresponds to the declared aims of the HELCOM Baltic Sea Action Plan [1]. The preoccupation for marine pollution produced the publication of Directive 2008/105/CE [30], which established the environmental quality standards (EQS) for priority substances and other pollutants and Directive 2009/90/CE in 2009 [29], with the technical specifications for the chemical analysis and the monitoring of the ecological status. Because of high risk of pollution with chemical substances, the port water should be tested continuously in order to reduce the inflow of pollutants into the sea and improve environmental management in harbours.

Test results for samples of water collected in year 2011-2019 from the channels of the Port of Gdynia are presented in this paper. A review of the result of test on the content of heavy metals and petroleum hydrocarbons are discussed. The BOD/COD parameter is also calculated.

2 PORT OF GDYNIA CONTAMINANTS

The Port of Gdynia is one of the major international seaport located in the central part of the southern Baltic coast, in the western coast of the Gulf of Gdansk (Poland). This port covers a total area of 7, 55km^2 and has a total quayside length of 17,7 km [7]. It consist of the West Port (Inner port) and the East Port (outer port) and is protected year-round by a 2,5 km breakwater and never freezes over during winter [16]. Although the it is protected year-round by the outer breakwater, which prevents mixing form currents or high waves in the port, during strong easterly winds it can decrease by as much as 0,6m and during sustained strong westerly winds the water level can rise by up to 0,6m. This phenomenon may cause intensive movement of water and lead to direct and consistent distribution of water toward individual docks. The individual docks of the Port of Gdynia provide easy access to the water mass from the sea. Taking into account this fact it may be assumed that storms and winds may play natural role in the transport of water mass in the port channels [17].

The Port of Gdynia is an universal modern port specializing in handling general cargo, mainly unitized cargo transported in containers and in a ro-ro system. The services are provided through a network of multimodal transport connections with the hinterland and through short sea shipping and ferry connections. The Port of Gdynia is an important link in the Corridor VI of the Trans-European Transport Network (TEN-T) and plays an important role in the economic development of Pomerania Region and in creating a sustainable society.

Efficiency in operations and high quality services provided by the port are aimed at consolidating its market position.

The coastal zone of the Southern Baltic sea is strongly influenced by anthropogenic inputs derived from industry tourism and shipping [14]. The characteristics of some of them are presented below.

2.1 *Oil pollutants*

The international sea transportation is responsible for the carriage of approximately 90 % of world trade, contributing to a substantial oil and chemical pollution. The Gulf of Gdansk and Port Gdynia are an area exposed to petroleum hydrocarbons due to highly developed shipping. Oil pollutants present in sea water mainly coming from ship drivers, tankers, pipelines or sea bottom seeps, moreover oil leaks from offshore extraction equipment also are possible. Most of the minor cases of oil pollution are result of scouring out the bilges of the engine rooms of the ship. In the sea water, various types of hydrocarbons can be found [3]. They are often complex substances composed of hundreds to thousands of individual aliphatic and aromatic hydrocarbons.

If heavy fuel enters to the marine environment, then the chemical composition of this substance changes slowly. If it is oil consisted of short carbon chains, one should expect a quick evaporation of volatile hydrocarbons into the atmosphere [8]. However, the quickest transformation of the composition of oil take place in crude oil. Oil pollution is very dangerous for the environment and can destroy habitats of many plants and animals, including the spawning areas of fish [15]. For a long time it was believed that, removing spilled oil from the surface of the water completely eliminates the risk of water pollution. However, studies have found that water-soluble fractions, which are most toxic, remain in water [13].

A legal regulation characterizes the content of petroleum hydrocarbons using a summary parameter the mineral oil index. It determines the content of hydrocarbons within the C10 to C40 carbon atoms range. UN regulations regarding priority substances in waters, sediments have been implemented to the Polish legal system as a part of the Regulation of the Minister of Environment (21th July 2016) on the methodology for classification of the condition of surface water body and environmental quality standards for priority substances. This regulation provides limit values of water quality indicators from the group of substances harmful for water environment. In case of high and good status waters (class I and II), the values for the petroleum hydrocarbons should be less than or equal to 0,2 mg/dm3. For waters of a lower status, the value of this parameter has not been provided [31].

