Chapter

Ballast Water Utopia and Some Environmental Protection Ideas

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Abstract

An environmental protection plan that would resemble a true utopia might still be distant however, employing advanced methods and innovation that will get the global community on the road to the best marine and other environmental protections should be every generation's intent. Ballast water management as related to shipping, trade, and the marine world as a special concern of this paper has been one of the most notable innovation drivers in the maritime space in the last couple of decades in order to close doors to the dangers of introducing new aquatic invasive species in sensitive environments around the world (bio invasions). This paper aims to selectively survey some established ballast water management methods reimagined by the latest innovations reflecting on some latest developments. The world is constantly facing troubling concerns over environmental protection issues particularly related to marine and maritime related endeavors. For example, what it may mean to lose many Russian scientists that are involved in arctic research as a result of the Russia-Ukraine conflict, especially with ship traffic and ballast water management slated to be more and more of a concern in that area as shipping channels become more open in that region.

Keywords: ballast water management, ship tech, marine pollution, green ship, solutions to invasive species, Arctic shipping lanes, scientists in Arctic research, pollution monitoring

1. Introduction

The term "Ballast Water Utopia" is not the author of this paper coined phrase but a term stated by William Burroughs of Freedom Ballast, a company that provides an innovative solution of ballast water treatment as a barge or portside service [1]. The strong language suggested by the term "Ballast Water Utopia" by the company's CEO inspired the discussion of cutting-edge innovations in ballast water management in this paper. To begin with, this paper's use of the word utopia attests to the commitment that certain innovators have in matters related to environmental protection especially in the marine world by focusing on ideas supported by technology that could potentially lead to the most ideal situations in dealing with invasive aquatic species (AIS) in shipping technologies for ballast water management. The International Maritime Organization (IMO) [2], dedicated over a decade of momentous efforts to react to the mission to control, prevent and close the door to aquatic invasive species that were or would be introduced by ships to foreign waters through ballast water tanks.

When empty, ships need to be ballasted (balanced) with water however that water needs to be thrown overboard when cargoes are taken aboard the ship and this is where invasive species and sediments (which may be teeming with organisms) from different parts of the world may find their way to a new world where they do not have natural predators and thus are able to grow into dangerous and environmentally threatening levels, at least that is how it would be if no care is taken whatsoever to treat foreign water containing invasive species [3].

The dangers of AIS from ballast water tanks are well documented [4] having the potential of destroying entire ecosystems, entire fishing industries, and various environments [5]. Some of the most infamous invasions include the zebra mussel, which costs millions of dollars in clean-up operations in the Great Lakes of the United States. This mussel is native to the Black Sea, the Caspian Sea, and waters just south of Russia and Ukraine [6]. Further examples of notorious marine bio-invasions include the green crab, the Cladoceran Water Flea, certain jellyfish, the lionfish, etc. In a post-Covid lock-downs world, with the exception of certain areas around the world that still hold on to lock-downs, humanity, in general, in 2022 is even more aware of the dangers of uncontrollable organisms working against the life spans and the quality of life of human beings. This means that there will always stand a moral obligation to respond expeditiously to environmental threats so that commercial activity does not hinder and destroy human being, their livelihoods, and the environment.

The ocean is constantly under monitoring through various scientific undertakings around the world. Scientists warn us through data-supported, intense research that the ocean faces many environmental challenges and these are studied under varied branches of study, to name a few examples, the ocean has environmental challenges with, coral bleaching [7], marine neurotoxins termed the red tides [8], noise pollution from ships [9], concerns about the devastations that can arise from the melting permafrost, particularly in the Arctic region [10] which would be devastating to communities in that environment and the globe, not to mention all the pollution from microplastics and other effluents. In this paper, we are just focusing on the ballast water management field but this must be read within the context of other environmental challenges that scientists are looking at. This is why we cannot afford to lose scientific minds in environmental threat management. Since this paper is concerned with ballast water management, it is important to consider the ballast water simulations [11] in regions that are changing as a result of global warming such as the Arctic.

When international rules for ballast water management were initially drafted, technologies to enforce such rules needed to be brought up to date with the demands of the rules. The rules were eventually adopted and came into force in the form of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (the Ballast Water Management Convention, 2004), also known as the BWM Convention, 2004 [12]. On 8 September 2017, this law came into force, with approved systems finally being available in the ship technology market. These approved systems are available and listed with the IMO and several port authorities around the world [13].

