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Onshore ballast water management systems: National perspectives

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Abstract. *The present paper focuses on ballast water management systems (BWMS) in line with the Ballast Water Management Convention, aiming to prevent marine pollution from harmful alien species transported through ships' ballast water. Three approaches of BWMS are considered: Ballast water exchange, Onboard and Onshore systems. Solutions regarding ballast water reception and treatment are proposed, including several options: for ports that are equipped with ballast water reception facilities (BWRFs); for ports not equipped with BWRFs and for companies with onshore facilities (OBWRFs).Thoroughly examined in the paper is the applicability of national onshore BWMS inclusive specifically of the expected users of the OBWRFs; suggested stakeholder groups involved in the process and their responsibilities; step by step procedure; documentation of the procedure related to the main parties - the Shipowner/ captain, Port authority, the company with OBWRFs. It has been found out that OBWRFs are more suitable to be applied on national level, bearing in mind that most of the Bulgarian ports are limited to increase their working area. Further research should be carried out about the possible location of the OBWRFs with regard to the necessary infrastructure, equipment, restricted zones, etc.*

Keywords: ballast water, bioinvasion, onshore facilities, ports, Bulgaria

1 Introduction

Ballast water is an indispensable part of maritime transport, as it is cheap and practical solution that guarantees maneuverability, stability and safe navigation especially when cargo is offloaded. However, ballast water (BW) discharged by ships in the marine environment is considered as one of the emerging threats nowadays. Since the early 20th century, scientists have noted that shipping causes an unintentional and uncontrolled transfer of alien species between areas that are far apart. It was found out that enormous amounts and variety of aquatic species can be transported through ballast water (Diasamidze and Shotadze, 2019). Some estimates show that at least 7,000 different species are transported around the world through the ballast tanks of ships (Tamelander et al., 2010). According to another forecast, more than 3,000 species are transported daily around the world by ballast water (Wonham, 2005). These species range from microorganisms to fish and would consist of viruses, bacteria, fungi, plants (eg. algae) and animals (eg. molluscs and crustaceans). Once discharged into the marine areas some deleterious consequences of environmental, social and economic dimensions could be observed. In some cases, an explosive and uncontrollable spread of newly introduced species can occur, often with irreversible and highly detrimental effects on local marine life (Wonham, 2005; Molnar et al., 2008; Nicastro et al., 2009). The ecological risks caused by bioinvasion are directly related to the loss of biodiversity as a result of competition. It is important to be noted that such biofouling is quite different from other types of marine pollution because of its permanent and irreversible consequences (Barry et al., 2008; Pam et al., 2013; Wang et al., 2020).

The International Convention for Control and Management of Ship Ballast Water and Sediments (Ballast Water Management Convention) (BWMC) is the first comprehensive and binding international legal instrument addressing that problem. BWMC ratification aims to prevent and reduce the negative effects to the environment, human health and resources due to the transfer of harmful aquatic organisms and pathogens, through management, knowledge and technologies (IMO, 2005; IMO, 2019).

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Regarding the BWMC requirements and its guidelines, ballast water management can be organized in three ways: Ballast water exchange, following D-1 standard; Ballast water treatment, using ballast water management systems (BWMS) in line with D-2 standard, as well as Ballast water isolation, related to discharge of ballast water to onshore reception facilities, or no discharge (David et al., 2013; IMO, 2013; IMO, 2016).

The ballast water exchange method has been suspended and replaced by more strict management standards, especially regarding the on-board treatment systems that must ensure minimum quantities of viable organisms discharged through ballast water.

According to BWMC Regulation B-3.7 the application of "alternatives" can be accepted for the ballast water treatment if such methods are reliable enough to ensure the same level of environmental protection (as required by Regulation D-2). It is precisely these "alternatives" that create new opportunities to explore other possible systems to reduce ballast water impact on the marine environment (IMO (2005).

Assessed in the present study is the relevance of the so called “alternatives" for ballast water management, especially onshore ballast water management systems and their national perspectives.

