ESTIMATING THE AMOUNT OF BALLAST WATER FROM SHIPS IN THE MEDITERRANEAN: ANTALYA BAY CASE STUDY

Ömer Harun Özkaynak, Gönül Tuğrul İçemer

Abstract: This study estimated how much ballast water ships can produce in the Gulf of Antalya, an important port city in the Mediterranean. The data used in the calculation was obtained from AIS (Automatic Identification System) of the ships arriving in Antalya Bay between 2018-2021. These ships' ballast water was determined using information from DWT (deadweight tons) using the methods given in the literature. It was calculated as a percentage of DWT according to ship types. As a result of the calculation, it has been determined that three to six million metric tons of ballast water produced in four years originates from bulk cargo ships. In addition, when other ship types are included in the Gulf of Antalya, it is evaluated that 7-12 million metric tons of ballast water may be produced, posing a severe threat to the Mediterranean ecosystem.

Keywords: Ballast Water Management, Ship Ballast, Mediterranean Ballast Water.

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Introduction

While navigating at sea, ships use ballast water to navigate safely in adverse weather conditions, ensuring their balance and stability when empty [1]. Ships take water into their ballast tanks when they are not taking on cargo. But the amount of ballast water a ship will discharge will vary depending on the cargo's weight. For example, all ballast must be unloaded to adjust the heel and trim of a ship carrying a heavy cargo load.

Although many ports are open to international trade in the Mediterranean, most do not have intercontinental importance. These ports connect to central ports worldwide, while local trade connects them to secondary Mediterranean ports. Therefore, the intense ship traffic in the Mediterranean mainly includes ships passing through transit.

Central ports in the Mediterranean are the sea at most significant risk, as they are most open to the intercontinental transfer of harmful aquatic organisms, including alien invasive species, and, therefore, to the primary introduction of Mediterranean invasive species. Shipping within the Mediterranean facilitates the transfer of species brought to central ports and, as a result, causes the secondary transfer of invasive species [2] [3].

The number of alien species in European seas has different patterns than in other parts of the world; this is because more than 50 % of introductions occur in the Mediterranean, with more than 650 species recorded, of which at least 325 are resident [4].

The ship's water from the marine environment to the ballast tanks contains suspended solids and various organisms [5]. Studies on the content of ballast water have shown that multiple plant, animal, and bacterial species can survive in ballast tanks and ballast water for a long time [6] [7] [8]. Some studies have shown that various organisms can survive in ballast tanks for several months or longer [9].

It has been determined that a species contained in the ballast water that each ship takes from one port and discharges to a different port has the potential to cause a significant negative impact on the receiving environment [9]. For example, after species introduction from one seashore to another via primary ballast water, secondary dispersal may occur in the receiving coastal waters by recreational boats or fishing activities [10]. In addition, other dynamic factors such as weather and sea conditions that ships may encounter while cruising, approaching shallow waters, and fuel and diesel consumption during the journey may also require ballast water operations [5]. For example, this may be the case for larger bulk carriers, which may load water into some central cargo holds to continue sailing safely in a "heavy ballast condition" when encountering heavy sea conditions.

Ship ballast capacity is determined by the ship's cargo capacity and the speed at which cargo operations can be carried out. The more cargo a ship can carry, the more ballast may be required when there is no cargo on board, and the more cargo operations there will be.

As defined in IMO: “Ballast Water Management means mechanical, physical, chemical and biological processes, alone or in combination, to remove, render harmless or prevent the uptake or discharge of Harmful Aquatic Organisms and Pathogens in Ballast Water and Sediments.”

The amount of ballast water discharged into the sea by ships on a global scale is estimated to be more than 10 billion tons [11], and Endresen (2004) [12] and other similar studies, it is estimated to be 3.5 billion tons. When these evaluations were made, approximately 5 billion tons of cargo were transported annually in world maritime trade. The cargo transported by maritime trade was 4.651 billion tons in 1995 and 5.871 billion tons in 2000 [13]. Endresen et al. (2004) [12] evaluation, it was accepted that world maritime trade is 8.734 billion tons of cargo, 5.434 billion tons of international, and 3.3 billion tons of national naval trade.

Ships carry many aquatic invasive species and different pollutants with the ballast water they take from the sea in another port [14] [15]. With increasing maritime trade and the number of ships sailing in the seas, the volume of ballast water carried will increase; therefore, the amount of pathogens and various pollutants in it will increase [16].

Ballast water capacity varies as a function of cargo carrying capacity and ship type, with an average value of 33 % of the ship's DWT [17]. The BWDA model considers all this, so the estimated discharge would be 33 % of the cargo volume in world maritime trade when excluding light cargo. It has been reported by IMO (2017) that approximately 10 million tons of ballast water containing different marine species are transferred from one port to another in the world [18].