2.2 *Heavy metals in surface water*

Trace element contamination is considered as one of the major issues in marine environment due to their diverse sources, bioaccumulation, non-degradability and harmful effects on biota. The ecological status of the aquatic environment can be evaluated by analysing the distribution of trace elements in water, sediments and marine organisms [19]. Most trace metals play an important role as micronutrients in maintaining the life of aquatic organisms, and toxic properties are only manifested when the concentration available to the body exceeds the value necessary to meet the nutritional needs. Trace metals such as: Cu, Fe, Zn, Mn, Co, are essential for metabolism. At the same time, exposure of aquatic organisms to high concentrations of the same elements may adversely affect their health or cause death. Pb, Cd, Hg and As, do not play an important role in the life cycle of organisms. However, they can damage the organism if they are available in the environment in concentrations exceeding the norm. Two common heavy metals associated with health risks in the Baltic Sea region are lead and cadmium. The strongest toxic properties are characteristic for inorganic metals compounds, which dissociate well and are easily soluble. Some heavy metals dissolve immediately and tend to accumulate in aquatic organisms [23].

Natural heavy metal concentration such as lead, zinc or cadmium, are usually very low. But large loads of these metals are emitted into the environment due to intense human activities. The Gulf of Gdansk is influenced by heavy metals of anthropogenic origin. The municipal, industrial and agricultural activities in the Pomerania Region resulted in a high level of contamination by metals and organic compounds in coastal area for the past 50 years [12].

Lead enters the environment during production, use and disposal of compounds containing lead, combustion fossil fuels and sewage sludge application to soil. The discovery that lead causes environmental and health damage led to phasing out of leaded gasoline. The lead concentration could be influenced by different source due to increasing human activities, economic and social development (e.g. mining, coal burning), use (batteries, pigments, plastics), recycling and disposal of compounds containing lead, and use of mineral fertilizers [27]. High concentration of lead has adverse effect on central nervous system, blood cells and may cause brain damage.

Cadmium is a relatively rare metal in nature. Its stability in water is a function of pH and oxidation-reduction potential. Its origin, from an industrial point of view, is related to plastics, engine oils, batteries and in products of thermal stability. For pH above 8, cadmium precipitates with carbonates. When mixing sewage with seawater, cadmium forms very stable complexes with chlorides. Cadmium does not degrade in the environment, but physical and chemical processes can alter its mobility, bioavailability and residence time in different environments.

Zinc is predominantly sourced from lithogenic components [24]. Compared to lead and cadmium, it shows a higher affinity to accumulate in marine organisms and tissues. Zinc under long-term high exposure conditions might cause neuron-related illness due to iron or copper deficiency occurrence [20].

Fish absorb heavy metals form surrounding environment depending on a variety of factors such as the exposure period, the concentration of the element, as well as abiotic factors such as temperature, salinity, pH and seasonal changes. Hence, heavy metals, released by anthropogenic activities will be accumulated in marine organisms through the food chains; as a result, human health can be at risk because of consumption of fish contaminated by toxic chemicals [6]. The pollution of sea food with heavy metals is still a problem from both the hygienic and eco toxicological points of view [17].

2.3 *Biochemical Oxygen Demand*

Oxygen enters the water by photosynthesis of aquatic biota and the transfer of oxygen across the air-water interface. The overall partitioning of oxygen between the atmosphere and the water is sensitive to mixing and biological production, as well as temperature and salinity. The solubility of oxygen decreases as temperature and salinity increase and is more depend on temperature variation than salinity variation.