2 Ballast water management options

Many different types of vessels carry ballast water, with ballast tank capacities ranging from several tons to several thousand tons. Ships carry BW from 30% to 40% of Dead weight tonnage (DWT) of ships in normal ballast condition and 38% to 57% in heavy ballast condition (table 1). The IMO established that about 10 billion tons of ballast water are transported around the world by ships every year (GEF-UNDP-IMO, 2010).

Table 1. Representative ballast water (BW) capacities for each ship type

Ship type	DWT	Ballast Condition			
		Normal (tonnes)	% of DWT	Heavy (tonnes)	% of DWT
Bulk carrier	250,000	75,000	30	113,000	45
Bulk carrier	150,000	45,000	30	67,000	45
Bulk carrier	70,000	25,000	36	40,000	57
Bulk carrier	35,000	10,000	30	17,000	49
Tanker	100,000	40,000	40	45,000	45
Tanker	40,000	12,000	30	15,000	38
Container	40,000	12,000	30	15,000	38
Container	15,000	5,000	30	n/a	
General cargo	17,000	6,000	35	n/a	
General cargo	8,000	3,000	38	n/a	
Passenger/RORO	3,000	1,000	33	n/a	

Different ballast water treatment methods have been applied pursuant to the ship type and DWT. Complying the technology of treatment with the type of the ship, the type of the ballast system, and taking into consideration the service of vessel is what represents the milestone of successful ballast water treatment system design (David et al., 2013). Since the adoption of BWMC, many scientific and technological researches have been conducted and management alternatives have been proposed. Ballast water management methods, such as Ballast Water Exchange (BWE) and Onboard Treatment are the most prominent methods acknowledged by IMO.

Ballast Water Exchange

BWE fulfils completely the requirements of BWMC Regulation D1 standards and is the most widely adopted management procedure. Nevertheless, some studies have reached the conclusion that the efficiency of this method failed to meet IMO's requirement (Wesley et al., 2006; Ruiz & Reid, 2007). It has been determined that approximately 95% of viable algae and 60% of zooplankton are removed by

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three times the exchange of ballast, but these levels are not reliable enough to reduce the transfer of invasive species. Thus, BWE Standard (Regulation D-1) was applied until 2016 and IMO, alternatively, provides for the new ships built after 2009 to have Ballast Water Treatment Systems (BWTS) on board and for ships constructed before 2009 to have retrofitted BWTS on board by 2016.

Onboard Ballast water management systems

A great variety of onboard BWTS are being developed nowadays including mechanical, physical, chemical, biological treatment, or a combination of these methods (Fig.1) (Albert et al., 2010; Lloyd's, 2011; David and Gollasch, 2016; David and Gollasch, 2017). Most of the BWTS on board, use several methods together to ensure that the quality of the treated ballast water follows IMO standards. The widely used treatment technologies include filter-UV system, filter and electrolysis, chemical disinfection with oxidizing or using biocides with ozonation.