According to studies conducted in previous years, 3000÷4000 different species are transported worldwide by ships every day [19]. More recent estimates indicate that the number of species transported by ships is likely around 7000 each day, and this does not include the transfer of microorganisms such as bacteria and pathogens [20]. Additionally, Tolian et al. (2020) [21] in the Persian Gulf, as a result of the analysis of ballast water samples taken from 32 ships, the amounts of Ni, Cd, Pb, and Cu heavy metals were 46.55, 3.93, 5.36, 58.83 and 26.41, 2.12, 2.59, 23.54 ppb (parts per million), respectively, and the values were determined to be above acceptable values.

Countries have coastal monitoring programs, but in most cases, there are no sampling stations at ports where ballast water is discharged or received. Early detection of new species that may be present in ballast water increases the possibility of quickly preventing the damage they may cause to the marine environment [22]. Thus, harmful species can be detected and eliminated early [23].

The primary goal of international and national legislation on ballast water is to prevent the effects of the discharge of harmful wastes containing Aquatic Organisms and Pathogens (HAOP) through ballast water. The most fundamental international legal regulation in this regard is the International Convention on the Control and Management of Ship Ballast Water and Sediments, London 2004 BWM Convention. The Convention entered into force on 8 September 2017, and 81 states ratified it, indicating that it has been accepted by 80.76 % of the total tonnage of the global merchant fleet as of 5 August 2019 [24]. This contract implements ballast water management in two ways: Ballast Water Exchange (BWE) and Ballast Water Treatment (BWT) according to D-2 and D-1 standards. In the BWE method, ships exchange 95 % of their ballast water in waters at least 200 m deep and at least 200 nautical miles from the nearest shore, according to the International Maritime Organization (IMO) Guidelines [25] [26]. It requires that the number of living organisms in the discharge of ballast water be below the limits established by rule D-2. The table created by David and Gollasch 2008 [27] regarding the standards that ships should apply according to their construction date and ballast water capacity has been rearranged and given in Table 1.

Some countries have ratified the BWM convention and implemented its requirements. Most of these requirements are based on the IMO Ballast Water Exchange (BWE) Standard (Regulation D -1). Some countries have implemented the Ballast Water Performance Standard (D-2), and a few have implemented applications for onshore ballast water intake facilities. In some countries, ships must keep a BWM plan and a ballast water record book [28].

If the ballast water exchange is impossible in some countries, other measures such as BWE or other water treatment practices should be implemented in a designated coastal area. For example, Canada has no regulations requiring saltwater treatment but does offer it as an option for ships arriving with tanks with salinities below 30 ppt. This method can only be applied if the number of tanks to be treated is small or for the remaining ballast [29].

As it is known, the Regional Marine Pollution Emergency Response Center (REMPEC) for the Mediterranean serves as the regional coordination organization. Regarding ballast water management, the Mediterranean strategy document created by REMPEC and the harmonized regulations for BWM in the Mediterranean region has also been adopted [30].

From 1 October 2012, ships leaving the Mediterranean Sea and bound for destinations in the North-East Atlantic or the Baltic Sea, and ships arriving in the Mediterranean from these areas, will be in the North-East Atlantic area and at least 200 nautical miles from the nearest land and at least The obligation to exchange ballast water in waters with a depth of at least 200 m has begun to be implemented. If this is not possible for operational reasons, BWE should be conducted as far as possible from the nearest land, at least 50 nautical miles from the nearest land, and in waters at least 200 m deep [31].

In addition to ballast exchange rules for ships arriving and leaving the Mediterranean, it has become mandatory for ships to have a Ballast Water Management Plan and keep records of all ballast water operations [28] [31].

Three methods for Ballast Water Exchange have been identified by IMO [32]:

Sequential method: A ballast tank is emptied and then refilled with reserve ballast water to achieve at least a 95 % volumetric change.

Flow method: A process in which water in one ballast tank is pumped into another, allowing the water to flow through overflow on the deck or other arrangements.

Dilution method: A process in which water in one ballast tank is filled from the top of another and simultaneously discharged from the bottom at the same flow rate, thus maintaining a constant water level throughout the BWE.

Besides the requirements that must be met regarding the BWE methods applied, a ship must also meet the criteria regarding where the BWE will be carried out. A ship must first perform ballast water exchange at a distance of at least 200 nautical miles from the nearest land and in a water depth of at least 200 m. If this is not possible, BWE should be carried out as far away from the nearest land, at least 50 nautical miles from the nearest land, and in waters at least 200 m deep [33].

Table 1 – The original phase-in plan of the ballast water performance standard (Regulation D-2) about the ballast water exchange standard (Regulation D-1) [27].

