



# **Ballast Water Management Systems on Vessels. The Water Cleanliness Requirements of New D-2 Standard Versus the Expectations**

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## **1. Introduction**

International shipping causes many hazards to the environment. Transport by sea is the most efficient (it needs the lowest energy demand). A contribution of transport by sea (in all types of transport) is about 90% taking into account transported mass (cargo) and the distance. Even during normal operation processes of vessels the environment is contaminated by bilge water, slops from cargo tanks, sewage, exhaust gases, ballast water and leakages from vessel systems (for example refrigeration gases). The main hazard are vessels accidents and disasters leading to serious sea pollution from cargoes, marine fuels, lubrication oils and many others.

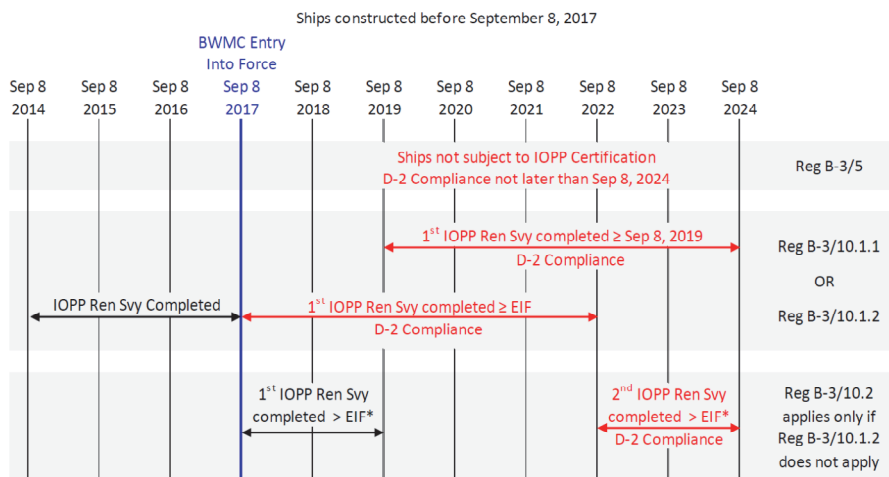
It was estimated that international voyages transfers about three to five billion tons of ballast water every year. Ballast water is essential for safe and efficient ships' operations (to compensate the change of cargo quantity, its different density and allocation).

Due to the transfer of invasive aquatic species poses a serious ecological, human health and economic threat. In February 2004 the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). There are regulations of ballast water discharges and methods of risk reducing the introduction of non-native

species (Herdzik 2016-1, Herdzik 2017, *International Convention...* 2016). To complement the BWM Convention, IMO has adopted the guidelines prepared as resolutions and circulars by the Maritime Environment Protection Committee (MEPC) (MEPC 10-23). In addition to IMO, other national or regional bodies have introduced their own regulations e.g. the United State Coast Guard rules (2012).

The BWM Convention has entered into force on 8<sup>th</sup> September 2017 after one year when the minimal conditions were fulfilled: ratification by 30 states (members of IMO), representing 35 percent of world's merchant shipping tonnage (*Understanding...* 2016, Chorab 2013).

All ships of capacity 400 and above will be required to have on board approved a Ballast Water Management Plan and Ballast Water Record Book, and to be surveyed and issued with an International Ballast Water Management Certificate. For existing ships it ought to be done during the International Oil Pollution Plan (IOPP) Certificate renewal survey (required every five years), for ships constructed after 7<sup>th</sup> September 2017 the compliance ought to be fulfilled on delivery. The plan of implementation the BWM requirements approved by MEPC 71 is presented in Fig. 1. After 8<sup>th</sup> September 2024 the BWM Convention requirements should be implemented in all vessels.