In this paper, there will be a consideration of some of the newer methods such as barge and port side ballast water treatment, as part of a survey of the latest developments in ship techs for ballast water management, there will also be a selective consideration of the effectiveness of a few sample ballast water management systems, as it would be impossible to discuss them all in this paper. Further, with the Arctic opening up more as a result of global warming and better ships and legal codes are developed to traverse that environment, naturally, concerns about ballast water management

also increase in that region. It will therefore be appropriate in this paper to also briefly consider what the loss of Russian scientists may mean for Arctic research and environmental protection endeavors as a result of the war between Russia and Ukraine. Further, a consideration of other bodies of water in relation to ballast water such as the Mediterranean Sea and Antarctica will also be considered as examples of how ballast water management has affected those areas.

2. The research methods and methodology

In order to avoid a superficial discussion of the concerns around the dangers of discharging untreated ballast water into the seas as a result of international trade or other maritime-related activity, it is essential to discuss the strategy for collecting data for an analysis used in this paper. This will assist the reader to determine the reliability and validity of the findings and observations in this paper. Before discussing the strategy, it is important to note that the research question to be answered in this paper may be couched as follows, 'Following the IMO treaty of Ballast Water Management, the BWM 2004 [14], which methods have actually been considered successful and with the success of those methods, which of them can be considered as new developments that solve problems around ballast water management?' Coupled with this question is, "What are some of the actual problems associated with ballast water management especially in sensitive ecosystems such as the Arctic, Antarctic and ancient traditional trading routes such as the Mediterranean Sea, as examples to sample ballast water management concerns as well as strategies?"

To answer these questions a combination of qualitative as well as quantitative methods have been employed in this research for data collection and analysis. Apart from the author's survey which was directed at various companies that deal with ballast water development tools to determine the attitude and preparedness to comply with the new compliance standards of the BWM, 2004, the data studies in this paper to answer these questions took the form of observational, experimental literature reviews as secondary data of experts in the field. For example, in the excellent research experiment conducted by Rosenhaim et al. [11] a study of movements of ships during various seasons and how it affects the accumulation of environmentally threatening discharges of ballast water is relied on to study, analyze and problem solve in the Arctic region. Similar research methods are employed in this paper.

In order to study industry attitude and preparedness for compliance with the BWM, 2004 standards and the moral sensitivity to the seriousness of ballast water threats, the author created a survey that contained seven multiple choice questions with a Likert scale response [15], with an 8th open-ended question asking maritime industry and developers or users of ballast water technologies if they had any comments about the ballast water regulations that were about to come into force as international law. Participants were given at least 5 minutes to answer the surveys anonymously. A hundred surveys were sent to various companies and a maximum of 20 surveys were completed. All returned surveys were considered to sample industry attitudes and preparedness [16]. The surveys represent those who have been following the alarming problem of untreated ballast water discharges from ships and have a direct interest in the developments and technologies to deal with the problem.

The theoretical positioning of this research paper shows the true power of collaborative data production and interdisciplinary engagement to solve environmental concerns and problem sets. Although some of the literature review is secondary in

nature, it is provided by those who have strong sound paradigms and compelling experimental results. Although the limitations of relying on secondary sources of data may be a reality, secondary sound data is far better that no data at all and it forms a powerful tool in making arguments such as the necessity of monitoring the data, if it exists for successful compliance with the ballast water management regulations which are now fully enforceable international law. The process and steps for data collection and analysis in this paper are logical, justifiable, and allow the questions raised above to be answered reasonably or raise further relevant questions that will lead to better future solutions.

3. Understanding the dangers of discharging untreated ballast water

It is important to note that a safe ship has to maintain balance by having water pumped into its ballast tanks. This gives the vessel stability as the weight of the vessel and its displacement in the water have to be carefully managed throughout the voyage which is all part of vessel stability. It has been said that water-based ballast systems and ship ballasting increased with the advent of steel-hulled ships [17]. Ships with ballast water systems are not only those that engage in the carriage of goods, for example, the dredger, ILembe, a Hopper Dredger flying under the South African flag, registered under IMO number 9741891 has a ballast water system which pumps in or out ballast water depending on how much sand and other by-products of dredging are taken on board the vessel. To keep the dredger from transporting invasive species around the coastline upon which it operates, the dredger's operations in law require that it exchanges its ballast water with local water before it gets into the new coastal waters [18]. This example shows us that ballasting may affect and type and size of vessel and the introduction of foreign waters is something that must as a result be managed carefully.