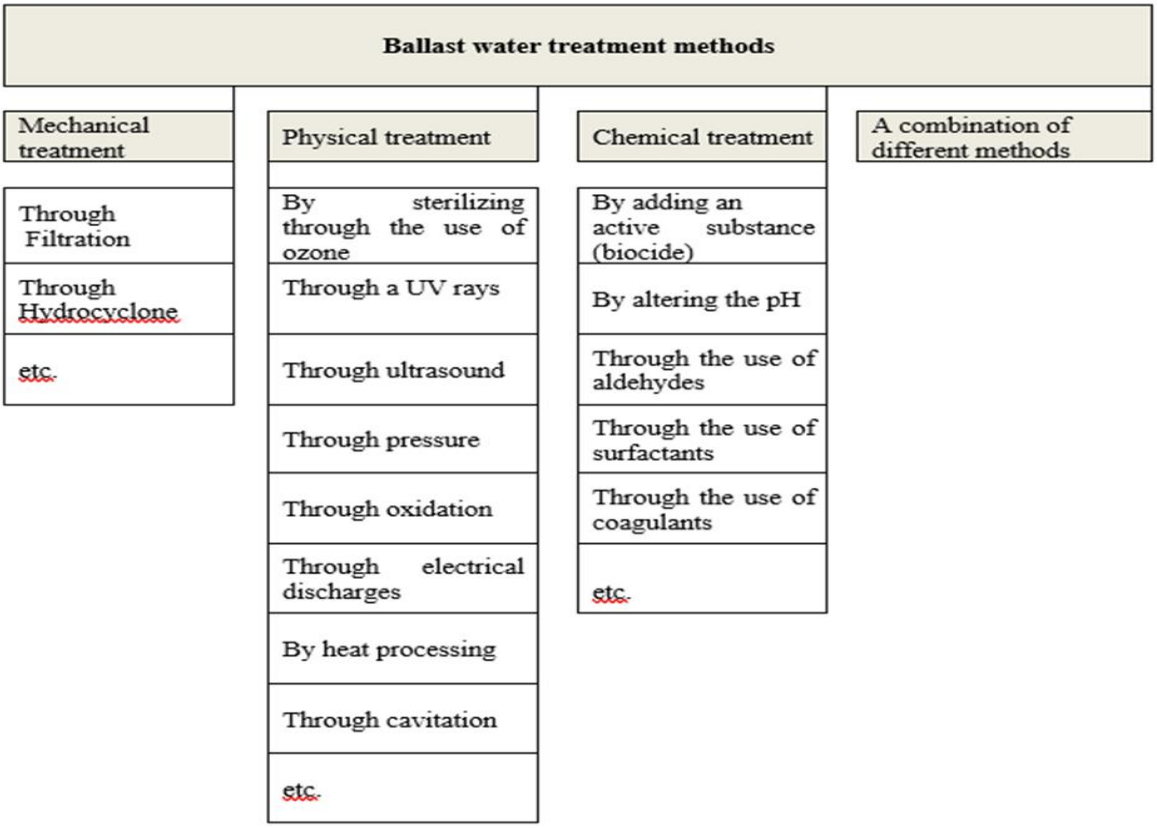

Fig.1. Ballast Water Treatment Processes

Some of the challenges with the implementation of BWMC are connected with the limited worldwide availability of the specific type-approved treatment systems. Many executive agencies seek, even today, to disallow the discharge of ballast water treated by BWTS. BWMS market shows that more than 60,000 merchant ships are expected to retrofit their systems and more than 6,000 seaports are required to install onshore systems - port or barge based. The monetary equivalent of these actions is estimated at USD$100 billion dollars and over (Kuroshi, 2017).

Onshore Ballast water management systems

Third option of preventing harmful organisms to be discharged into the marine environment is the application of shore-based facilities, that could be port ballast water reception facilities (PBWRFs), or onshore ballast water reception facilities (OBWRFs) (Tamelander et al., 2010; Donner, 2010). The use and provision of port waste reception facilities (PWRFs) for ship-generated wastes and residues and port ballast water reception facilities (PBWRFs) is fundamental to the overall success of the MARPOL

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BWMC. According to some authors, the establishment of appropriate PWRFs is a necessary step to reduce and eliminate pollution generated by ships (Subaşi and Dogan-Saglamtimur, 2013). Following the requirements of the Convention (Article 5), all ports and terminals must have adequate units for cleaning or repairing ballast tanks to receive the sludge (IMO, 2006).

The application of OBWRFs, including reception and treatment shows some advantages, identified by many researchers such as: economies of scale, proficiency of operators, spatial advantage, redundancy, affordability, safety of crew, etc. (Donner, 2010; Kuroshi and Ölçer, 2016).

3 Onshore ballast water management systems on a national scale

3.1. Proposed procedure for ballast water reception and treatment

The statistics show that at present most of the ports have not yet met the requirement of reception and treatment of ballast water from ships. Although the obvious advantages of onshore BWMS, they are not normally considered as an option to eliminate pollution generated by ships because it is not a mandatory requirement of BWMC. It should, however, be taken into account that some ports will be not able to secure adequate area for PBWRFs, so another viable option for such facilities would be to have them constructed on appropriate shoreline areas away from the ports. These potential areas can be determined after precise analyses by the use of different criteria and methods (e.g. existing infrastructure, access to the facility, ship-to-shore transfer possibilities, protected areas, etc.).

Brought forth in the present study are several options for ballast water reception and treatment. Generally, the procedure for reception and treatment of ballast water from ships can be established by port equipped with reception facilities or onshore terminal situated outside the port (Fig. 2.)