**Fig. 1.** Approved BWM implementation scheme according to MEPC 71 (IMO 2017)  
**Rys. 1.** Zatwierdzony przez MEPC 71 plan wprowadzania konwencji BWM

Some exemptions are possible for ships which operate exclusively within one “Captain of the Port” (COTP) zone, non-seagoing vessels, vessels that takes on and discharge ballast water exclusively in one COTP zone or without any water ballast tank or with only closed ballast tanks.

## **2. Ballast water treatment standards required by the BWM Convention**

The D-1 standard was the first one required from February 2004 by BWM Convention. The method for fulfillment of D-1 standard was the ballast water exchange at mid-ocean (over 200 nautical miles from shore). There are two possibilities to achieve it:

- the sequential method – in each ballast tank, water should be discharged until suction of the pumps is lost, and stripping pumps or eductors should be used, if possible. The emptied tanks are then refilled. Emptying and filling three times allows for at least 95% water exchange,
- “flow-through” method – tanks are overfilled by pumping. There is little change to the condition of the ship. It is necessary to pump in three times the volume of the tank to achieve at least 95% change of water.

It should be noted that clean seawater does not make a problem but many non-native species living inside. Some species may survive in water and sediment of ballast water tanks. For the reason, some port states do not allow to use stripping pumps when emptying a ballast tank in the harbor, even if the ballast water was exchanged in mid-ocean. The routine ought to be the cleaning the ballast tank to remove sediments, possible in mid-ocean or under controlled arrangements in port or a dry dock. The tank cleaning should be logged in the Ballast Water Record Book also.

From 1<sup>st</sup> January 2017 the BWM Convention requires regulation D-2 as standard for discharged ballast water. The requirement for D-2 standard is presented in Table 1.

Ballast water treatment systems must have an approval certificate in compliance with the IMO Guidelines (MEPC.125(53) 2005, MEPC.174(58) 2008). It should be noted the difference between the USCG treatment discharge standard and the BWM Convention D-2 standard. The BWM Convention standard specifies measurement of “vi-

able” organisms, while the USCG standard specifies measurement of “living” organisms.

**Table 1.** The IMO D-2 standard for discharged ballast water (PRS 2016, Lloyd’s Register 2016)

**Tabela 1.** Wymagania standardu D-2 usuwania wody balastowej za burtę

Organism category	Regulation
Plankton, >50 µm in minimum dimensions	<10 cells/m <sup>3</sup>
Plankton, 10-50 µm	<10 cells/ml
Toxicogenic <i>Vibrio cholera</i> (O1 and O139)	<1 colony forming unit (cfu)/100 ml or less than 1 cfu/g (wet weight)
<i>Escherichia coli</i>	<250 cfu/100 ml
Intestinal Enterococci	<100 cfu/100 ml

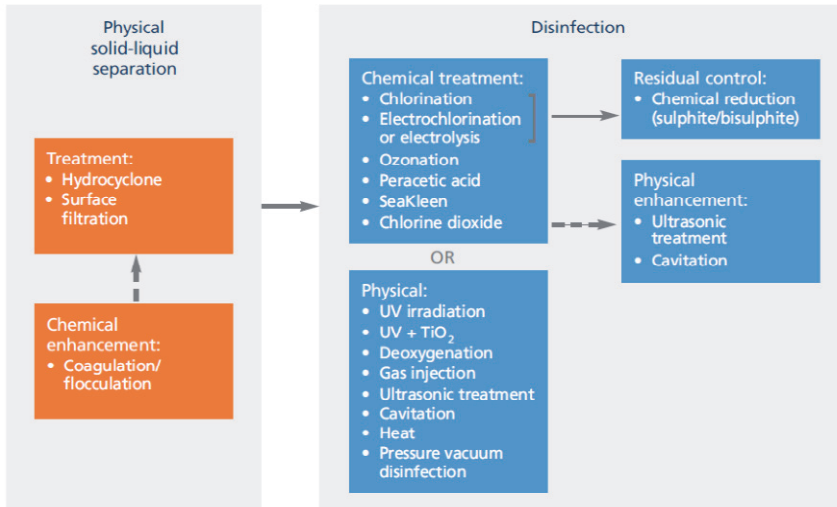
### 3. Generic ballast water treatment technology

