RISK ASSESSMENT MODEL OF COASTAL SEA POLLUTION BY BLACK (SEWAGE) WATERS FROM VESSELS

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SUMMARY

Qualitative risk assessment using the risk matrices recommended by International Maritime Organization (IMO) and International Standards Organization (ISO) cannot be used for the risk assessment of the pollution of precisely determined part of the coastal sea by black waters from various vessels. Therefore, an original model has been set for risk assessment by means of multiplicative matrices at three levels, allowing risk assessment for very complex assessments with a lot more input factors unlike the classic risk matrix that has two input factors (frequency of occurrence, intensity of consequences). The proposed model of risk assessment uses matrices which first determine the vessel risk index taking into consideration the factor of device for the processing of black waters and the factor of regulations that are applied to the respective vessels. Later, the location sensitivity index is determined, which takes into consideration the sensitivity factor of the location and the factor of impact on the location. Finally, at the third level the assessed risk of sea pollution by black waters is determined according to the type of vessel at precisely defined maritime zone locations. The offered model of risk assessment using multiplicative matrices has practical application and can be used also for many other risk assessments that take into consideration many input factors that affect the risk. The result of risk assessment of the pollution of the coastal sea can be used in decision-making in risk management for undertaking measures in order to protect the coastal sea, human health, and economic activities of a certain area in the coastal sea.

1. INTRODUCTION

Sanitary wastewaters on ships are usually considered as “black waters” and “grey waters” (IMO, MARPOL 73/78 Annex IV). Black wastewater generated on ships is different regarding retention time and lower water content than the faecal wastewaters from land installations (Hannien & Sassi, 209). It is less diluted (of higher concentration) as consequence of less water used for rinsing of sanitary devices (Hanninen & Sassi, 2009).

Regulations regulate the discharge of black and grey waters into the sea from the vessels.

Under the International Convention for the Prevention of Pollution from Ships, 1973, as modified by Protocol of 1978 (MARPOL), marine vessels are allowed to discharge raw sewage at distance greater than 12 nautical miles (nm) offshore and speed greather than 4 knots.

The potential adverse impacts of pollutants from black waters on the quality of water in the coastal environment are multiple and depend on the quantity of discharge, chemical composition and concentration of black waters (Owili, 2003; Henrickson *et al*. 2001; Baker *et al*. 1995.; Gray *et al.* 2002.). The most common consequences in the coastal zone are related to pathogenic organisms, nutrients, chemicals, and metals that are found in black water (Owili 2003; Koboević & Kurtela, 2012.). The issue of the adverse impact of black waters in the sea and their effect have been studied and published by many authors.

Many authors have dealt with the analysis of various human diseases caused by black waters in sea water (Henrickson, *et al.* 2001). The study included the problems of hypoxia and eutrophication in the sea (Smith *et al.* 1999; Gray *et al.* 2002; Hanninen & Sassi 2009; Shenping *et al*. 2010). Spoke generally about the problems of faecal pollution of the coastal regions. (Pommepuy, *et al*. 2006).

According to the international standard ISO 31000:2009 the risk is defined as “impact of insecurity on the objectives”. This definition includes both a positive and a negative impact on the realization of objectives (International Standards Organization, ISO 2009). The International Maritime Organization (IMO) defines the risk as: “Combination of frequency and seriousness of consequences” (IMO 2002). Risk analysis is related to various maritime actions and its effect in various ways in the environment has been already previously studied (Kristiansen 2005.; Mullai 2006.).

Risk management aims to develop a coordinated set of activities and methods used to direct an operation and to control the safety system and the risks that can affect the operation performance and the ability to successfully reach its objective (ISO, 2009.;). Thus, risk management should be linked to the identification and strengthening of the conditions which represent the basis for the successful performance of an operation (Dekker 2014; Hollnagel 2014).

Risk assessment is part of a unique process of risk management (Brandsater 2002; Gavrilescu 2007.). Because of the negative impact of black water from the vessel on the living world in the coastal sea, humans connected to coastal sea and industry in the coastal sea (tourism, fishery, and fish and shellfish farming) (Koboević *et al.* 2012.; Diedrich 2010.) it is necessary to assess which types of vessels belong to the group which represents most risk to the pollution of coastal sea from the vessels.

Hence, this study presents a model for assessing the risk of pollution by sewage wastewater („black water“) from vessels in coastal sea area.

2. MATERIALS AND METHODS

The methodology utilized for the risk assessment of pollution by black water from vessels in coastal sea is based on the Formal Safety Assessment (FSA) by International Maritime Organization (IMO). FSA is defined as a rational and systematic process for assessing the risks associated with shipping activity and for evaluating the costs and benefits of IMO's options for reducing these risks (IMO, 2005).

Analysing IMO Guidelines for Formal Safety Assessment (FSA), the international norm ISO 31000:2009 and US Environmental Protection Agency (EPA), model of ecological risk analysis (US EPA 1998), it may be concluded that all these acts are based on the more or less similar logical considerations and sequence of activities, and therefore their basic assumptions are very similar, and the differences lie mainly in the method or procedures used to reach the set goal – assessment and evaluation of risk in order to define the measures to act on it (handling, its minimisation, avoidance, etc.).

However, not one of these acts does offer a comprehensive and generally applicable procedure that could be easily applied as a model in sea pollution by black waters from the vessels. Because sea pollution by black waters from the vessels is a very complex issue related to several different fields of science. The existing risk matrices are only guidelines, and not a final model or procedure on the basis of which one could undertake action.

Therefore, using recommendations and good practices from IMO guidelines for Formal Safety Assessment and standard ISO 31000:2009, the original model of sea pollution by black waters from the vessels is set. It consists of three main steps: hazard identification as part of risk identification, risk assessment and risk evaluation.