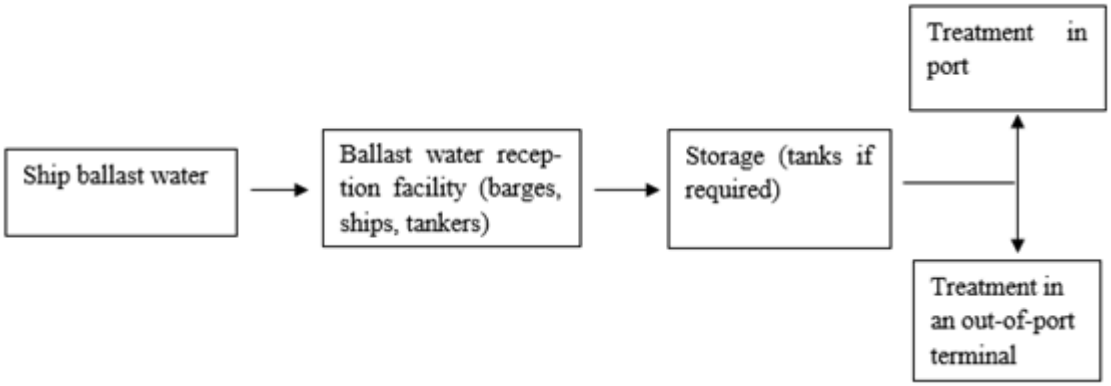

Fig. 2. Proposed procedure for ballast water reception and treatment

Theoretically, several approaches are possible for the reception and treatment of ballast water using onshore BWRFs, shown in Fig. 3.

Option 1 - The port has overall responsibility for reception and handling. Reception, transport and treatment will be provided by a onshore BWRFs, which is an external company.

Option 2 - The port ensures the reception of ballast water from ships. Transportation and treatment will be provided by an onshore BWRFs, which is an external company.

Option 3 - A company with onshore BWRFs provides the reception, transportation and treatment of ballast water.

Fig. 3. Options for ballast water reception and treatment applying OBWRFs

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The first option is suitable for ports that are not equipped with BWRFs, but are conveniently placed to companies that have been licensed to operate with ballast water - to collect and treat ballast water. The responsibilities of each party taking part of the process is shown in Fig. 4.