Many manufacturers of marine equipment have tried to solve the problems of ballast water treatment. The classification societies (*A guide... 2016, Guidelines... 2016, Understanding... 2016, International Convention... 2016*) give their own propositions. The generic ballast water treatment technology process option is presented in Fig. 2 (*Understanding... 2016*). The process is divided into two stages:

- physical solid-liquid separation (mainly filtering) with possibility of chemical enhancement,
- disinfection by using different methods (presenting in Fig. 2).

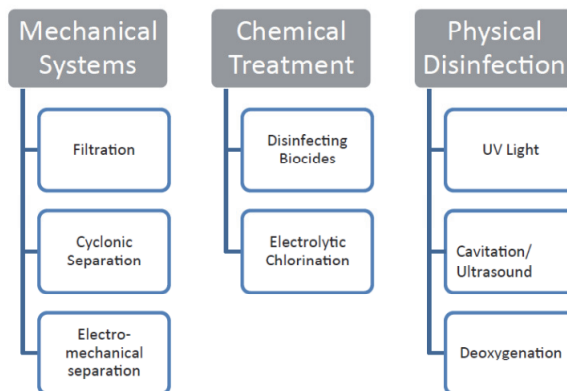
Similar proposition is presented in Fig. 3. There are three stages of ballast water treatment that may work singularly or in combination. The arrangement of cleaning process has essential influence on the standard for discharged ballast water (outboard).

A small quantity of ballast water may be used for water injection into burning process in marine boilers (Szkarsowski et al. 2017) in aim of decreasing the nitrogen oxide emission to the atmosphere. Ballast water used for this purpose may be without the required cleaning process.



**Fig. 2.** Generic ballast water treatment technology process option (Lloyd's Register 2016)

**Rys. 2.** Podstawowe technologie obróbki wód balastowych



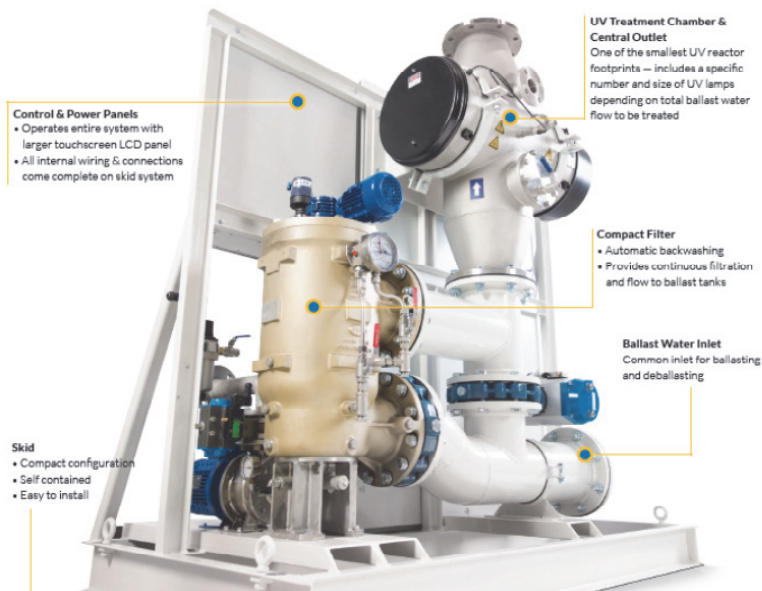
**Fig. 3.** Ballast water cleaning systems – singularly or in combination (*A guide...* 2016)

**Rys. 3.** Systemy oczyszczania wód balastowych – pojedyncze i w kombinacji

Marine market is so considerable and important for manufacturers that they prepared completely ready systems and tried them to develop as to:

- the effectiveness of cleaning process,
- the fulfillment of cleanliness standard,
- the minimal mass and dimensions of the pack,
- the minimal required electric energy,
- automatic operation with very little crew attention,
- series of types (different capacities) – the most often proposition is only with one capacity, for bigger capacity there is a possibility by using more than one pack,
- the long term life,
- the total cost of investment and operation.