Ships built	BW capacity (m^3)	Phase in of the D-2 standard of the BWM Convention							
		2009	2010	2011	2012	2013	2014	2015	2016
Before 2009	1500 - 5000		D-1 or D-2					D-2	
After 2009	1500-5000		D-1 or D-2						D-2
2009	<5000		-	D-1 or D-2			D-2		
After 2010	<5000	-				D-2			
2009- 2012	>5000		D-1 or D-2						D-2
After 2012	>5000		-				D-2		

Suppose the depth and distance requirements mandatory for BWE cannot be met. In that case, a ballast water exchange area (BWEA) may be determined by the standards specified by IMO in consultation with other neighbouring port states.

The amount of ballast water discharged into the sea from ships engaged in international maritime trade is estimated to be 3.1 billion (3.1x109) tons per year [5]. According to the "Ballast Water Performance Standard Regulation" determined by IMO (International Maritime Organization), it is mandatory for ships performing ballast water management to have a ballast water treatment system that will meet the standards specified in Table 2. (D-2 standards) in the ballast water to be discharged. However, this obligation has been applied to ships produced since 2009.

Table 2 – Ballast water standards can be discharged into the sea [33].

Microorganism Category	Regulation
Plankton, Length > 50 µm	< 10 1/ m^3
Plankton, Length 10-50 µm	< 10 1/mL
Toxicogenic *Vibrio cholerae*	< 1 cfu (colony forming unit) /100 mL
Escherichia coli	< 250 cfu/100 mL
Intestinal Enterococci	< 100 cfu/100 mL

Although the D-2 standard introduced by IMO leads to a significant reduction in the number of released organisms, it is estimated that it cannot prevent 100 000 different species from entering the marine environment, assuming that ships carry up to 100 000 tons or more of ballast water and approximately 10 000 tons of this is discharged into the sea. Another weakness of the D-2 standard is that it does not take into account organisms below 10 µm (minimum size), such as harmful algae (for example, Phaeocystis spp., Pfiesteria spp., and Chrysochromulina spp.) [5].

The study aims to estimate the amount of ballast water originating from ships in the Gulf of Antalya, which hosts one of the important ports of the Mediterranean, and to guide the studies on ballast water in the coming years regarding its possible effects. This provides a basis for structural and legal regulations that can be taken on this subject by ensuring that the extent of the ecological impacts that ballast water may cause in the Mediterranean is estimated.

Material and Methods

Calculating the Amount of Ballast Water a Ship Can Create

General cargo and Ro-Ro ships generally use around 20 % of their DWT and even more than 40 % of ballast water, with some exceptions [5]. In addition, ships intended to transport liquid and dry bulk cargo, such as tankers and dry cargo ships, require significantly more significant amounts of ballast water, often between 30 % and 50 % of their DWT. This means using more than 100 000 m^3 of ballast water per ship.

A summary of the ballast water capacities for the main ship types identified by different authors and the types of ships placed in the Anatolian Gulf is presented in Table 3 [34].

Table 3 – Ballast water amounts of ships according to their DWT size [34].

Vessel type/ DWT (Ton)	AQIS (1993) [35]	Carlton et al. (1995) [36]	Walters (1996) [37]	Hay and Tanis (1998) [38]	Suban (2006) [17]	This Study
Cruise Ships	33	-	38	-	43	33-43
Bulk Cargo	-	43	41	60	33	33-60
Bulk Cargo /250 000	30–45	-	-	-	-	30-45
Bulk Cargo /150 000	30–45	-	-	-	30–45	30-45
Bulk Cargo /70 000	36–57	-	-	-	30–45	30-57
Bulk Cargo /35 000	30–49	-	-	-	33–57	30-57
Tanker		38	26		-	26-38
Tanker 100 000	40–45	-	-	-	-	40-45
Tanker/40 000	30/38	-	-	-	43	30-43
Container		32	30	30–60	35	30-60
Container /40 000	30–38	-	-	-	28–40	28-40
Container /15 000	30	-	-	-	30	30
General Cargo		-	35	30–60	29	29-60
General Cargo /17 000	35	-	-	-	-	35
General Cargo /8 000	38	-	-	-	-	38

The ballast water capacity of a ship varies as a function of cargo carrying capacity and ship type [12]. With this information, the annual amounts of ballast water carried can be estimated as a function of the total cargo carried annually. However, the amount of cargo carried varies widely. Since this is the case, it would be a more accurate approach to calculate the amount of ballast water according to the ship's DWT.