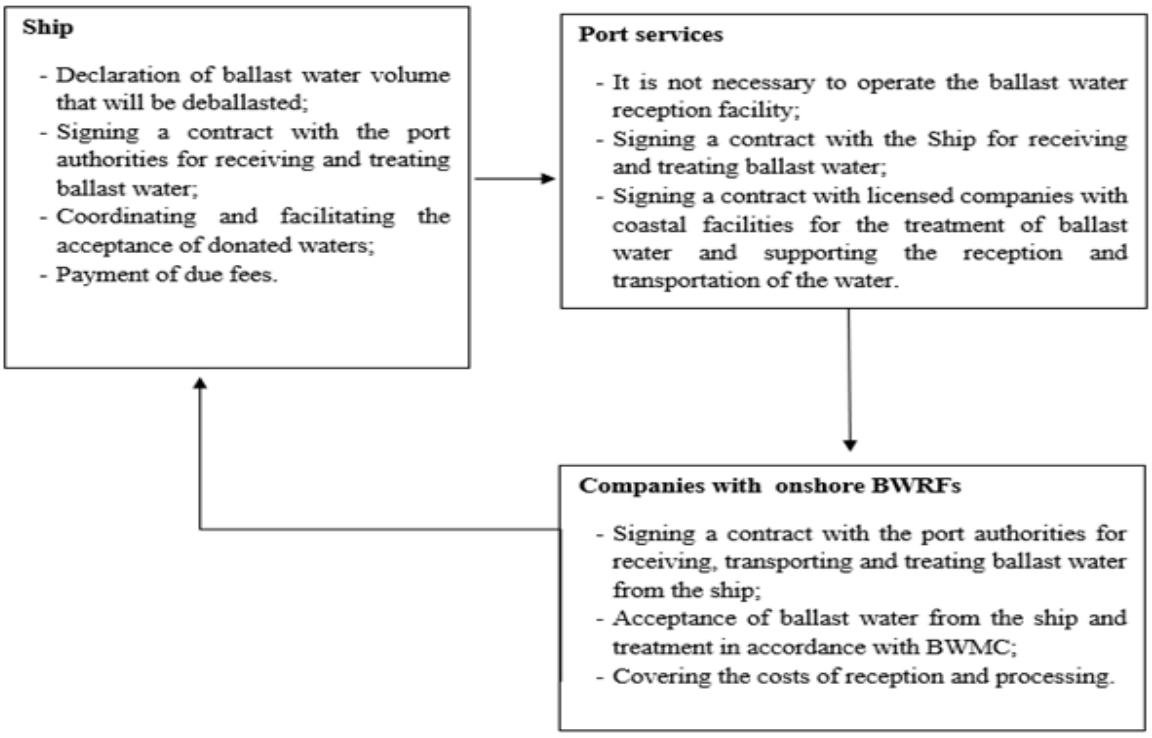

Fig. 4. First option for ballast water reception and treatment. Responsibilities of the Port, Shipowner and the Company occupied in the process

The second option is suitable for ports with BWRFs, and companies that have onshore ballast water treatment facilities (Fig. 5).

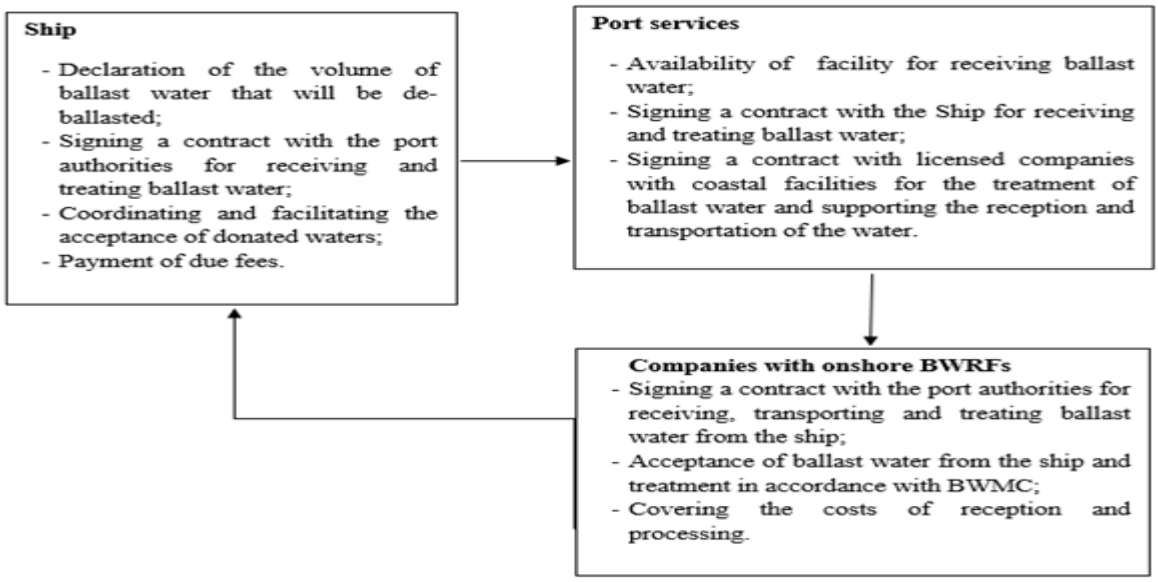

Fig. 5. Second option for ballast water reception and treatment. Responsibilities of the Port, Shipowner and the Company occupied in the process

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The third option is to steer clear of the central role of the port and leave it to the shipowner to operate directly with the OBWRFs (Fig. 6). However, from a financial point of view, the investments for this option will be significant for any company.