An example of cleaning system of Hyde Marine based on mechanical filters and UV lamps is presented in Fig. 4.

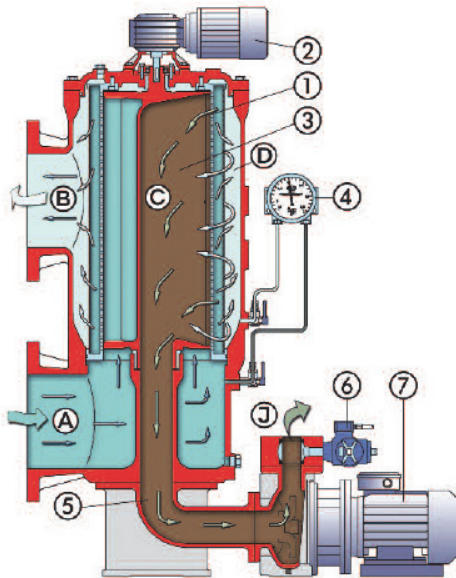


**Fig. 4.** HG250GS BWMS, Hyde Marine (*Hyde Guardian...* 2017)  
**Rys. 4.** System HG250GS firmy Hyde Marine

The cleaning system used in HG250GS is the most popular at present. An automatic backwashing filter with continuous filtration and flow to ballast tanks is the first stage. The second stage uses a high intensity of ultraviolet (UV) treatment for disinfection. UV dosage depends on a combination of lamp power flow path and exposure time. The cleanliness of UV lamp glasses is very important, so the washing systems for lamp glasses ought to be installed. The advantages of UV disinfection are:

- low corrosion risk (without using of chemical oxidants),
- use of no chemicals,
- no danger for overdosing (no effect on killed organisms),
- no harmful toxic or significant nontoxic products after disinfection process,
- safe to the crew and environment.

The mechanical filtering of ballast water may be efficient. The zooplankton removal efficiency is 20  $\mu\text{m}$  or 40  $\mu\text{m}$  (on request). An example of such system is presented in Fig. 5.



**Fig. 5.** Filtration and cleaning of ballast water (*Ballast Water Filters...* 2016)

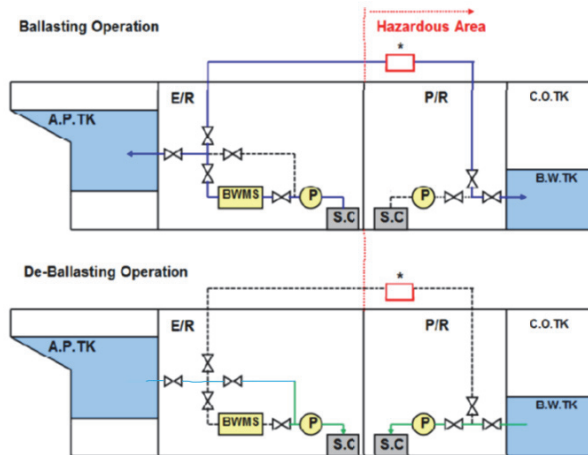
**Rys. 5.** Proces filtracji mechanicznej wody balastowej

- |                                       |  |
|---------------------------------------|--|
| <i>A – entrance of ballast water</i>  | <i>1 – filter element</i>                |
| <i>B – exit of ballast water</i>      | <i>2 – backwashing system</i>            |
| <i>C – cleaning chamber (inside)</i>  | <i>(electric motor in “on” position)</i> |
| <i>D – cleaning chamber (outside)</i> | <i>3 – backwashing shaft,</i>            |
| <i>J – cleaning duct (outlet)</i>     | <i>4 – pressure gauge</i>                |
|                                       | <i>5 – duct of filter cleaning,</i>      |
|                                       | <i>6 – backwashing valve</i>             |
|                                       | <i>7 – backwashing pump</i>              |
|                                       | <i>with electric motor (optional)</i>    |

There is presented the process of filtration of ballast water and parallel process of filter cleaning (when the pressure drop on filter activated the cleaning process of the filter).