2.1 SETTING THE MODEL FOR RISK ASSESSMENT

The first step, identification of hazard, is the initial step which identifies the problem or hazard, and the subjects or resources that may be affected are defined.

The second step, risk assessment is the most comprehensive part and consists of three parts. In the first part the source of threat and vulnerability of the sea from black waters from the vessels is determined. In the second part the method for risk assessment is selected and the model for risk assessment is set, whereas in the third part the set model is applied and the risk level for various vessels is defined.

The third step, risk evaluation, implies the definition of criteria or limits according to which the risk will be compared and evaluated, with determination of priorities that should be handled first, in order to avoid or reduce higher risks.

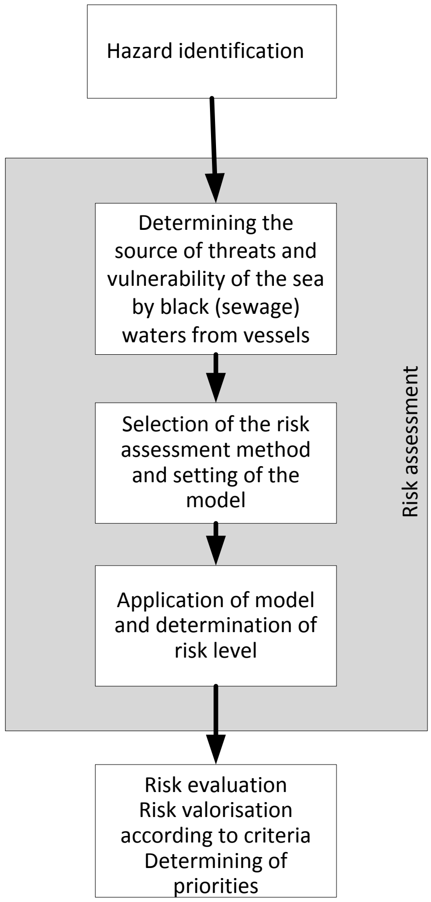

Figure 1: Model for risk of sea pollution with black waters from vessels

2.2 IDENTIFICATION OF HAZARD

Based on the analysis of harmful effect of black waters on the sea, people and industry, there is no doubt that every discharging of black waters from the vessels into the sea has negative impact on the sea. They have been established and they do exist. One may say that discharge of black waters has been identified as unquestionable threat or hazard for the sea and the people.

What negative effects these discharges will produce depends on many factors and particularly on the distance of the vessel from the coast, the quantities discharged, frequency of discharge, composition of the black waters (processed or unprocessed) existence and application of rules that regulate this issue, existence and use of land installations for the reception of black waters from the vessel to the shore, with awareness and conscience of people who perform operative activities on the vessels, etc.

However, it has not been determined yet which are the vessels which more or less negatively affect the sea on this matter, that is, which vessels are more or less risky for pollution of the sea by black waters from the vessels. It is therefore necessary to assess the risk of pollution of the sea with black water from vessels in order to have the basic assumptions to make the decisions regarding the protection of the sea and sea resources in order to utilise them in a sustainable manner both in the present and in the future time.

2.3 DETERMINATION OF SOURCE OF THREAT AND VULNERABILITY OF THE SEA WITH BLACK WATERS FROM VESSELS

Source of threats for the sea are different types of vessels with their equipment for black waters, related to the possibilities for defined handling of such waste. Apart from the vessel itself and the available equipment, an important role belongs to the international and national regulations that determine the permitted and unpermitted handling of black waters on vessels in certain areas or distances of these vessels from the coast.

The sea, on which the black waters from the vessels have negative impact, is not at every location either equally resilient or equally endangered. This vulnerability related not only to the quality of the seawater but rather also to the flora and fauna in the sea, beauty of the sea environment, people in direct contact with the sea, and even to various branches of industry and human activities related to the sea.

Therefore, for the risk assessment against such pollution from the vessels, one should take into consideration the factors that determine the extent of threat of a certain vessel, and these are regulations factor and factor of installed devices and equipment for black water on the vessel. Apart from factors that influence the vessel, also those have to be considered that define the vulnerability of the location, such as, for instance, its sensitivity factor and the factor of location impact.

2.4 SETTING THE ORIGINAL MODEL FOR RISK ASSESSMENT WITH MULTIPLICATIVE MATRIX

In order to assess the risk from sea pollution by black wastewater from the vessels in the lack of exact numerical data the choice of the method is reduced to one of the qualitative methods. Here most often used and universally applicable is the risk matrix. Therefore, it is the logical choice.

However, the risk matrix recommended by the International Maritime Organization and has 4 x 4 fields, the same as the risk matrix according to the standard ISO 31000:2009 with 5 x 5 fields, cannot be applied here, as well as any other risk matrix regardless of the number of fields, because all these matrices have only two inputs and the result is obtained by the product or sum of the two variables. For the risk assessment of sea pollution by black waters from the vessels more than two factors (variables) which should help in achieving the best possible or a more credible qualitative assessment need to be taken into consideration.

Therefore, it was necessary to devise how to use the risk matrix as a tool, but one that could handle more than two variables.

Apparently, a request with irreconcilable contradictions cannot be resolved at once. After intensive researching and combining how to channel a greater number of factors at only two inputs of the matrix, an original model with multiplicative matrices at three levels has been designed. Using such a matrix and inputting at every level two variables in the matrix, it gradually comes to the last matrix (3rd level matrix) which yields the final result on risk level.

This satisfies the requirement for more factors that participate in the risk assessment and result in a single solution (risk level). Figure 2 shows the flowchart of the model for risk assessment of the sea pollution with black wastewaters from vessels.