The heavy pollution of communal sewage , which comes from industry, ships, as well as that from agriculture, has led to large input of plant nutrients, especially nitrogen and phosphorus compounds. Eutrophication of the sea's ecosystem is known as a major problem and has led to reduced water quality which contributes to oxygen deficit and can damage to biodiversity. The eutrophication process can be divided into three key elements: (1) increased nutrient levels leading to (2) production of particulate and dissolved organic matter and (3) degradation of the organic matter leading to lower oxygen concentration [10]. When the organic matter decomposes, it is upon by aerobic bacteria. In this process, organic matter is broken down and oxidized (combined with oxygen). Biochemical Oxygen Demand (BOD) is amount of oxygen required by aerobic microorganisms to stabilize the organic material of wastewater, wastewater treatment plan effluent, polluted water, or industrial waste [18]. The BOD is usually proportional to the amount of organic matter present and, therefore, is a measure of the strength of the waste. A low BOD is an indicator of good quality water, while a high BOD indicates polluted water Biochemical oxygen demand is useful parameter for assessing the biodegrability of dissolved organic matter in water. At the same time, this parameter is used to evaluate the efficiency with which certain processes remove biodegradable natural organic matter [21]. Because organic matter needs varying time spans to be oxidized, and in order to standardized BOD as indicator, the BOD5 measurement has been defined to be the oxygen consumption, in a sample, after 5 days of incubation at $20^{o}C$ [22]. The BOD5 protocol is well defined by national and international standards applicable to freshwater and wastewater, but is unsatisfactory for saltwater or seawater, in which most dissolved organic matter is resistant to microbial oxidation.

A practical measure of organic pollution, whether biodegradable or not, is expressed by a value known as Chemical Oxygen Demand (COD). COD values are typically higher than BOD, and the ratio between them will vary depending on the characteristics of the wastewater. BOD/COD ratio has been commonly used as an indicator for biodegradation capacity. Wang et al. [25] introduced biodegradability as the mass concentration ratio of BOD/COD understood as the ability of a substance to be broken down into simpler substances by bacteria. Facing to untreated materials such as raw water or wastewater, on one side, the BOD/COD ratio is higher than 0.5.The high BOD/COD ratio can be found in natural waters, which contains BOD of less than 10 mg/L and COD of less than 20 mg/L . On the other side the low BOD/COD ratio can be found in seawater, which contains low concentrations of BOD and COD. For high COD and low BOD values, the BOD / COD ratio may indicate the toxic nature of pollutants present in the water [19].

3 EXPERIMENTAL

3.1 *Location of water sampling points*

Samples of water were collected in 2011÷2019 from the selected locations of the Port of Gdynia.

Table 1 presents the sampling points of surface waters for the testing. One locations were designated for each of the docks.

Table 1. Location of sampling points in the port of Gdynia

Sample number	Location
1	South Channel
2	Dock I-Presidental Dock
3	Dock II – Wendy Dock
4	Dock III-Coal Dock
5	Outer harbour
6	Dock IV –Marshal Pilsudski Dock
7	Dock V- Minister Kwiatkowski Dock
8	Dock VI
9	Dock VII
10	Dock VIII (Harbour Channel)

3.2 *Methods*

Samples of surface water for the study of the level of contamination with heavy metals were obtained in accordance with the standard PN-ISO 5667-9:2005. The contamination level of Port Gdynia waters was measured using the methods presented in Table 2.

Table 2. Methods of used in the research

Number	Parameter	Method
1.	Pb	Mass spectroscopy method (ICP-MS), standard PN-EN ISO 17294-2:2016
2.	Cd	Mass spectroscopy method (ICP-MS), standard PN-EN ISO 17294-2:2016
3.	Zn	The method of atomic emission spectroscopy with excitation in inductively coupled plasma (ICP-OES), standard PN-EN ISO 11885:2009
4.	Mineral oil index	Gas chromatograph with flame ionisation detector (GC/FID) after extraction of water samples, standard PN-EN 14345:2008; standard PN-EN 14039:2008
5.	Biochemical Oxygen Demand BOD 5	Dilution and inoculation method: Standard PN-EN 1899-2:2002 Dissolved oxygen was analysed through the use iodometry: Standard PN-EN 25813:1997
6.	Chemical Oxygen Demand COD	The dichromate method according to the PB-19 test procedure.