#### 4. Cleanliness of ballast water tanks. Possibility of checking

The cleaning process is always active during ballasting operations. Some ballast water systems work only during ballasting operation, others during ballasting and de-ballasting operations. Ballast Water Managements Systems (BWMS) arrangement depends on a method approved by the Administration. The idea of BWMS, which does not require an after treatment, is presented in Fig. 6.



**Fig. 6.** BWMS which does not require after treatment (*Guidelines...* 2016)

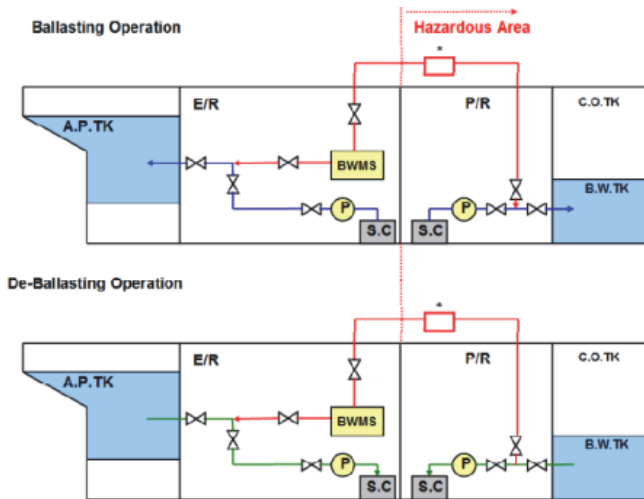
**Rys. 6.** System BWM niewymagający dodatkowej obróbki wód balastowych



*S.C* – sea chest, *P* – ballast water pump, *E/R* – engine room compartment, *P/R* – pump room compartment, *A.P.TK* – after peak ballast tank, *B.W.TK* – ballast water tank

During a de-ballasting operation the ballast pump works directly from ballast tank to the sea chest.

The idea of BWMS, which require the after treatment, is presented in Fig. 7. There is a small difference during de-ballasting process. The ballast water is pumped again through the BWMS pack.



**Fig. 7.** BWMS which require after treatment (injection type) (*Guidelines...* 2016)

**Rys. 7.** System BWM wymagający obróbki wody balastowej przed odpompowaniem za burtę

The standard D-2 of ballast water cleanliness should be reached after proper treatment through the BWMS. Certificates of BWMS inform that the cleanliness requirements were fulfilled during certification process at first examined installation of such type and such manufacturer. For other installations we received in reality the copy of mentioned certificate (*Wärtsilä Aquarius*® 2016).

The effectiveness of ballast water treatment depends on many factors:

- type of BWMS,
- the degree of water contamination,
- proper parameters of BWMS work,
- autoregulation system of BWMS pack on different temperature, salinity of sea water, etc.

The final effect should be reached during the de-ballasting operation by measuring cleanliness of ballast water in the outboard outlet pipeline. At sea during ballast operation there is a big problem to measure continuously cleanliness of discharged water (see Table 1). It is possible that cleanliness of ballast water may change during de-ballasting operation. A first time of pumping the parameters will be proper only if at the end they will be over the permitted limits. The ballasting operation should be done to the end. The ballast tank should be empty or full of water, never partly filled up. And additional question – what to do when the parameters of cleanliness exceeds the limits and the vessel is deep at sea? It is time for preventive exchange of ballast water or cleanliness processes at tanks.