Table 3 shows that the amount of bilge water that may occur depending on the ship type can be determined according to different percentages according to DWT. According to previous studies, this study calculated the minimum and maximum amount of ballast water that can be formed using the smallest and largest ratios. In this study, the values used to calculate a ship's ballast water capacity are also given in Table 3.

Determination of the Amount of Ballast Water That Can Be Created by Ships in the Gulf of Antalya

The information on tankers, bulk cargo, general cargo, containers, and passenger ships cruising in Antalya Bay between 01 January 2018 and 31 December 2021 was tracked and recorded via AIS (Automatic Identification System). The region where ship movement information is recorded is shown in Figure 1. The amount of ballast water ships sailing in the area in question was calculated using DWT information. They were using the percentage rates given in DWT information Table.3, the minimum and maximum amount of ballast water ships can carry in Antalya Bay has been calculated.

Figure 1 – Registration area where ship information is recorded.

Results and Discussion

The number of ship movements and DWT averages according to passenger ship types in Antalya Bay between 01 January 2018 and 31 December 2021 are given in Table 4.

Table 4 – Movement numbers and DWT averages of ships cruising in Antalya Bay between 2018-2021.

Ship Type	Number of Ship Movements	DWT Average (Ton)
Tanker	261	22848.57
Container	267	23930.46
General Cargo	526	7000.07
Bulk Cargo	244	41244.83
Cruise ship	14	3436.357

The amount of ballast water that can be produced by the types of ships sailing in the Gulf of Antalya has been calculated using the percentage rates according to the DWT given in Table 3. The maximum and minimum totals of estimated ballast water amounts are shown in Table 5. While calculating the ballast water amounts of the ships, it is not taken into account that they will not receive ballast water when they arrive loaded and will use some of their ballast water capacity according to weather and sea conditions to ensure the ship's stability. These were not taken into account because, in a previous study conducted in Koper Port, it was determined that ships discharged more than 80 % of their ballast water [39]. In addition, in this study, the amount of ballast water created by ships was estimated previously. As stated in a survey, it was found that the ballast water coming to a port is critical when evaluated in terms of the content of ballast water [3]. In the ballast water sampling study carried out in Koper Port (Slovenia), it was determined that ballast water coming from ports in the same region (Mediterranean and mostly Adriatic Sea) also contained non-native species that have not yet been recorded [2].

Table 5– Ballast water amounts of ships cruising in the Gulf of Antalya in 2018-2021.

Ship Type	Minimum Amount of Ballast Water (Ton)	Maximum Amount of Ballast Water (Ton)	Annual average (Ton)
Tanker	2 107 945.1	2 628 075.51	657 018.8775
Container	1 589 642.88	2 477 380	619 345
General Cargo	-	1 339 794.37	334 948.5925
Bulk Cargo	3 019 121.4	5 387 920.14	1 346 980.035
Cruise ship	15 875.97	20 686.87	5 171.7175
Total	6 732 585.35	11 853 856.89	2 963 464.22

When Table 5 is examined, it is seen that the bulk carriers have the highest amount of ballast water, which is evaluated to have a capacity of approximately 8.5 million tons for four years. It is seen that the annual amount of ballast water varies between 619÷1 346 980 tons. Since the amount of ballast water discharged into the sea by ships on a global scale was previously estimated to be more than 10 billion tons, and in other similar studies, it was calculated to be 3.5 billion tons [11] [12], the amount of ballast water calculated in this study is also calculated in the Mediterranean Sea. It can be said that it is mainly acceptable for the Gulf of Antalya, one of Turkey's essential traffic lines.

Considering the total amount of ballast water calculated, the amount of ballast water is approximately 7÷12 million tons for four years. Considering that this amount comes from different ports of the world and takes ballast water from these ports and discharges it in the Gulf of Antalya, an important port city in the Mediterranean, it will not be difficult to predict the severe damage it will cause to the marine ecosystem. As the introduction mentions, ballast water contains many substances that harm the marine environment, including heavy metals and species foreign to the ecosystem into which it is discharged.

Conclusion

In this study, since ship ballast water amounts are calculated according to DWT information, these issues appear as limiting factors for the calculated ballast water amount since it cannot fully show the quantity of ballast water on the ship, and ships will not receive ballast water when they take on cargo.

Estimating the amount of ballast water discharges alone will not be sufficient to determine the harmful effect of ballast water on the marine ecosystem. In future studies, when samples are taken and the amount of harmful aquatic organisms and pathogens that may be found in ballast water is evaluated, the effects of the results on the marine environment will be more clearly visible.

Another severe issue from this study is that the intake of ballast water by waste reception facilities in ports and its strict control can prevent the ecosystem degradation caused by ballast water, which poses a significant threat to the Mediterranean and the World seas. However, no legal regulation gives port waste reception responsibility for ballast water.

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