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Establishment of Storm Water Treatment Facilities for Shipyards

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Establishment of Storm Water Treatment Facilities for Shipyards

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Abstract. The article demonstrates high level of pollution in the waters and sediments of Ulysses Bay. The pollution can be traced through the sea life vital activity indicators. One of the causes of the negative effects on the bay ecosystem from human use is the lack of storm water treatment by shipyards which operate in the coastal zone and in the waters of Ulysses Bay in Vladivostok (Peter the Great Bay, the Sea of Japan). In this article it has been shown that the organoleptic and chemical indicators for the storm water discharged without treatment into the bay used for fishing activities do not comply to the requirements for storm water quality. The article suggests the design for the storm water treatment facility to be used at the shipyard which was used for the research. The use of the suggested facility – the combined facility for oil and sand interception – would ensure that the amount of pollutants discharged into Ulysses Bay are compliant to the maximum allowable concentration (MAC).

1. Introduction

Like any other living creatures, humans are only able to survive by using the nature resources. The use of nature can be both rational and irrational. Rational use of nature resources is relatively a new concept of nature management where the nature protection is a part of the day to day operation for the businesses which are involved in the use of the nature resources. The economy with its technogenic nature disruptive characteristic is the main offender for biosphere degradation. The population growth and the increased consumption intensify the effect from the manufacture activities on the environment.

This publication is devoted to the study of environmental activities of shipyards located in the conservation area of Peter the Great Bay, the Sea of Japan, and the type of the storm water treatment facilities.

2. Relevance of the research and literature review

The nature management in the coastal area causes a number of environmental issues. The pollution of the sea waters from the waste and storm water from both households and businesses has worsened in the last decade. This has happened due to the costly nature of the nature management and the lack of will from the businesses and other stakeholders involved in the use of the nature resources. Russian law, however, requires businesses to comply with statutory requirements. The Artcile 65 of the Water Code of Russia (paragraph 16) only allows the businesses to operate in the water protection zone if they ensure protection of the sea from pollution, contamination, siltation and depletion of water [1]. One of the requirements is the presence of storm water treatment facilities. This result in the high cost for nature resource users required for design of the water treatment facilities, the calculation of the permissible level of pollution discharge, the compulsory hydrometeorological research, the research of the existing predevelopment level of water pollution, the estimative level of the biological harm they activities would cause, and the other expenses related to the issuance of the resource consent. Failure to comply with the legal requirements can result in fines or in case of repeated offence – the suspension of the activities [2].

Besides the compliance with the Water Code requirements businesses have to comply with the sanitary regulations. The removal and discharge of the surface storm water into the water bodies have the same requirements as for the underground storm water. The storm water can be discharged into the water bodies if the hygienic requirements are met which is dependent on the type of the use of the water body [3].

The volume of storm water collected on the territory of a single company can reach tens of thousands of cubic meters per year. Compare to the domestic, industrial storm water contain a large amount of oil, heavy metals and hard waste.

The pollution of the coastal sea waters of Primorskiy Region has a local nature.

The main culprits are the untreated storm water discharge from the city households and businesses, the port activities, landfill sites and the ash dump from the Thermal Power Station-2 (TPS-2) [4].

The Ulysses Bay, a high-rank water body in which water is used for fishery, juts out into the northern shore of the Eastern Bosphorus Strait between Cape Ostryi (43°05'N, 131°54'E) and Cape Nazimov located at the distance of 8 cable lengths SE from it. The shores of the bay are formed by steep hill slopes, which are bluff in some places [5]. Shipbuilding facilities are located on the shore of the bay.

The Overall Water Pollution Index (WPI = 1.26) of the bay corresponds to Class IV of the water quality - «polluted», according to the data provided by Primorsky Department of Hydrometeorology and Environmental Monitoring (PDHEM). The main pollutants present in the waters of the Ulysses Bay are hydrocarbons, surfactants (SAS), phenols [6-8]. According to the data for the year 2009, insufficiently purified wastewater in the volume of 671.1×10^3 m^3 and 104.0×10^3 m^3 was discharged without treatment to the Ulysses Bay. The weight of the pollutants discharged to the Ulysses Bay in excess of the permissible limit was equal to 554.01 t/year [6].