After identification of the threat/hazard, risk assessment continues with determining of the source of threats and vulnerability of the sea. Since it has been determined that the source of threat are vessels at sea and the vulnerability of the sea location on which they are located, it should be determined precisely which type of vessel it is and at which location.

For the type of vessel one can use the classification of vessels by size and purpose, or according to the maritime code which gives the definitions for various types of vessels, and the choice is then done according to one such classification.

The locations can be determined according to those typical locations at which the vessels stay to perform some of their purpose-intended activities.

After determining which type of vessel is in question and at which typical location such a vessel is staying, one has to assess the risk of that vessel, which is determined by a 1st level matrix, (Figure 3.) and as result one gets the "vessel risk index". The factor of regulations that refer to that vessel enters the 1st level matrix, and this is done by the choice of one of three offered options:

1. Regulations refer to the vessel and vessels are controlled – this is an option offered for the vessels

on which international regulations such as MARPOL Annex IV are applied, controlled by the institutions PSC (*Port State Control*) in the states in which the Paris Memorandum is applied.

2. Regulations refer to the vessel, but the vessels are not controlled – the option is for vessels to which international regulations such as MARPOL Annex IV are applied but the investigations performed by PSC (*Port State Control*) do not refer to them, since the Paris Memorandum does not apply to them;
3. Regulations do not refer to the vessel – the option is for the vessels to which international or national regulations do not apply due to their smaller size or navigation category.

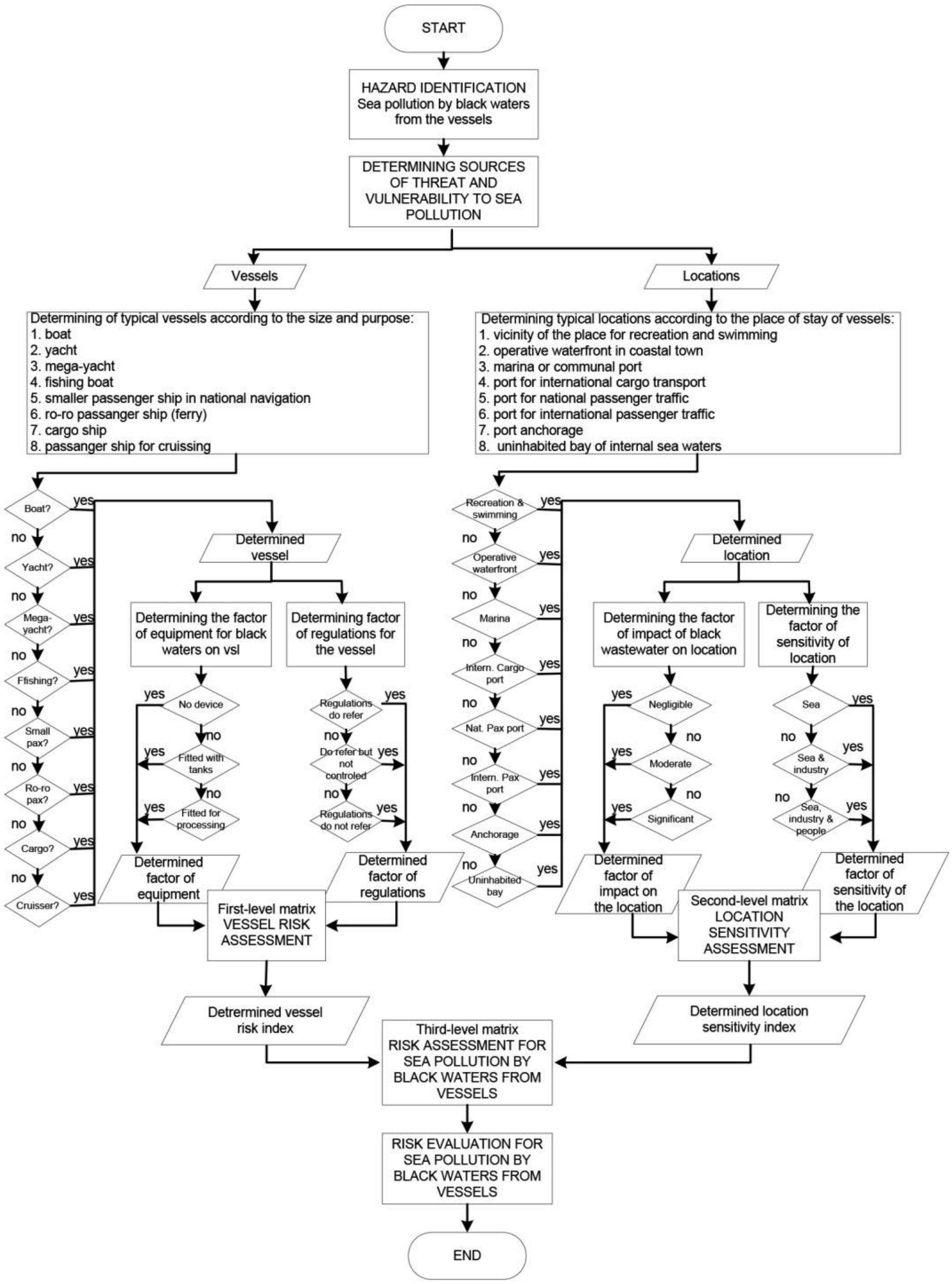

Figure 2: Flowchart of the model for risk assessment of sea pollution by faecal waters from vessels.