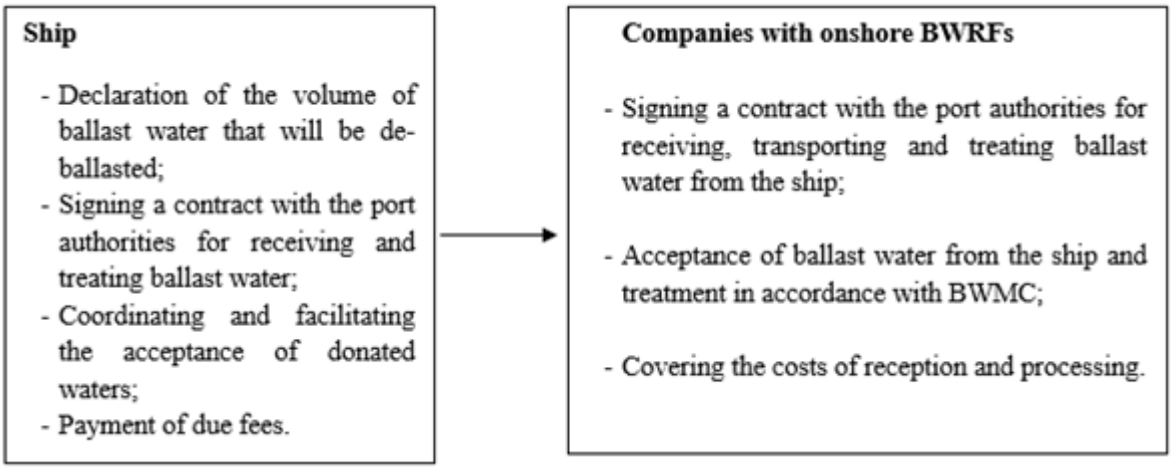

Fig. 6. Third option for ballast water reception and treatment. Responsibilities of the Shipowner and the Company occupied in the process

3.2. Proposed procedure for onshore ballast water management

The statistics and forecast show that bulk carriers are expected to be the most frequent customers entering the marine territory of Republic of Bulgaria, usually transporting very large quantities of cargo and ballast accordingly. The largest ships that the country ports shall be capable to manage are around 50,000 tons. It follows, that the maximum single deballasted amount of water is very likely around 18,860 tons, which imposes certain requirements on smaller specialized ships or port mobile ballast water treatment systems in accordance with the requirements of the BWMC.

Located on the Bulgarian Black Sea aquatory are the Port of Varna, Port of Burgas and Port of Balchik. Port of Varna has two terminals "East" and "West", which are about 30 km from each other. It should be emphasized that up to now the Bulgarian seaports have not yet fulfilled the requirement for ship ballast water management and there are no designated areas for ballast water exchange in the Black Sea. Currently, only "Marine antipollution enterprise" JSC, Branch Burgas deals with the receipt of bilge, ballast, sludge water (from tankers and cargo) and oily waters from ships. Several companies such as FIDELITAS Ltd, SGS Bulgaria Ltd and others are accredited to provide testing services of wastewater from ships, including ballast water testing.

It is important to highlight that almost all Bulgarian ports are constrained to enlarge their working area for PBWRFs because of the urbanized territories adjacent to the ports. For that reasons, the ballast water reception facilities are more suitable to be located away from port. The OBWRFs can operate directly with the ships or through a mobile vessels /barge or tanker/, which will receive and transport ballast water to the facility. The location of the OBWRFs should be determined with regard to the necessary infrastructure, equipment and machinery, restricted and safety zones, etc.

The expected users of the OBWRFs could be:

- Small vessels (for example, river-sea type operating in the Black Sea and the large rivers flowing into the sea) for which onboard BWTS will be economically unprofitable;
- Old vessels that do not meet the requirements of the BWMC regarding onboard BWMS;
- Vessels that by 2024 have not installed onboard BWMS;
- Vessels with onboard BWMS that does not comply with the requirements of the Convention;
- Vessels that undergo dock repairs and need to discharge their ballast water.

Ballast water reception activities can be carried out by: private companies, municipal companies, state companies and companies with jointly municipal-state involvment. Regardless of the ownership of the companies, an obligatory requirement for their activity should be an approval of the Council of Ministers, in particular the Ministry of Transport.

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3.2.1. Planning of onshore ballast water management procedure

Planning of onshore ballast water management procedure is a key step in the process of OBWMFs construction and should cover the questions indicated in Fig. 7.