3.3 *Results and Discussion*

The concentration of heavy metals deleted in the sea water at all sampling location during period 2011 to 2019 are summarized in Table 3÷5.

Table 3. Zinc concentration in the study areas

Sample number	Concentration of Zn [mg Zn /dm^3]				
	2011-2013	2014	2015	2016	2017-2019
1	BDL	BDL	BDL	BDL	BDL
2	BDL	BDL	BDL	BDL	BDL
3	BDL	0,023±0,003	BDL	BDL	BDL
4	BDL	BDL	BDL	BDL	BDL
5	BDL	BDL	BDL	BDL	BDL
6	BDL	BDL	BDL	0,066±0,01	BDL
7	BDL	0,023±0,003	BDL	0,027±0,004	BDL
8	BDL	BDL	BDL	BDL	BDL
9	BDL	BDL	BDL	BDL	BDL
10	BDL	BDL	BDL	BDL	BDL

BDL – below detection limit

Table 4. Lead concentration in the study areas

Sample number	Concentration of Pb [µgPb/dm^3]			
	2011-2016	2017	2018	2019
1	BDL	BDL	0,293±0,059	0,010±0,002
2	BDL	BDL	0,71±0,4	0,03±0,01
3	BDL	BDL	0,360±0,072	0,010±0,002
4	BDL	BDL	0,428±0,086	BDL
5	BDL	0,204±0,041	0,458±0,092	0,010±0,002
6	BDL	BDL	0,57±0,11	BDL
7	BDL	0,014±0,003	0,54±0,11	0,010±0,002
8	BDL	0,267±0,053	1,17±0,23	0,010±0,002
9	BDL	0,055±0,011	1,19±0,24	0,010±0,002
10	BDL	0,116±0,023	1,27±0,28	0,010±0,002

BDL – below detection limit

Table 5. Cadmium concentration in the study areas

Sample number	Concentration of Cd [µg Cd/dm^3]				
	2011-2015	2016	2017	2018	2019
1	BDL	BDL	0,035±0,008	BDL	0,010±0,002
2	BDL	BDL	BDL	BDL	0,010±0,002
3	BDL	0,9±0,2	0,03±0,007	BDL	0,03±0,01
4	BDL	BDL	BDL	BDL	0,010±0,002
5	BDL	BDL	BDL	BDL	0,010±0,002
6	BDL	BDL	0,025±0,005	BDL	0,010±0,002
7	BDL	BDL	0,031±0,007	BDL	0,010±0,002
8	BDL	BDL	0,036±0,008	BDL	0,010±0,002
9	BDL	BDL	0,02	BDL	0,010±0,002
10	BDL	BDL	BDL	BDL	0,010±0,002

BDL – below detection limit

The metal concentrations in the water were compared with the limit values presented in Table 6.

Table 6. The concentration limits of heavy metals

Time period [year]	Class of water	Zn [mg/dm^3]	Cd [µg/dm^3]	Pb [µg/dm^3]
2012-2014	I-II	≤1	≤ 0,45-1,5	7,2
	III-V	LND	MAC	MAC
2015-2019	I-II	≤1	≤1,5	14
	III-V	LND	MAC	MAC

LND - limits not determined
MAC - maximum allowable concentration
Source: [31]

Physicochemical parameters of surface waters in the Port of Gdynia fall within the values specified for class II of the quality of surface water bodies.