In international trade, **Figure 1** below shows us that ballast water discharge into the environment as shown in the illustration, in this case, it introduces invasive species into a new environment if such ballast water being discharged is not sufficiently

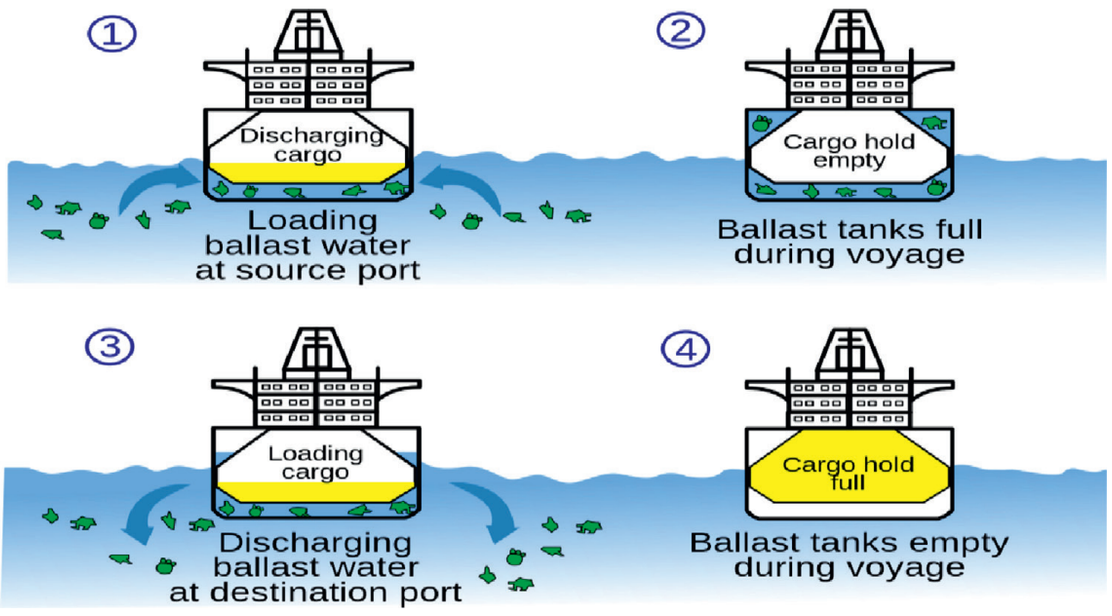

Figure 1.
Ballast water management and its implications (Miami shark research, 2016).

treated [19]. This discharge of ballast water is part of ensuring that the vessel can load cargo at the port of loading in a safe manner such that the illustration shows how the water is replaced by the cargo and vice versa. In trade, a cargo empty vessel is ballasted by water and a fully cargo-loaded vessel is ballasted by a combination of cargo and the appropriate amount of water as the operations of the vessel require. On board are sensitive ballast water systems fitted with alarms and are carefully monitored by the captain and his or her crew who give the appropriate instructions for what is considered the appropriate levels of ballasting is needed for each unique situation.

It has been established by the scientific community that ship ballasting seems to work best with water and that coming up with a technology of ballast-less ships is probably a pipe dream because the current methods are safer, economical, and have shown ship construction soundness [20]. Unfortunately, the science of avoiding invasive species from entering new worlds with shipping as a vector moved along at a slower pace when compared with just how many invasive species were historically and more recently being introduced around the world.

Untreated ballast water can introduce not only dangerous robust nonindigenous species to a new environment, but these species tend to cause economic and environmental harm by creating self-sustaining, dominant populations that disrupt the indigenous environment. Some invasive species demonstrate *allelopathy*, a condition that allows invasive species to produce chemicals that inhibit the growth of other organisms, particularly in plants, and this is of particular importance in cases of seaweed invasions. This means that billions in financial losses occur in fishing and other aquaculture sites as a result of ships with untreated ballast water bringing in parasites, viral and bacterial pathogens that may cause cholera and other cysts of toxic dinoflagellates which can be poisonous [21]. The IMO's GloBallast [22] initiative which recorded this negative phenomenon around the world also keeps records of invasions by country as a public record. This report contains alarming data which is why the BWM 2004 Convention was eventually prepared and published as is now in force. This is also the reason, the author ran a survey to find out what industry attitudes were concerning readiness to deal with untreated ballast water and to ask those within the industry if they have thought of methods not only to manage new ballast water invasions but in future hopefully deal with current invasions with an aim to reduce them significantly with the hope of reviving damaged ecosystems and other affected fishing businesses, etc.

