Ecological safety of water resources of the seaport

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Abstract. In the conditions of port activities, the object of protection is the natural environment, primarily water and aquatic biological resources, as the most sensitive to external influences. The issues of environmental risk assessment are considered as measures for the protection of water resources in the face of an increase in cargo flows of a large seaport. Firstly, the risk of accidents during sea bunkering operations, and secondly, the environmental risk (the risk of introducing bioinvasions with ballast water) during deballasting of sea vessels. The general scheme for assessing environmental risk in relation to the components of the natural environment is considered. The number of bunkering operations in a large seaport has been calculated (2200 - 2500 per year in recent years). On the basis of statistical data, the frequency of accidents with oil spills during bunkering operations was found. Its numerical value was 2.9 \times 10^{-4} 1 a year per one operation. The volume of deballasting of individual sea terminals and the entire port has been determined - 55 million m³ per year. Basins for primary ballast intake for tankers and dry-cargo ships have been determined for ship entries to the loading port in 2020. This makes it possible to rank the discharged ballast according to the level of environmental risk (risk of bioinvasions), which is determined by the basin of its primary intake and/or transit time.

1. Introduction

Of all natural resources, water resources are the most sensitive to external influences and the most significant for society. At the same time, for sea transport, water is not only a natural component to be protected, but also directly performs an economic function of a transport medium for ships. The increasing intensity of shipping, the increasing volumes of dangerous goods transportation increase the level of pollution of natural resources, the risk of emergencies and the scale of possible consequences.

At present, one of the important problems in the field of ensuring the ecological safety of ships is the problem of preventing the introduction of alien species into water bodies closed to their natural habitat. To a large extent, this problem is caused by the development of shipping and the transfer of organisms in ship’s ballast water and sediments. The importance of this route of introduction of alien and dangerous organisms for the region will increase with the intensification of navigation, therefore, each vessel transporting and discharging ballast water can be viewed as a source of potential environmental hazard.

The operation of sea transport is impossible without the use of ships bunkering with fuel and, as practice shows, such accidents with oil spills often occur in ports. It is important to establish parameters for the risk of bunkering accidents and to mitigate this risk. In addition, ballasting of ships
is an integral part of maritime transport technology. The ballasting process is essential for the safety of navigation, but from the point of view of ensuring environmental safety, it can pose a serious threat to marine ecosystems. The damage caused by alien marine organisms to the new habitat is possible due to the disruption of the natural balance of the marine ecosystem, which often threatens the complete extinction of any local species of flora and fauna.

2. Assessment of the environmental risk of bunkering operations

Bunkering (refueling) operations are common in the practice of seaports, when sea transport and other vessels receive fuel at the port of call to continue navigation. Such operations are often carried out with the help of specialized bunkering vessels by pumping oil products (diesel fuel or fuel oil) to transport vessels at anchorage or at the berths. The operation is environmentally responsible, any incident with an oil spill in the port water area is considered an accident in accordance with the norms of national legislation. Despite the measures taken, such situations sometimes occur, causing significant damage to water resources. The main cause of emergencies of this type is, as a rule, the human factor.

According to the established practice in the field of safety [1, 2], the assessment of environmental risk can be performed taking into account the frequency of occurrence of an undesirable event (accident) and damage caused by this event. The mathematical formalization of the calculated value of the predicted risk may look like this:

\[
R_{\text{env}} = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{l} \lambda_i P_{ij} P_{ijk} Y_{ijk},
\]

where \( R_{\text{env}} \) is the value of the environmental risk; \( i = 1...n \) is the number of calculated scenarios for the occurrence and development of an accident; \( j = 1...m \) is the number of damaging factors types that determine the nature of the impact on environmental objects during the implementation of the \( i \)-th accident scenario; \( k = 1...l \) is the number of objects of the natural environment; \( \lambda_i \) is the frequency of the \( i \)-th accident scenario per year; \( P_{ij} \) is the probability of realization of the \( j \)-th type of damaging factor for the \( i \)-th scenario; \( P_{ijk} \) is the probability of occurrence of consequences (causing harm, damage) to the \( k \)-th object of the natural environment (natural component); \( Y_{ijk} \) - consequences (harm, damage) for the \( k \)-th object of the natural environment by the impact of the \( j \)-th damaging factor during the implementation of the \( i \)-th accident scenario.

The value \( \lambda_i \) in formula (1) has a probabilistic nature and when predicting environmental risk (a priori risk), its value is often taken based on the events that have occurred, i.e. operating experience of an analogous facility in recent years (posterior risk):

\[
\lambda_{\text{a}} = \frac{N_t}{Q_t},
\]

where \( \lambda_{\text{a}} \) is the frequency of the \( i \)-th accident scenario over time \( t \), years, per year; \( N_t \) is the number of accidents during time \( t \), years; \( Q_t \) is the number of bunkering operations over time \( t \), years.