First-level matrix VESSEL RISK INDEX		**Factor of regulations**		
		Regulations refer to vessels and vessels are controlled (1)	Regulations refer to vessel but the vessels are not controlled (2)	Regulations do not refer to the vessel (3)
Factor of devices	No device or fitted with a retention tank only (3)	3	6	9
	Fitted with a device for grinding and disinfection (2)	2	4	6
	Fitted with a device for complete processing of black waters (1)	1	2	3

Figure 3: First-level matrix

Apart from the factor of regulations the factor of devices installed on the vessel (presented in Figure 3) enters also the 1st level matrix, where three options have been offered as the categorized devices in MARPOL Annex IV:
1. The vessel is fitted with a device for complete processing of black wastewaters;
2. The vessel is fitted with a device for grinding and disinfection of black wastewaters;
3. The vessel is fitted only with a tank for retaining black wastewaters, and there is no device for their processing.

The sensitivity of this location is assessed by the 2nd level matrix (Figure 4), which is used to determine the “location sensitivity index”. The factor of location sensitivity enters the 2nd level matrix. First factor refers to the possible harmful activities at that location, using a choice of one of the three offered options:
1. action on the looks of the sea and biological world in the sea;
2. action on the looks of the sea, biological world in the sea and on the industry;
3. action of the looks of the sea, biological world in the sea, on the industry and on the people.

The second factor that enters the 2nd level matrix is the impact factor on the location according to the choice of one of the offered options:
1. has negligible impact;
2. has moderate impact;
3. has significant impact.

Second-level matrix LOCATION SENSITIVITY INDEX		**Location sensitivity factor**		
		The sea (look and bio. world) (1)	The sea (look and bio. world) and industry (2)	The sea (look and bio world) industry and people (3)
Impact factor on location	Affects significantly (3)	3	6	9
	Affects moderately (2)	2	4	6
	Affects negligibly (1)	1	2	3

Figure 4: Second-level matrix

The vessel risk index and location sensitivity index are input data for the 3rd level matrix (Figure 5), which is used to assess risk of sea pollution by black waters from the vessels, in order to determine the risk level of sea pollution by black waters from vessels.

Third-level matrix has 6 x 6 fields: exactly as many inputs as the matrices 1 and 2 can have result that is numerical values of the fields occupied by these indices in matrices of the 1st and 2nd level. For the 3rd level matrix it is necessary to determine in advance the area of risk level.

Third-level matrix RISK OF SEA POLLUTION WITH BLACK WASTEWATERS FROM VESSELS		**Location sensitivity index**					
		1	2	3	4	6	9
Vessel risk index	9	9	18	27	36	54	81
	6	6	12	18	24	36	54
	4	4	8	12	16	24	36
	3	3	6	9	12	18	27
	2	2	4	6	8	12	18
	1	1	2	3	4	6	9

RISK LEVEL
Low risk (1-10)
Medium risk (11-30)
High risk (31-81)

Figure 5: Third-level matrix

By colouring the fields in the risk matrix visual separation is achieved and detecting of the levels of risk. Thus, the yellow coloured area (with lower numerical levels) is of low risk. Then the medium area in the matrix, coloured green, is the area of medium risk. The red coloured area, the outermost, with the highest numerical levels of the fields is the area of high risk. Numbers in coloured area of the matrix represents Risk Index, (multiplicity of factors Vessel Risk Index and Location Sensitivity Index). Those numbers shows to us just its position in the matrix, and does not value the risk as quantitative category. So that we are taking in consideration numbers as qualitative measure, and no need to be considered as so accurate indicator with precision values.

Figure 6 shows an example of the model of multiplicative matrices at three levels for risk assessment of sea pollution by black waters from the vessels for a certain type of vessel that is at a certain location.

Application of the model for risk assessment of sea pollution by black waters from vessels.

After having set the original model of risk assessment one can concretely apply and assess the risk for exactly determined vessels at certain locations.

The vessels can be classified into several typical categories such as:

1. Boats,
2. Yachts,
3. Megayachts,
4. Fishing boats,
5. Smaller pax. ships in national navigation (“cabotage ships”),
6. RO-RO passenger ships (ferries),
7. Cargo ships,
8. Passenger ships for cruising (cruisers).