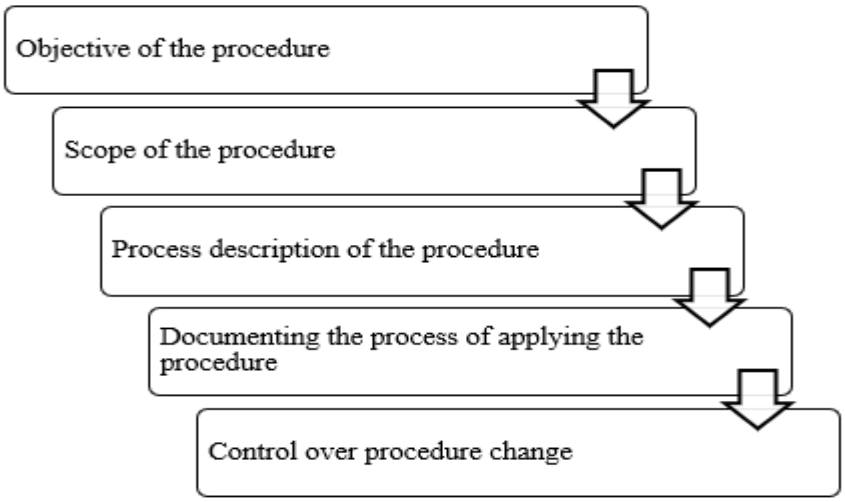

Fig. 7. Scope of the onshore ballast water management procedure

The objective of the procedure - to regulate the responsibilities and the actions of all participants in the process: the ship's crew, the management and operators of OBWRFs.

Scope of the procedure - should apply to all expected users of the OBWRFs.

Responsibilities of the procedure - should include suggested stakeholder groups involved in developing the procedure. The state and local management that could be involved in the process is presented in table 2.

3.2.2. Proposed Step by step organization of the procedure

In general, the procedure for arrival, receipt, storage, transportation and treatment of ballast water in OBWRFs with regard to ships visiting the Bulgarian seaports, should include the following steps, in adherence to the Convention, as well as "Maritime Administration" Exacutive Agency requirements (Ministry of Transport, Information Technology and Communications, 2019):

1. Duly filled-in Advanced Waste Notification and Ballast Water Reporting Form from the Master of a ship and submitted to ship's Agent who assists in the arrangement of ballast delivery to a port reception facility. Ballast water reporting form should provide information on the types and quantities of ship generated ballast;
2. Ballast Water Reporting Form submitted from the ship's Agent to the relevant Bulgarian Maritime Administration regional directorate;
3. Active or passive approval of the documents by the Maritime Administration inspectors or another competent authority nominated by the Member State;

In case of some enforcement action imposed by the Competent Authority the following authorities should be informed:

- the enforcement authorities;
- the port authority;
- the port state control authority;
- the OBWRFs providers, and
- the Flag State of the ship

4. Notification for receipt, storage/treatment of ship's ballast water sent from the Maritime Administration inspectors to the Port authorities;
5. Notification including relevant information about ballast water sent from the Port authority to the licensed companies of OBWRFs
6. Information about the capabilities of the OBWRFs licensed companies sent to the ships that intend to use the facility.

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Table 2. Responsibilities of suggested state and local stakeholder groups related to OBWMFs