The concentration of zinc in the tested waters of the port basins of the Port of Gdynia was in almost all cases below the limit of quantification of the analytical method used (< 0,022 mg/dm^3).At several points (between 2014 and 2016) the mean values of zinc found in samples of seawater range from 0,023 mg/dm^3 to 0,066 mg/dm^3, so the results are still below the norm. These values are lower than the limit values specified in the Polish Regulation of the Minister of the Environment.

The determination of lead in water samples gives information on the content of this metal in the sea. Between 2017 and 2019 the average concentrations range from 0,01µg/dm^3 to 1,27µg/dm^3. These values are lower than the limit values specified in the Regulation of the Minister of the Environment. Between 2011 and 2016, the concentration of lead in the tested waters of the port basins of the Port of Gdynia was in all cases below the limit of quantification of the analytical method used.

Between 2011 and 2016 the concentrations of cadmium are in most cases lower than the limit of quantification of the analytical method used. In 2017 and 2019 the mean values of cadmium recorded in the studied water fluctuate between 0,01µg/dm^3 and 0,9 µg/dm^3. These values are lower than the limit values specified in the Regulation of the Minister of the Environment.

The concentration value of the mean metal concentration on significant differences between 2011 and 2019 showed that only lead concentration had changed. Zinc and cadmium did not show changes through time.

The largest contamination load was found in samples collected from West Port –docks: VI, VII and VIII. A characteristic feature of the regions is the prevalence of anthropogenic factors originating from port: high level of industrialization, removal of waste from ships, release of pollutants from ships hulls and repair and handling works [4]. There are two shipyards in the closeness of the West Port. In this area, the large shipping terminal The Baltic Container Terminal is located.

Organic matter parameters were determined as BOD, COD and BOD/COD ratio. The maximum, minimum and average values of BOD along with the comparison of inland and offshore values of BOD during the period of four years are given in Table 8

BOD_5 refers to organic matter biodegraded by organisms in biochemical process. The analysed waters are characterised by rather low organic matter content. The mean values of BOD5 recorded in the studied water fluctuate between 0,72 mg O2/dm3 to 7,8mg O2/dm3.No significant differences were found between ten samples point located in Port Gdynia, since their organic matter was similar. Concentration of BOD5 exceeding 4 mgO2/dm3 were found at a few measuring points. Water which such values of BOD5 are referred to as polluted waters. BOD5 values for examined waters are in the second class of water.

Table 7. Seawater BOD5 from various points sources of Port Gdynia

Sample number	BOD_5 mgO_2/dm^3							
	year 2011	2012	2014	2015	2016	2017	2018	2019
1	2,4±0,66	2,03±0,55	2,62±0,82	1,04±0,47	2,68±0,84	1,3±0,41	1,74±0,47	0,73±0,26
2	3,07±0,84	1,51±0,41	3,71±1,17	2,05±0,68	2,46±0,78	7,2±1,9	0,96±0,35	0,86±0,3
3	2,13±0,39	2,81±0,78	2,62±0,82	1,92±0,64	1,88±0,59	2,13±0,67	1,9±0,51	0,86±0,3
4	2,6±0,22	2,96±0,53	1,71±0,54	2,7±0,9	2,49±0,78	2,4±0,76	1,7±0,46	1,10±0,39
5	2,67±0,76	2,91±0,51	6,03±1,63	2,44±0,81	1,88±0,59	2,86±0,9	2,06±0,65	0,98±0,34
6	2,67±0,76	2,55±0,69	2,8±0,88	3,1±0,1	2,52±0,79	3,13±0,0,99	1,34±0,36	0,73±0,26
7	2,67±0,76	2,3±0,62	4,25±1,14	4,0±1,3	2,05±0,65	1,94±0,61	1,12±0,3	1,1±0,39
8	2,27±0,62	1,51±0,41	1,53±0,48	3,3±1,1	2,05±0,65	2,33±0,0,73	0,72±0,25	1,1±0,39
9	4,5±1,2	3,85±1,04	2,07±0,65	2,79±0,88	3,02±0,95	1,53±0,48	2,06±0,65	1,1±0,39
10	3±0,83	1,45±0,39	1,71±0,54	3,4±1,0	1,85±0,58	7,8±2,1	1,9±0,51	1,28±0,45