## **5. Operational problems of ballast water systems**

An exchange of ballast water and the process of cleanliness may be the reasons for potentially dangerous situations for ship safety and crew. It should be done where the sea state, vessel operational state etc. allow for such operations (Herdzyk 2016-1, Herdzyk 2016-2).

Due to the International Safety Management Code (ISM Code) the BWMS needs to prepare appropriate procedures to avoid the above mentioned threats and to provide proper operation, service and routine maintenance (*Wärtsilä Aquarius*® 2016).

The unsolved problem is the cleanliness state inside the ballast tanks and inside the ballast water pipelines. There is a real possibility of corrosion (contact with seawater), contamination of plankton, bacteria and viruses not killed by BWMS, other substances (chemicals) produced in the ballast tanks during a voyage. It should decrease the effectiveness of BWMS and make under the question mark the reasonableness of utilization necessity such systems.

The possible solution is a frequent inspection of ballast tanks but it may be done only when the ballast tank is empty. How to check the tank cleanliness (and the pipelines) when there is no visible contamination but still possible from the bacteria and viruses? If a ballast tank is contaminated it is necessary to wash it (only by water or with chemicals?) and what to do with the tank washings. The next question is who will decide about the evaluation of ballast water tank cleanliness, when and where to do it.

The simplest solution is to treat ballast water during ballasting and de-ballasting operation (it doubles the time of BWMS work, waste energy etc.) but it does not still recognize a state inside the tank.

## 6. Will the expectations be fulfilled? Final remarks

The expectation is minimizing the threats of transport to the sea and environment. The hot discussion will be about the new required parameters, the limits decreasing, procedures, additional processes etc.

The BWMS is and will be installed on vessels according to required regulations (being in force in day of renewal survey – Table 1). Some answers to the above mentioned questions should be done before the decision of BWMS type choice. It needs some calculations to choose the best (maybe the cheapest) solution. The experience and opinions about considered type (and manufacturer) from crew or superintendents may be helpful for the correct decision.

The BWMS should be friendly to the environment and the crew. The next essential cost for ship-owners or operators should be justified by benefits for the environment and all of us.

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## **Systemy zarządzania wodami balastowymi na statkach. Wymagania czystości wód nowego standardu D-2 w porównaniu do oczekiwań**

### **Streszczenie**

W lutym 2004 roku Międzynarodowa Organizacja Morska (IMO) wprowadziła Międzynarodową konwencję o kontroli i zarządzaniu statkowymi wodami balastowymi oraz osadami z wód balastowych (Konwencja BWM). Przedstawiono w niej regulacje możliwości usuwania wody balastowej za burtę oraz metody zmniejszenia ryzyka wprowadzania do środowiska obcych gatunków. Dopełnieniem Konwencji są przewodniki, rezolucje i okólniki przygotowane przez Komitet Ochrony Środowiska Morskiego (MEPC). Dodatkowo, oprócz IMO, narodowe lub regionalne administracje morskie mogą wprowadzać własne regulacje np. wymagania Amerykańskiej Straży Granicznej (USCG). Początkowo standard D-1 wód balastowych był obligatoryjny. Po wejściu wymogów Konwencji BWM w dniu 8 września 2017 roku, wymaga się spełnienia standardu D-2 czystości wód balastowych.

W artykule przedstawiono systemy zarządzania wodami balastowymi, wymagania czystości, rozwiązania obróbki wód balastowych oraz oczekiwania związane ze zwiększeniem jakości wód balastowych i zmniejszeniem ryzyka dla środowiska. Poddano dyskusji standard D-1 obowiązujący od lutego 2004 roku oraz jego niedoskonałości. Czynnością rutynową winno być czyszczenie zbiorników balastowych z osadów, możliwe do przeprowadzenia na otwartym oceanie lub pod kontrolą urządzeń portowych lub suchego doku.