Pollution of waters and bottom sediments has been registered in the bay for a long period of time, which is shown in a number of publications. The data obtained at the national observation network station, located at the exit from the bay, over the 2009-2014 observation period, are indicative of the oil hydrocarbons predominance in the sea waters. In different years, their maximum concentrations varied from 2 to 48 MAC [9]. As a result of sorption of the oil hydrocarbons on the suspended particles they settle on the bottom [10]. Besides oil hydrocarbons, heavy metals are present in the bottom sediments, and also it was found that threshold values of organochlorine pesticides are exceeded [11].

Biological effects of the pollution that formed in the 2000s were investigated on the various levels of the living systems' organization – from molecular to organismal and biocoenotic [5]. Thus, changes on the molecular level were identified in mollusks and fish [12, 13], various types of morphological pathologies were detected, high indices of histopathologycal changes were found in the gonads of marine invertebrates [14, 15], as well as disturbances in the structure of the fish organs' tissues [16]. By the results of biological testing, the waters in the Ulysses Bay produce toxic effect on hydrobionts [6]. The level of anthropogenic load is also evaluated in terms of taxonomic and species composition, and in terms of the species abundance of benthos. Benthos of the Ulysses Bay is represented by 29 species, which belong to 8 faunal groups. 14 species are characterized by the highest frequency of occurrence (over 60%), among them the maximum quantitative indices are registered in the bivalve *Acila insignis* (dominates in terms of biomass, on average 10.9 g/m^2) and polychaete *Dipolydora cardalia* (dominate in terms of the quantity, 290.9 specimens/m^2). Echinoderms account for the main portion of the benthos biomass (53%) together with bivalved mollusks (29%). Two types of polychaetes – recognized pollution indicators – *Capitella capitate* and *Tharyx pacifica* are present in the bottom sediments. Overall, low numbers of benthos (963.54 specimens/m^2) is typical for the Ulysses Bay as compared to other water areas of the Vladivostok port. When evaluating the pollution, it is necessary to bear in mind the cumulative impact of all types of chemical compounds on the living organisms, which, undoubtedly, exceeds the toxic effect of the pollutants considered individually [17-19]. A high level of the Ulysses Bay water pollution affects the composition of fauna, indicators of the organisms' life activities. One of the reasons of the negative consequences of the anthropogenic press on the ecosystem of the bay is non-compliance by the users of natural resources with the requirements for discharge of wastewater.

Ulysses Bay is distinguished by the complexity of hydrodynamic and hydrometeorological conditions, differently directed wind-driven and tidal flows causing non-uniform distribution and differently directed movement of pollutants in the bay waters. Tidal events constitute the main systemic factor that determines water exchange between the Ulysses Bay and the Eastern Bosphorus Strait. When the water level increases, it flows into the bay, when the level subsequently decreases – it flows out of the bay. Depending on the direction of the wind, floating rubbish and petroleum products on the surface are accumulated between the ships and berths near the opposite shores. When the sea calms, under the influence of the tidal currents the pollutants spread all over the bay and the adjacent waters of the Eastern Bosphorus Strait [9]. The model for calculation of the current velocity fields and spreading of the admixtures, developed in the Pacific Oceanological Institute of FEB RAS, shown that when the north winds of any intensity are blowing and also under no-wind conditions, the polluted water masses (first of all, surface layer and oil films) are moving from the bay to the south, thereby polluting the northern bays near the Russian island: Ajax Bay, Paris Bay, Bay of Zhitkov [10]. It is worthwhile to take into account that the data obtained in the various hydrometeorological conditions, are not homogeneous, cannot be subjected to comparative analysis and joint processing for obtaining generalized characteristics. Difference in the assessment of the mass of substances present in the bay simultaneously received by the results of observations in different hydrometeorological conditions, are equal to 10 and more times [9].