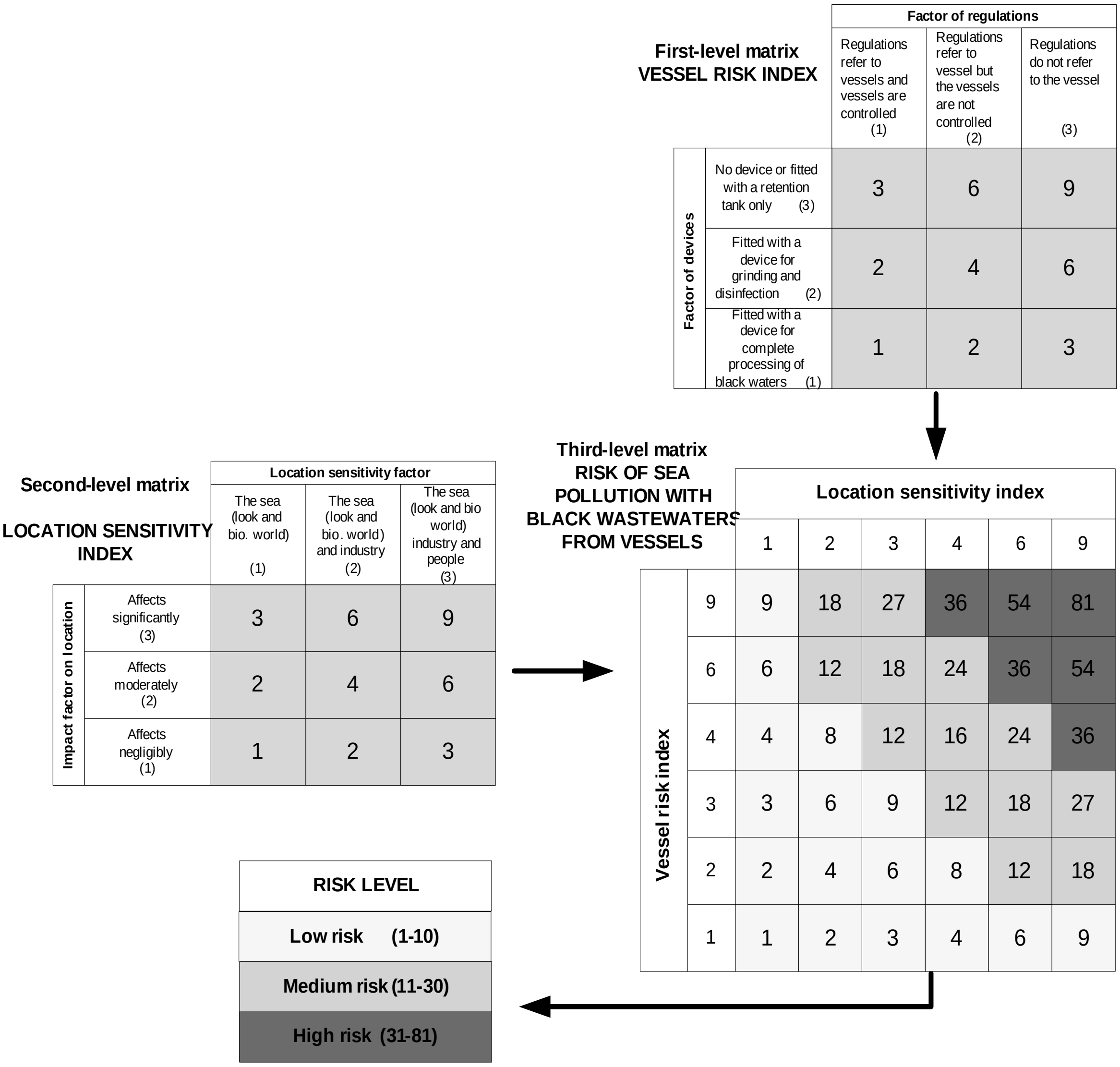

Figure 6: Model of multiplicative matrix at three levels used to assess risk of sea pollution by black waters from vessels

Typical locations, at which the vessels stay for performing of their purposeful activities or rest, can be divided into:
1. sea next to the place of recreation and swimming;
2. operative waterfront in the coastal inhabited place;
3. marina or communal port;
4. port for international cargo traffic;
5. port for national passenger traffic;
6. port for international passenger traffic;
7. port anchorage;
8. uninhabited bay in internal sea waters.

The risk assessment of sea pollution by black waters for a certain vessel at a certain location, can be done by the mentioned multiplicative matrices of the 1st, 2nd and 3rd level, that is, with the set model (Figure 2) using the already obtained result of the 1st level matrix – Vessel Risk Index (Figure 3) and the results of the 2nd level matrix – Location Sensitivity index (Figure 4). The results of the matrices of the 1st and 2nd levels are at the same time input data for the 3rd level matrix whose result is the level of risk by sea pollution with black waters from a certain vessel at a certain location. (Figure 5).

3. RESULTS AND DISCUSSION

For the following risk assessment, the vessels and locations need to be correlated. Since in real life it is not possible to find every typical vessel mentioned in this classification, on every location (e.g. cruiser in a marina or boat in a harbour for international cargo transport), only rational combinations of vessels on certain locations that are possible and are encountered most often in real life have been selected. Figure 7 shows the combinations of vessels and locations for the following risk assessment.

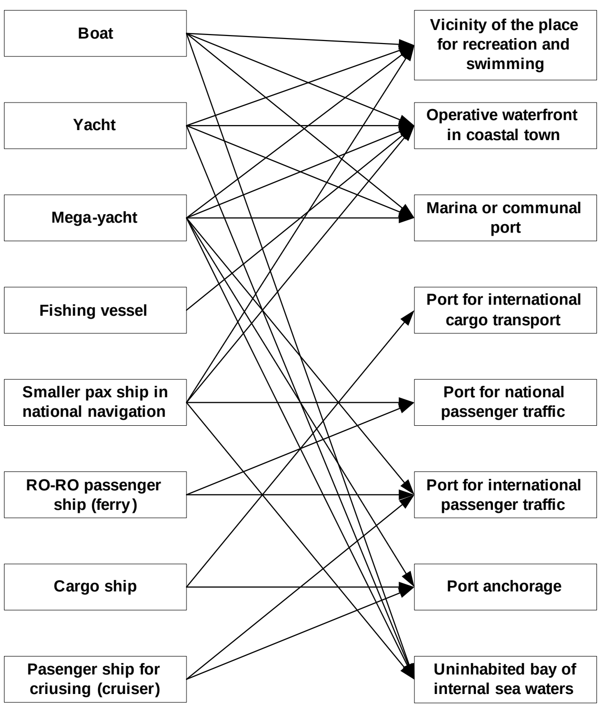

Figure 7: Typical vessels and typical locations for risk assessment of sea pollution by black waters from the vessels