Table 1 shows the number of bunkering operations carried out in the large seaport of Novorossiysk over 6 years and the number of accidents during this period.

| Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|------|------|------|------|------|------|------|
| \( Q_t \) | 5128 | 2905 | 2492 | 2358 | 2268 | 2203 |
| \( N_t \) | 1 | – | – | 1 | 3 | – |
In accordance with the data presented, the frequency of an accident during bunkering operations in the port was (2):

$$\lambda_t = 2.9 \times 10^{-4} \text{ year}^{-1},$$

per one bunkering operation. The depth of the statistical database for this a posteriori estimate was 6 years, which is consistent with the guidelines in this area. Such a value often has independent practical significance as a probabilistic component of risk assessment [1]. This example shows the combined use of methods of environmental and industrial safety. The result of the risk assessment can be used, for example, in predicting emergencies with oil spills, as well as in the development of documentation with an environmental focus.

3. Environmental safety when deballasting vessels
Sea transportation is impossible without ballasting of vessels in order to ensure the seaworthiness of the vessel during the passage. At the same time, according to various estimates, 3-5 billion tons of water are transported in ballast tanks of ships. The process and quick results of ballast water discharge are difficult to detect visually, unlike the discharge of oily water or oil products, however, the consequences of deballasting can exceed the severity of oil pollution. Even a decade ago (2010), the volume of deballasting in the port of Novorossiysk was 38.5 million m³, and in 2020 it exceeded 55 million m³.

The Ballast Water Management Convention (BWMC) entered into force in September 2017 [3]. Additional measures were envisaged for the ecologically safe disposal of ballast water [4]. At the same time, according to the results of 2020, it was established that only in 20% of ship calls the vessel had a ballast water treatment plant certified in accordance with the BWMC Convention. In the port of Novorossiysk, the data on ship calls were processed during 2020, and the ballast was discharged into the port water area in 4121 cases. In 2,143 cases of them, express control of samples from ships' ballast tanks and from ballast scuppers was carried out during deballasting operations at the berths. The control was carried out according to the indicators of ballast water density using an AMV GOST 18481 hydrometer or an ATAGO ACT-S / Mill-E refractometer.

The total volume of ballast discharge into the port water area in 2020 amounted to 55,033 thousand m³, of which:

- from tankers 43816 thousand m³, including:
  - at the KTK-R oil terminal - 26,853 thousand m³;
  - at the NGSH oil terminal - 13267 thousand m³;
  - at oil terminals 4th and 5th pier - 3697 thousand m³;

- 11207 thousand m³ were discharged from dry cargo ships into the port water area.

The results of deballasting at the terminals of the port of Novorossiysk in 2020 are presented in Figure 1.

The issues of ecological safety of the deballasting process and its consequences [5] largely depend on the geographic location and the presence of alien invasive species of biota of the primary ballast intake basin. When considering all possible ways of handling ship's ballast water (in order to neutralize invasive species), the most realistic and promising are ways to neutralize ballast aboard, but there are still few such certified installations on ships.

In addition, the risk of keeping live specimens in ballast depends on the duration of the ballast passage. All living organisms need a certain level of oxygen, which gradually decreases over time in hermetically sealed ballast tanks. This creates the possibility of ranking the discharged ballast according to the level of environmental risk (the risk of introducing invasions), which is determined by the basin of its primary intake and the time of passage.

Figure 2 presents data on the initial ballast intake in the basins of the oceans for tankers and dry cargo vessels by ship calls at the port of Novorossiysk in 2020.
In accordance with the proposed scheme for assessing initial ballast by the level of environmental risk, the following criteria can be used. For the Black Sea ports, the risk is insignificant, since the ballast intake / discharge basin is the same. For the basins of the Indian and Pacific Oceans, the risk of deballasting in the port of Novorossiysk can be considered low due to the length of the passages. Atlantic crossings can also be long, more than 10 days, so the risk in this case should be considered low. If the passage to Novorossiysk takes less than 10 days, the risk should be considered average.

For the ports of the Mediterranean Sea, the ecological risk of ballast water should be perceived as increased. An analysis of the transport activities of tankers and dry cargo vessels in the port of Novorossiysk (2020) showed that most often the initial ballast intake was carried out in the Mediterranean basin.

The listed criteria for assessing the risk of introducing invasions with ship's ballast water are of a qualitative, rather linguistic nature. More research is needed to obtain more accurate, quantitative estimates.

4. Conclusion
Schemes for assessing environmental risk were analyzed as measures for the protection of water resources in the face of an increase in freight traffic and economic activity in a large seaport. This is, firstly, the risk of accidents at sea bunkering operations, and secondly, the environmental risk (the risk
of introducing invasions in the composition of ballast water) during deballasting of sea vessels in the port.

A scheme for calculating the environmental risk of sea bunkering operations is presented and the frequency of occurrence of accidents of this type (with the spill of oil products) is determined. The statistical data on the operation of the large port of Novorossiysk were used. During the operation of seaports and oil terminals, the risk of incidents with oil spills, including those associated with bunkering operations, exists constantly. Such calculations or their results are often in demand in predicting the risk of marine accidents, as well as in the development of documentation in the field of environmental safety.

A brief analysis of the volume of deballasting in the port and for individual terminals (in 2020 it exceeded 55 million m³) showed its increase by 1.4 times over the decade. The ranking of the discharged ballast according to the level of ecological risk (the risk of introducing invasions in the content of the ballast) with "insignificant", "low", "medium" and "increased" criteria is proposed.

References

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