3. The problem statement

The purpose of this paper is to study the qualitative and quantitative characteristics of polluting the waters of the Ulysses Bay by storm water runoff from the shipbuilding facility and selection of the efficient system for treatment of the storm water generated in the shipbuilding facility, which performs management of natural resources in the Ulysses Bay of the Amur Gulf (Peter the Great Bay, Sea of Japan) both for preservation of the environment, and for compliance with the environmental legislation by the users of natural resources.

4. Practical results and suggestions

The calculation of the storm water volume was conducted using a standard methodology [20] (for disposal of storm water to the treatment facilities) for a facility with the area of the water conservation zone equal to 134,510 m^2 within the plot of land of the water user, and the area of the coastal strip equal to 7,600 m^2 within the plot of land of the water user.

The total annual volume of rainwater and melt water discharged from the territory of the facility is equal to 63,375.13 m^3; the volume of the surface runoff during the warm season (54,281.59/214 days/24 = 10.5689 m^3/hour); the volume of the surface runoff during the cold season (3,625.97/151 days/24 = 2.50926 m^3/hour). Wastewater of the facility is discharged by way of the controlled disposal of the surface runoff to the storm water catch basin.

Concentrations of pollutants in the sea water were determined at the distance of 250 m from the point of the surface runoff discharge, as well as in the storm waters discharged from the territory to the Ulysses Bay via the deep-water discharge belonging to one of the shipbuilding facilities carrying out the use of the natural resources within the waters of the bay. The sampling was conducted on a quarterly basis in the course of the production ecological monitoring within the period 2015-2017 according to the approved schedule of sampling and performing chemical analysis. The samples were taken and analyzed by the specialists of the accredited laboratory FSBI «Center of the Laboratory Analysis and Technical Measurements in the Far Eastern Federal District». Concentrations of the pollutants were determined– phosphates, ammonium, anionic surfactants (anionic surface active agents), phenols, petroleum products, soluble Fe, Cu and Zn, total gross Fe, suspended matter, organoleptic indicators (transparency, color, smell), biological oxygen demand BOD (total), permanganate oxygen consumed, pH, floating matter.

It was established that the storm water from the territory of the facility and the samples of water taken at the distance of 250 m from the place of discharge do not correspond to the hygienic requirements relative to the water in the fishery water body by the majority of indicators. Petroleum products in the runoffs and sea water were at the level of 6 MAC (maximum allowable concentration). Concentration of the anionic surfactants in the wastewater of the facility was equal to 0.3-1.9 MAC, in sea waters – 0.01-0.2 MAC. Several-fold exceeding of the iron concentrations in the wastewater of the facility was established at the level from 6 to 36 MAC, in sea water iron concentrations were lower and equal to 0.2-1.6 MAC. Concentrations of copper and zinc at the distance of 250 m from the point of discharge were not larger than MAC (< 0.4 and < 0.1 respectively). Single-time exceeding of MAC for copper in the sea water was noted in April 2015 (16 MAC). And yet, exceeding of MAC with regard to these elements was not found in the waste waters (Cu < 0.4 MAC, Zn < 0.1 MAC). Concentrations of the ion NH_4^+ were equal to 3.54-16.46 MAC in the discharged wastewater. In the second and third quarters of 2015, exceeding in the sea water of the ammonia ions concentration (NH_4^+) was established at the level of 3 MAC. In the rest of the samples, concentration of the ammonia ions was less than 0.7 MAC. Concentration of the phosphates in the discharged wastewater was less than 0.8 MAC, in the sea water – less than 0.07 MAC. Maximum exceeding of MAC was found for suspended matter – in the discharged wastewater – 32-96 MAC, in the sea water – 12-26 MAC. Quality of the storm water in terms of organoleptic indicators does not correspond to the sanitary and hygienic norms established for the fishery water bodies. There were no floating admixtures in the sea waters. pH of the sea water (7.04-7.96) and discharged wastewater (6.67-7.29) corresponds to the weakly alkaline and neutral values. The permanganate oxidation value of the discharged wastewater was at the level of 1 MAC. BOD indicator (full) of sea water corresponded to the established requirements, except two samples taken in the second and third quarters of 2015 (1.82 and 1.04 MAC, respectively).