Rynek urządzeń okrętowych jest tak istotny i ważny dla producentów, że są oni w stanie przygotować w pełni gotowe systemy, będą je rozwijać, aby spełnić wymagania efektywności procesu czyszczenia, wymagania standardów czystości, jak najmniejszej masy i gabarytów urządzenia, jak najmniejszego zapotrzebowania na energię elektryczną, automatyzacji procesu z jak najmniejszą pracochłonnością dla załogi, budowy typoszeregu (o różnych wydajnościach – obecnie propozycje dotyczą jednego typu urządzenia z jedną wydajnością, można zastosować kilka urządzeń w celu zwiększenia wydajności), wieloletniego okresu użytkowania, całkowitych kosztów inwestycji i eksploatacji.

Jako przykład przedstawiono system HG250GS firmy Hyde Marine. Ważnym rozwiązaniem jest zastosowanie w pierwszym stopniu automatycznego filtra umożliwiającego pracę urządzenia podczas jego czyszczenia. Jako drugi stopień stosuje się intensywne napromieniowanie ultrafioletem (lampami UV) w celu dezynfekcji wody balastowej. Dawka promieniowania lamp UV jest ustalana jako kombinacja mocy lampy UV i czasu naświetlania. Czystość

szkieł lampy UV ma decydujące znaczenie dla skuteczności procesu, dlatego zainstalowano system ich czyszczenia. Wskazano na wiele parametrów, od których zależy efektywność obróbki wody balastowej. Istniejącym i nierozwiązanym problemem jest stan czystości zbiorników balastowych i rurowciągów obsługujących tę instalację w czasie eksploatacji. Kończącą uwagą jest, że oczekiwania dotyczące skutecznej obróbki wód balastowych nie zostały w pełni zweryfikowane.

### **Abstract**

In February 2004 the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). There are regulations of ballast water discharges and methods of risk reducing of introducing non-native species. To complement the BWM Convention, the IMO has adopted the guidelines prepared as resolutions and circulars by Maritime Environment Protection Committee (MEPC). In addition to the IMO, other national or regional bodies have introduced own regulations for example the United State Coast Guard rules. At first the D-1 standard of ballast water was obligatory. The BWM Convention has entered into force in 8<sup>th</sup> of September, 2017 and it needs the D-2 standard of ballast water cleanliness.

The article presents the ballast water managements systems, the cleanliness requirements, solutions of ballast water treatment and expectations for improvement the quality of ballast water pumped outboard and the decreased risk for the environment. It was discussed the D-1 standard of ballast water required from February 2004 and its imperfections. The routine ought to be the cleaning of the ballast tank to remove sediments, possible in mid-ocean or under controlled arrangements in port or dry dock.

The marine market is so considerable and important for manufacturers that they prepared full ready systems and still tried them to develop as to the effectiveness of cleaning process, the fulfillment of cleanliness standard, the minimal mass and dimensions of the pack, the minimal required electric energy, automatic operation with very little crew attention, series of types (different capacities) – the most often proposition is only with one capacity, for bigger capacity there is a possibility by using more than one pack, the long term life, the total cost of investment and operation etc.

As an example it was presented the HG250GS system of Hyde Marine. As an very important solution is an automatic backwashing filter with continuous filtration and flow to ballast tanks is the first stage. The second stage uses high intensity of ultraviolet (UV) treatment for disinfection. UV dosage results from a combination of lamp power flow path and exposure time. The cleanli-

ness of UV lamp glasses is very important, so the washing systems for lamp glasses ought to be installed. The effectiveness of ballast water treatment depends on many factors – they were indicated. The existing and unsolved problem is the cleanliness state inside the ballast tanks and inside the ballast water pipelines. As a final remark – the expectations concerning to ballast water treatment systems are not properly verified.

**Słowa kluczowe:**

woda balastowa, system zarządzania, Konwencja BWM, standard D-2, czystość wody

**Keywords:**

ballast water, management system, BWM Convention, D-2 standard, water cleanliness