Institution	**Areas of expertise and responsibility**
Transport and Communications Ministry, Republic of Bulgaria	Development and implementation of ballast water management plans (in line with the national strategy); Provision of relevant infrastructure.
Executive Agency "Maritime Administration" (as part of Transport and Communications Ministry) / Bulgarian Ports Infrastructure Company	Port control; Enforcement of conventions and legislation related to shipping.
Environment and Water Ministry, Republic of Bulgaria	Management of invasive species; Implementation of conventions and facilities related to biodiversity and environment.
Agriculture Ministry - Fisheries and Aquaculture Executive Agency	Regulation and monitoring of fisheries and aquaculture; Observance of ballast water management plans.
Food Safety Agency (BFSA) - Ministry of Health Republic of Bulgaria - Regional Health Inspectorates	Supervision and evaluation of port sanitary control activities; Establishment and enforcment of regulations, preventing the introduction and transfer of diseases and pathogens.
Municipalities / Regional administrations	Jurisdiction over areas around ports, over ports and port activities.
Shipowners, agents and other port operators	Procedures and activities on board of the ships. Relevant information about the requirements of the ports to be visited, sent to the ship's administration, the maritime, health, immigration and customs authorities.
Shipyards, shipbuilders, etc.	Matching the construction of new ships to the internationally accepted principles regarding ballast water.
Fisheries and aquaculture companies	Prevention of the possible input vectors for the species and negative impacts on ecosystems and the environment, influenced by ballast water.
Companies developing activities in the energy industry	Prevention of oil, gas and mining activities that can provide vectors for introducing species.
Universities and research institutes	Identifying species taxonomy and quality of marine environment; Applying adequate research methods.
NGOs and the general public	Activities to prevent deterioration of marine environment; Assistance in monitoring for biofouling.

3.2.3. Documenting of the procedure

The documentation of the procedure relates to the main parties: the Shipowner/ captain/ etc. - Port authority- The company with OBWRFs.

- ✓ *Documentation of the procedure by the Shipowner/captain*: The Convention requires that all the ships to implement a "Ballast water management plan" should apply a given standard. All related information about the ballast water and sediments must be recorded in "Ballast water Reporting Form" and “Ballast water Record Book” signed by the responsible officer.

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✓ *Documentation of the procedure by the Port authorities:* In cases when ports are responsible for reception of ballast water (Option 2), the process of implementing the procedure should be developed in line with Ballast Water Management Plan and the national plans for the development of port systems. The plan must aim at providing rules for the construction and/or maintenance of adequate reception facilities and the relevant infrastructure.

✓ *Documentation of the procedure by the Company with OBWRFs:* Guidelines for ballast water reception facilities as referred to in Regulation B-3.6 of the Convention are provided by IMO (IMO, 2006) and could be implemented by the Company through its Ballast Water Management Plan. The Plan should provide technical solutions for the operation and safety of the facility, such as the procedures for reception, storage, treatment of ballast water, etc. Details available to ships should be included as described in the a.m. guidelines.

4 Conclusion

The Republic of Bulgaria is a party to the BWMC, ratified and entered into force on July 30, 2018. In conformity to the requirements of the Convention, the ships' ballast water discharge must be carried out only through BWMS. Located within the Bulgarian Black Sea aquatory are the Port of Varna, Port of Burgas and Port of Balchik. At present, the Bulgarian seaports have not yet fulfilled the requirement as to the ship ballast water management and there are no designated areas for ballast water exchange in the Black Sea. Currently, only "Marine antipollution enterprise" JSC, Branch Burgas deals with the receipt of bilge, ballast, sludge water (from tankers and cargo) and oily waters from ships in Burgas aquatory. Several companies such as FIDELITAS Ltd, SGS Bulgaria Ltd and others are accredited to provide testing services for wastewater from ships, including ballast water testing.

The statistics and forecast show that bulk carriers are expected to be the most frequent customers in the Bulgarian aquatory, transporting large quantities of cargo and ballast accordingly. The largest ships that the country ports are capable to handle are around 50,000 tons and the maximum single deballasted water is around 18,860 tons, which imposes certain requirements on smaller specialized ships or port mobile ballast water treatment systems in accordance with the requirements of the BWMC. Since the Bulgarian ports are not able to secure adequate areas for establishment of PBWRFs, the application of OBWRFs seems, wherefore, an appropriate option.

The OBWRFs applicability needs further studies to be carried out. Potential areas must be determined after precise analyses through different criteria and methods (e.g. existing infrastructure, access to the facility, ship-to-shore transfer possibilities, protected areas, etc.). The benefits and challenges peculiar to OBWRFs must be assessed in both technical and legal aspects, using quantitative and qualitative methods. SWOT analysis should be additionally conducted to determine the strengths and weaknesses of the current situation concerning the design and construction of OBWRFs. Likewise, the economic feasibility regarding OBWRFs should also be considered relative to the other options such as the use of smaller specialized vessels or port mobile ballast water treatment systems, provided that ballast water volumes are appropriate.

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