3.1 DETERMINING RISK INDEX FOR CERTAIN TYPES OF VESSELS

Risk index of vessels is obtained from the first-level matrix (described in Figure 3) by entering the first-level matrix for the selected vessel with the factor of regulations and the factor of device. Thus Table 1 is valid for the selected vessels:
1. Boat – factor of regulations 3 has been selected because the international regulations are not applied to boats, and there are no national ones for the regulation of this issue. Factor of device is 3 because on smaller boats there are toilettes with direct discharge using manual or electric pump, whereas the majority of boats are fitted with a tank for collecting black waters (see 4.1.1). In both examples the factor of device is the same. The resulting risk index of a boat is 9.
2. Yacht – factor of regulations is 2 because yachts usually sail under a foreign flag and are mainly in international navigation, which is why MARPOL Annex IV is applied to them. However, since they are not ships but yachts the Paris memorandum is not applied to them so they are not subject to periodical inspections of the “Port State Control” inspector. The factor of device is 2 since the yachts are most often equipped with a black water tank which also has the device for grinding and disinfection. The resulting yacht risk index is 4.
3. Megayacht – factor of regulations 2 has been selected for the same reason as for the yacht, which means because megayachts sail under a foreign flag and are mainly in international navigation, and therefore MARPOL Annex IV is applied to them and since they are not ships but yachts, they are not subject of the Paris memorandum so there are no inspections by “*Port State Control*” inspector. The factor of device is 1 since yachts are usually equipped with the device for complete processing of black waters. The resulting yacht risk index is 2.
4. Fishing boat – the selected factor of regulations is 3 because the domestic fishing boats are constantly in national navigation and therefore MARPOL Annex IV is not applied to them. Factor of device is 3 because fishing boats usually have installations consisting only of a tank for collecting black waters and a discharge pump for such a tank when it gets full. The resulting fishing boat risk index is 9.
5. Smaller passenger ship in national navigation – the selected factor of regulations is 3 as well as for the fishing boats because they also constantly navigate in national navigation so that MARPOL Annex IV is not applied to them. Factor of device is 3 because these ships are usually equipped with the installation consisting only of a tank for collecting black waters and a discharging pump when it is full. The resulting risk index of a smaller passenger ship in national navigation is 9.
6. RO-RO passenger ship (ferry) – factor of regulations is also 3 as well as for other ships that navigate in

national navigation and so MARPOL Annex IV is not applied to them, and the factor of device is 1 since these ships are usually equipped with the device for complete processing of black waters. The resulting risk index of Ro-Ro passenger ship is 3.

7. Cargo ship – factor of regulations for this type of ship is 1 since these ships sail in international navigation and MARPOL Annex IV is applied to them. The selected factor of device is 1 because they are equipped with devices for complete processing of black waters. The resulting cargo ship risk index is 1.
8. Cruiser – factor of regulations is the same as for the cargo ship 1 since they sail in international navigation and MARPOL Annex IV is applied to them. The selected factor of device is also 1 because they are equipped with the devices for complete processing of black waters, using the most efficient and most complex devices of today, produced precisely for this type of ships in order to satisfy the needs of a large number of people on-board, but also the strictest ecological standards and national regulations of the most demanding countries. The resulting cruiser risk index is 1.

Table 1. Vessels risk indexes

VESSEL	Factor of regulations	Factor of equipment	VESSEL RISK INDEX
Boat	**3**	**3**	**9**
Yacht	**2**	**2**	**4**
Megayacht	**2**	**1**	**2**
Fishing vessel	**3**	**3**	**9**
Smaller pax ship in national navigation	**3**	**3**	**9**
RO-RO passenger ship (ferry)	**3**	**1**	**3**
Cargo ship	**1**	**1**	**1**
Passenger ship for cruising (cruiser)	**1**	**1**	**1**

Table 2. Locations sensitivity indexes

LOCATION	Factor of impact on the location	Factor of sensitivity of the location	LOCATION SENSITIVITY INDEX
Vicinity of the place for recreation and swimming	**3**	**3**	**9**
Operative waterfront in coastal town	**2**	**3**	**6**
Marina or communal port	**3**	**3**	**9**
Port for international cargo transport	**1**	**3**	**3**
Port for national passenger traffic	**2**	**3**	**6**
Port for international passenger traffic	**2**	**3**	**6**
Port anchorage	**1**	**2**	**2**
Uninhabited bay of internal sea waters	**3**	**2**	**6**

3.2 DETERMINING THE SENSITIVITY RISK FOR CERTAIN TYPES OF LOCATIONS

Location sensitivity index is obtained from the second-level matrix (described in Figure 4) by entering the second-level matrix for the selected location with location factor of sensitivity and impact factor on the location. Thus, for the selected location there follows Table 2:

1. The vicinity of the place for recreation and swimming – location sensitivity factor 3 has been selected, because there is impact of black waters in the vicinity of a place for recreation and swimming on all subjects at the location (the sea, economic activities performed there, and the people themselves in contact with the sea). The selected impact factor on the location is 3 because it affects significantly all three subjects of sensitivity. The resulting location sensitivity index is 9 for the vicinity of the place for recreation and swimming.
2. Operative waterfront in the coastal settlement – the location sensitivity factor 2 has been selected because black waters affect the sea and the economic activities near the operative waterfront, whereas swimming is usually prohibited at operative waterfronts so that there is no impact on the human health. The impact factor on the location is 3 because it has significant impact on both subjects of sensitivity. For operative waterfront in the coastal settlement the resulting location sensitivity index is 6.
3. Marina or communal boat harbour – location sensitivity factor is 3 because black waters have impact on all subjects at the location (the sea, economic activities performed there and the people themselves who are in contact with the sea due to performing procedures of technical nature related to vessels). The selected impact factor on the location is 3 because it has significant impact on all three subjects of sensitivity. The resulting sensitivity index of the location is 9 for the marina or communal boat harbour.
4. Harbour for international cargo transport – location sensitivity factor is 1 because black waters have impact on the sea, but they do not affect the industry nor people since in cargo harbours there are no tourists or similar activities. Impact factor on the location is 3 because it has significant impact on the sea in the harbour since it has limited depth and currents. The resulting location sensitivity index is 3 for the harbour for international cargo transport.
5. Harbour for national passenger traffic – location sensitivity factor is 2 because black waters at this location have impact on the sea as well as on the industry; a large number of domestic and foreign tourists pass through this location, and it is related to tourist activity. Impact factor on the location is 3 because it has significant impact on the sea and the industry. The resulting sensitivity index is 6 for the harbour for national passenger traffic.
6. Harbour for international passenger traffic – the same as the harbour for national passenger traffic, it has location sensitivity factor 2 because black waters at this location have impact on the sea and on the industry; a large number of tourists pass through so that the location is related to tourist activity. The impact factor of the location is 3 because it has significant impact on the sea and the industry. The resulting sensitivity index is 6 for the harbour for international passenger traffic.
7. Port anchorage – location sensitivity factor is 1 because black waters at this location have impact only on the sea. The impact factor on location is 2 because it has moderate impact on the sea due to the depth, sea currents and its openness. The resulting sensitivity index is 2 for the national passenger traffic harbour.
8. Uninhabited bay in inland seawaters – location sensitivity factor is 2 because black waters have impact on the sea, but also on the industry since the visitors of such bays are precisely the boaters with their own or rented vessels, who seek clean sea and shelter; it is, thus, connected with tourist activity. The impact factor on location is 3 since it has significant impact on the sea and industry. The resulting sensitivity index is 6 for uninhabited bay in inland sea waters.