Table 8. Biodegradability ratio (BOD5/COD) for seawater from Port Gdynia

Sample number	BOD_5/COD year					
	2012	2015	2016	2017	2018	2019
1	0,06	0,04	0,01	0,07	0,05	0,03
2	0,09	0,60	0,07	0,41	0,03	0,02
3	0,11	0,03	0,05	0,13	0,05	0,03
4	0,09	0,04	0,07	0,08	0,05	0,04
5	0,08	0,03	0,05	0,09	0,07	0,04
6	0,09	0,05	0,07	0,12	0,35	0,06
7	0,10	0,03	0,07	0,06	0,04	0,07
8	0,06	0,04	0,06	0,10	0,02	0,06
9	0,16	0,05	0,08	0,07	0,03	0,07
10	0,05	0,03	0,06	0,26	0,06	0,07

Monitoring has showed a low COD values. It oscillates between 17,5 mg O_2/dm^3 to 50,1 O_2/dm^3. However, these values are several times greater than the recorded BOD_5 values. The ratio of biodegradability allows us to assess the derivability of organic matter. The ratio of biodegradability concerns the BOD/COD ratio, which serves to specify the degree of biodegradability of the organic matter at the sites studied (Table 8). The trials analysed in 2012-2019 showed a BOD/COD ratio typical for Port Gdynia seawater.

The main source of oil pollutions into the environment are shipping accidents, illegal oil discharges and port activities. The condition of Port Gdynia seawater from the point of view mineral oil contamination is presented in Table 9.

Table 9. Values of Mineral Index oil in Port Gdynia

Sample number	Mineral Oil index mg/dm^3 year				
	2011	2012	2014-2016	2017	2018-2019
1	0,01±0,003	0,02±0,0106	BDL	BDL	BDL
2	BDL	0,02±0,0106	BDL	0,1±0,003	BDL
3	BDL	0,02±0,0106	BDL	BDL	BDL
4	BDL	0,02±0,0106	BDL	0,06±0,02	BDL
5	BDL	0,02±0,0106	BDL	BDL	BDL
6	BDL	0,02±0,0106	BDL	BDL	BDL
7	BDL	0,02±0,0106	BDL	BDL	BDL
8	BDL	0,02±0,0106	BDL	0,04±0,01	BDL
9	BDL	0,02±0,0106	BDL	0,06±0,02	BDL
10	BDL	0,02±0,0106	BDL	BDL	BDL

BDL – below detection limit

The analysis of Port Gdynia water demonstrated that Mineral oil index was in almost all cases below the limit of quantification of the analytical method used. The mean values of Mineral oil index recorded in the studied water fluctuate between 0,04 mg/dm^3 to 0,1mg $/dm^3$ .The higher pollution is typical for coastal port waters, where intensive economic activity is carried out (such as navigation canal, shipyard, container terminal).The analysis demonstrated the absence of pronounced annual variations of mineral index oil. Overall, no marked changes in values of Mineral oil index were evident during the last ten years.

4 CONCLUSIONS

The water environmental quality is closely related to the discharge of pollutants and natural factor such as temperature. Analysis of sea water is the direct way of assessing the pollution status of the Baltic environment.

Due to their negative effects on human and ecosystem health, heavy metals are of particulate concern worldwide. As a result of the analysis of pollutants in water from port Gdynia, low content of lead, zinc, cadmium and oil products was found. It should be emphasised that levels of dissolved species of heavy metals are very low, even near the detection limit of the method used. The highest levels of metals content were discovered in samples collected from regions with a high industrialization.