The results of the production environmental monitoring have shown noncompliance of the facility's wastewater composition in terms of chemical and organoleptic indicators. In this connection, it is obvious that there is a necessity to install the storm water treatment plant at the shipbuilding facility that carries out the use of natural resources in the coastal zone of the city of Vladivostok. It is possible to allow the discharge only of those wastewaters that do not change the composition of the seawater.

A comparative analysis was conducted with regard to the use of various models of the combined sand and oil traps for treatment of the storm water runoff under consideration for the purpose of reducing concentration of pollutants in the wastewaters of the enterprises.

Storm water treatment plants depending on the qualitative characteristics of the water being purified can contain the following types and units of equipment: sand catchers, oil catchers, sorption filters, UV disinfection systems, sewage pumping systems, separating chambers, accumulating tanks, settling basins. Depending on the manufacturer, composition of the equipment may vary. Storm water treatment can be performed according to several different schemes, selection of which depends on several factors. Among these factors, apart from everything else, the possibility of peak loads should be taken into account – for example, during long periods of rain or rapid thawing of snow.

The standard scheme of installation is designed for purifying water from the presence of petroleum products and suspended matter. If it is necessary to perform treatment of the storm water from more specific admixtures, the equipment more suitable to this task shall be offered.

Finally, for treatment of the storm water discharged from the shipbuilding facility, combined sand and oil traps were selected – these are special devices for cleaning of the domestic wastewater and storm water from heavy suspended matter, oily substances and petroleum products (Table). Throughput capacity of the combined sand and oil traps is from 5 to 75 L/sec.

Table 1. Comparative Characteristic of the Combined Sand and Oil Traps.

Combined sand and oil trap	*Suspended Matter, mg/L*			*Petroleum Products, mg/L*		
	at the inlet	*at the outlet*	*Percentage of treatment*	*at the inlet*	*at the outlet*	*Percentage of treatment*
Ecolos	<2000	10-20	99.0-99.5	<200	0.3-0.5	99.7-99. 8
Modern Engineering Solutions	900	3	99.7	100	0.05	99.9
AquaBioM	600	50-100	83.3-91.7	60	0.3-0.5	99.2-99.5

Combined sand and oil traps manufactured by Modern Engineering Solutions Company are the most acceptable in terms of the selected parameters of treatment (concentration of suspended matter and petroleum products, percentage of treatment). This model provides a system for complex treatment of storm water, which includes: sand separator, oil and gasoline separator, sorption unit. Once this equipment is installed, the concentrations of pollutants in the wastewater at the outlet will reach the values lower than MAC (0.33 MAC for suspended matter and 0.003 MAC for petroleum products). Achieving MAC values for the pollutants in the storm water will allow the company to reduce costs associated with producing negative impact on the environment, having eliminated the payment for discharge according to the above-limit rates and compensation of damage.

5. Conclusions

Storm water treatment facilities are intended for purification of the storm water in case of their pollution by petroleum products or other wastes. The system of combined sand and oil traps allows to ensure the greatest degree of treatment throughout the entire operation period with the maximum efficiency. For solving the environmental problems connected with pollution of the Ulysses Bay waters, it is necessary to apply a comprehensive approach to the system of nature use in the coastal zone, including the improvement of the environmental legislation system, which determines the conditions for conducting business activities in the water conservation zones within the high-category water bodies used in fisheries. It is necessary to tighten control over those water users who discharge wastewater of improper quality.

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