3.3 EXAMPLE OF RISK ASSESSMENT FOR BOAT IN THE MARINA OR COMMUNAL BOAT HARBOUR

The assessment starts with the first-level matrix, and ends in the result of the third-level matrix.

First-level matrix: Factor of regulations x Factor of device = Vessel risk index (3 x 3 = 9).

Second-level matrix: Location sensitivity factor x Impact factor on the environment = Location sensitivity index (3 x 3 = 9).
Third-level matrix: Vessel risk index x Location sensitivity index = Risk of sea pollution by black waters from vessels (9 x 9 = 81).

Risk level 81 is considered *high risk* and therefore a ***boat in the marina or communal harbour will be of high risk from sea pollution by black wastewaters.*** (Figure 8)

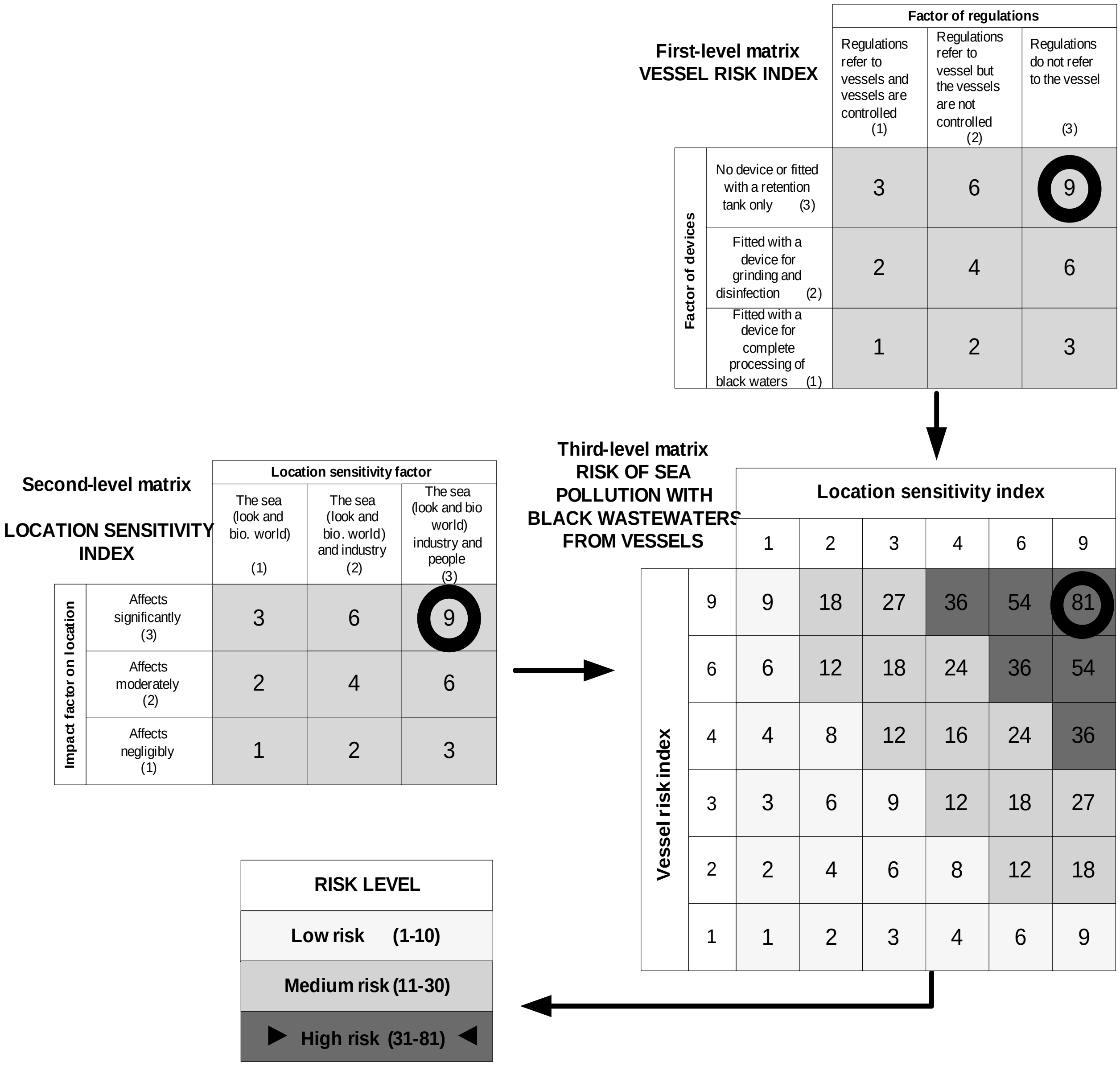

Figure 8: Multiplicative matrix for assess risk of sea pollution by black waters from the boats in the marina or communal boat harbour