The values Biochemical Oxygen Demand obtained are characteristic of unpolluted waters, which can be used to suggest that the discharge of waste from ships are negligible. The BOD / COD ratio, which provides information on the biodegradability of a water pollutant, shows values typical for seawater.

Oil hydrocarbons occasionally come to the marine environment as a result of occasional spills, accidents and discharges. The low value of Mineral Oil Index in the recent years can be an indication to the efficiency of the measures taken to prevent oil pollution.

It can be concluded that the quality of examined waters is relatively good with respect to Polish Standards of water quality.

REFERENCES

1. Ahtiainen, H. et al.: Public preferences regarding use and condition of the Baltic Sea—An international comparison informing marine policy. Marine Policy. 42, 20–30 (2013). https://doi.org/10.1016/j.marpol.2013.01.011.
2. Backer, H. et al.: HELCOM Baltic Sea Action Plan – A regional programme of measures for the marine environment based on the Ecosystem Approach. Marine Pollution Bulletin. 60, 5, 642–649 (2010). https://doi.org/10.1016/j.marpolbul.2009.11.016.
3. Baszanowska, E., Otremba, Z.: Properties of the Baltic Crude Oil in the Oil-in-Water Emulsion Form: Excitation-Emission Spectra. Journal of KONES. 25, 1, 7–14 (2018). https://doi.org/doi:10.5604/01.3001.0012.2438.
4. Bolałek, J., Radke, B.: Aspects of pollution in the harbours located near the river mouth using the example of the Gdańsk and Klaipeda harbours. Prace i Studia Geograficzne. 44, 249–265.
5. Burskyte, V. et al.: Sustainable development of deep-water seaport: the case of Lithuania. Environmental Science and Pollution Research. 18, 5, 716–726 (2011). https://doi.org/10.1007/s11356-010-0415-y.
6. Copat, C. et al.: Heavy Metals Concentrations in Fish from Sicily (Mediterranean Sea) and Evaluation of Possible Health Risks to Consumers. Bulletin of Environmental Contamination and Toxicology. 88, 1, 78–83 (2012). https://doi.org/10.1007/s00128-011-0433-6.
7. Filipkowska, A. et al.: Organotin compounds in surface sediments from seaports on the Gulf of Gdańsk (southern Baltic coast). Environmental Monitoring and Assessment. 182, 1, 455–466 (2011). https://doi.org/10.1007/s10661-011-1889-x.
8. Fingas, M.F.: Modeling Oil and Petroleum Evaporation. Journal of Petroleum Science Research (JPSR). 2, 3, 104–115 (2013).
9. Galassi, S. et al.: A multispecies approach for monitoring persistent toxic substances in the Gulf of Gdańsk (Baltic sea). Ecotoxicology and Environmental Safety. 69, 1, 39–48 (2008). https://doi.org/10.1016/j.ecoenv.2006.11.015.
10. Gray, J.S. et al.: Effects of hypoxia and organic enrichment on the coastal marine environment. Mar Ecol Prog Ser. 238, 249–279 (2002).
11. Haseler, M. et al.: Marine Litter Pollution in Baltic Sea Beaches – Application of the Sand Rake Method. Frontiers in Environmental Science. 8, (2020).
12. Höglund, A., Meier, H.E.M.: Environmentally safe areas and routes in the Baltic proper using Eulerian tracers. Marine Pollution Bulletin. 64, 7, 1375–1385 (2012). https://doi.org/10.1016/j.marpolbul.2012.04.021.
13. Kurylenko, V., Izosimova, O.: Study of the impact of petroleum hydrocarbons on sea organisms. J. Ecol. Eng. 17, 1, 26–29 (2016). https://doi.org/10.12911/22998993/61186.
14. Lang, S.-C. et al.: Assessing PCB pollution in the Baltic Sea - An equilibrium partitioning based study. Chemosphere. 191, 886–894 (2018). https://doi.org/10.1016/j.chemosphere.2017.10.073.
15. Pazikowska-Sapota, G. et al.: The tests on stabilization of the contaminated sediments for sustainable management in the Baltic Sea region. Testy stabilizacji zanieczyszczonych osadów jako metoda zrównoważonego zarządzania w rejonie Morza Bałtyckiego. (2016).
16. Radke, B. et al.: Aspects of Pollution in Gdansk and Gdynia Harbours at the Coastal Zone of the South Baltic Sea. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation. 7, 1, 11–18 (2013). https://doi.org/10.12716/1001.07.01.01.
17. Radke, B. et al.: Seasonal changes in organotin compounds in water and sediment samples from the semi-closed Port of Gdynia. Science of The Total Environment. 441, 57–66 (2012). https://doi.org/10.1016/j.scitotenv.2012.09.006.
18. Radwan, M. et al.: Modelling of dissolved oxygen and biochemical oxygen demand in river water using a detailed and a simplified model. null. 1, 2, 97–103 (2003). https://doi.org/10.1080/15715124.2003.9635196.
19. Samudro, G., Mangkoedihardjo, S.: Review on BOD, COD and BOD/COD ratio: A Triangle Zone for Toxic, Biodegradable and Stable Levels. International Journal of Academic Research. 235–239 (2010).
20. Shahabi-Ghahfarokhi, S. et al.: Baltic Sea sediments record anthropogenic loads of Cd, Pb, and Zn. Environmental Science and Pollution Research. 28, 5, 6162–6175 (2021). https://doi.org/10.1007/s11356-020-10735-x.
21. Simon, F.X. et al.: Improvement of the analysis of the biochemical oxygen demand (BOD) of Mediterranean seawater by seeding control. Talanta. 85, 1, 527–532 (2011). https://doi.org/10.1016/j.talanta.2011.04.032.
22. Staniszewska, M., Boniecka, H.: Petroleum hydrocarbons - a necessity of monitoring in a dredged material in the Polish coastal zone. Bulletin of the Maritime Institute in Gdańsk. 46–53 (2018). https://doi.org/10.5604/01.3001.0012.7458.
23. Szyczewski, P. et al.: Research on Heavy Metals in Poland. Pol. J. Environ. Stud. 18, 5, 755–768 (2009).
24. Walker, T.R. et al.: Monitoring effects of remediation on natural sediment recovery in Sydney Harbour, Nova Scotia. Environmental Monitoring and Assessment. 185, 10, 8089–8107 (2013). https://doi.org/10.1007/s10661-013-3157-8.
25. Wang, Z. et al.: Landfill leachate treatment by a coagulation–photooxidation process. Journal of Hazardous Materials. 95, 1, 153–159 (2002). https://doi.org/10.1016/S0304-3894(02)00116-4.
26. Weintrit, A., Neumann, T.: Information, communication and environment. Introduction. Information, Communication and Environment: Marine Navigation and Safety of Sea Transportation. 9–10 (2015). https://doi.org/10.1201/b18514.
27. Zaborska, A.: Anthropogenic lead concentrations and sources in Baltic Sea sediments based on lead isotopic composition. Mar Pollut Bull. 85, 1, 99–113 (2014). https://doi.org/10.1016/j.marpolbul.2014.06.013.
28. Zalewska, T. et al.: Temporal changes in Hg, Pb, Cd and Zn environmental concentrations in the southern Baltic Sea sediments dated with 210Pb method, (2015).
29. Commission Directive 2009/90/EC of 31 July 2009 laying down, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, technical specifications for chemical analysis and monitoring of water status. (2009).
30. Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council. (2008).
31. Ministry of the Environment. 2016. Regulation Ministry of the Environment of 21 July 2016 on the method of qualifying the status of surface water bodies and environmental quality standards for priority substances. Limit values of water quality indicators from the group of substances harmful to the aquatic environment relating to bodies of surface waters of all categories. (Journal of Lawsitem. 1187). (2016).