Table 3: Level of risk of sea pollution by black waters for assessed vessels at certain locations

Risk index	Risk level	Vessel on location
81	**high**	**Boat** – Vicinity of the place for recreation and swimming
81	**high**	**Boat** – Marina or communal port
81	**high**	**Smaller pax ship in national navigation** - Vicinity of the place for recreation and swimming
54	**high**	**Boat** – Operative waterfront in coastal town
54	**high**	**Boat** – Uninhabited bay of internal sea waters
54	**high**	**Fishing vessel** – Operative waterfront in coastal town
54	**high**	**Smaller pax ship in national navigation** – Operative waterfront in coastal town
54	**high**	**Smaller pax ship in national navigation** – Port for national passenger traffic
54	**high**	**Smaller pax ship in national navigation** – Uninhabited bay of internal sea waters
36	**high**	**Yacht** – Vicinity of the place for recreation and swimming
36	**high**	**Yacht** – Marina or communal port
24	**medium**	**Yacht** – Operative waterfront in coastal town
18	**medium**	**Yacht** – Uninhabited bay of internal sea waters
18	**medium**	**Megayacht** – Vicinity of the place for recreation and swimming
18	**medium**	**RO-RO passenger ship (ferry)** – Port for national passenger traffic
18	**medium**	**RO-RO passenger ship (ferry)** – Port for international passenger traffic
18	**medium**	**Megayacht** – Marina or communal port
12	**medium**	**Megayacht** – Operative waterfront in coastal town
12	**medium**	**Megayacht** – Port for international passenger traffic
12	**medium**	**Megayacht** – Uninhabited bay of internal sea waters
6	**low**	**Pasenger ship for criusing (cruiser)** – Port for international passenger traffic
4	**low**	**Megayacht** – Port anchorage
3	**low**	**Cargo ship** – Port for international cargo transport
2	**low**	**Cargo ship** – Port anchorage
2	**low**	**Pasenger ship for criusing (cruiser)** – Port anchorage

The results of the qualitative risk assessment of sea pollution by black waters from certain vessels at certain locations, and the risk levels that have been obtained from the assessment are presented in Table 3.

The table lists top-down the vessels at locations starting from the highest risk index. The top of the table belongs to vessels at locations with high risk of sea pollution by black waters from the vessels, whereas at the bottom there are vessels at locations that have low risk of sea pollution by black waters from the vessels.

Considering Table 3, it is obvious that, depending on the location of the vessels, they are included in the categories of high, medium or low level of risk as follows:

1. **High risk level** of sea pollution with black waters from the vessels includes:
   - Boats;
   - Yachts;
   - Fishing boats;
   - Smaller passenger ships in national navigation.
2. **Medium risk level** of sea pollution by black waters from vessels includes:
   - Yachts;
   - Megayachts;
   - RO-RO passenger ships (ferries).
3. **Low risk level** of sea pollution by black waters from vessels includes:
   - Cruisers;
   - Cargo ships;
   - Megayachts.

Based on the application of the multiplicative matrices model for the risk assessment of sea pollution by black waters from the vessels and determination of risk level for the vessels, i.e. the risk assessment results indicate that smaller vessels such as boats, yachts, fishing boats and smaller passenger ships in national navigation represent significantly higher risk of the group of vessels for sea pollution by black waters from the vessels than cruisers, cargo ships and megayachts that have low risk level.

4. CONCLUSIONS

Risk matrix as tools for ranking risk has also been popular as "matrix of probability and consequence", and therefore it exists in various contexts used by ISO and IMO. However, this matrix is limited to the application in more complex qualitative risk assessments when more than two input parameters have to be taken into consideration (frequency of incidence and consequences), i.e. when more than two input parameters have to be taken into account for consideration and risk assessment.

Risk assessment of the coastal sea pollution by black waters from vessels in a coastal water area is a very complex procedure that has to take into account several factors for good risk assessment. Therefore, the offered original model of risk assessment can consider a larger number of different vessel categories (typical vessels), at different parts of the coastal water areas (typical locations). Several input factors are used such as factor of installed devices for the processing of black waters on the vessel, factor of regulations that are applied on the vessel, factor of location sensitivity and factor of impact on the location. The procedure is assessed on several different levels and for each vessel the vessel risk assessment can be defined, and for every location one can determine the location sensitivity assessment, so that on the last level the risk assessment of sea pollution with black waters from the vessels be determined.

Frequency of incidents in proposed model is used only in their ultimate value, i.e. the state of zero or one. So when there is a vessel at the location there is a risk of pollution that can be determined by the proposed model, or when there is no vessel at the location then there is no risk, state of zero - no risk at all.

Proposed multiplicative risk matrix is an originally offered tool for the risk assessment that can be used also for other fields of risk assessment and not only for the risk assessment of the pollution of the coastal sea by faecal waters from the vessels. Multiplicative risk matrix gives solution for very complex risk assessments since risk assessment is done gradually in several steps on several levels where in a targeted way and at the same time a larger number of factors can be taken and their results are channelled towards the given level – level of risk, based on which the decision will be made regarding the measures that need to be taken in the process of risk management.

Based on the application of the multiplicative matrices model for the risk assessment of sea pollution by black waters from the vessels, the sea pollution risk along the coast with black waters from the vessels is higher and less acceptable during navigation and stay of smaller and recreation vessels in the coastal water area than during navigation and stay of big cruisers.

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