Here are the general findings of that survey which shows that the industry leaders in this sector have not only understood the dangers of ignoring ballast water management but are keen to turn to technologies and other methods to manage ballast water AIS.

- 'The survey attracted the attention, answers, and comments from a significant portion of persons directly and heavily involved with ballast water management as their regular occupation.

- The survey also attracted members of the public who care about the marine environment, who may not be exposed to the general daily technicalities of ballast water management matters but they are concerned with potential destruction of the marine environment through shipping activities.

- A significant portion of shipowners and port officials are prepared to implement the new Convention standards (as of now, the regulations have been in force for over 3 years already).

- Decision makers in companies and ports that have to implement the standards are well aware of the new regulations and have been ready to implement them.

- In terms of financial preparedness, a smaller portion of shipowners seemed ready to spend higher capital investments on their ballast water management systems.

- A significant portion of shipowners are ready to implement the standards but do not wish to automatically spend high capital investments installing expensive ballast water treatment systems.

- A significant portion of shipowners are financially prepared for investing in compliant ballast water systems but seem suspicious of overly budget-friendly systems while some owners are most definitely interested in budget-friendly ballast water treatment systems.

- Morally participants care for the environment and wish to take responsibility for the environment being preserved. This restores hope in the technicalities of international trade.

- Unfortunately, there is a call for something to be done by the invasions that have taken over now but there is also a concern that perhaps it is too late to do anything about existing invasions.

- Many shipowners believe in the D2 standard for future compliant ships and believe in its effectiveness and a smaller portion of shipowners do not only believe in the D2 standard readiness but they are also currently prepared. It is submitted that such shipowners probably have newer ships and have ordered compliant ballast water systems for such ships in time.

- Participants who wrote some comments showed serious concerns about doing something about current invasions, some called for standardization throughout the globe so there is no weak link in ballast water management across the globe while some participants warned shipowners to be careful not to invest in a system that may not pass because it simply is not effective. Last but not least, the survey results showed serious concerns about accurate monitoring [16]. The survey results show that the BWM 2004 standard is far more prepared for by the maritime industry and this is why it is essential to discuss some of the new methods and developments in ballast water management and consider the data following the BWM 2004 regulation coming into force.

4. New methods: Barge and port side ballast water treatment

In a now-published book in 2022 written by the author of this paper with several authors who are also researchers, scholars and practitioners, in the field of ballast water management [16], it is recorded that the ballast water technologies and innovations tabulated in **Table 1** below are currently available in general on the market and they are usually employed by various shipowners. These methods have been passed by the IMO [23, 24]. The IMO has rigorous standards established in sound standards for

Physical Filtration Systems
Screens/Discs
Hydrocyclone
Coagulation
Magnetic Field Treatment
Chemical Disinfection Ballast Water Treatments
Oxidizing Biocides
Non-Oxidizing Biocides
Ultra-Violet Treatment Method
De-Oxygenation
Electric Pulse and Plasma Treatment (also available on the market is Acoustic (Cavitation Treatment) and Thermal (Heat) Solutions

Table 1.
Table of ballast water treatment systems on the market.

passing these technologies however many of them still need to be further developed and improved their effectiveness double-checked against data available after years of employment of these methods. The use of chlorine in ballast water treatments, for example, which has been one of the more simpler and popular methods of ballast water treatment, has been criticized for its potentiality to form toxins in the water because, further chlorine still carries the status of extremely dangerous chemical because in its gas form, it is so harmful that it was a chemical weapon in the first world war [25].

The IMO and ballast water management of just laws of nations around the world obviously seek only safe methods of managing ballast water to comply with IMO standards [26]. This is why it is crucial to have an understanding of technologies as recorded in **Table 1** below. This table provides us with performance data for technologies that have been popularized by the industry in its zeal to comply with the BWM 2004. The fact that there are complaints about some of the methods being considered 'dangerous' for human health means that we still have to work more on compliance methods as well as monitoring. Otherwise, this means that we are still ignoring environmental impact problems created by shipping and the necessity of trade.

In **Table 1** below the technologies which could be considered new generation to make compliance with the BWM 2004 Convention possible seem to be more popular because they deliver the D2 standards for water approval for safe discharge. These technologies also provide for easy monitoring or more developed monitoring systems which the survey conducted showed was of particular importance to the industry. The monitoring of ballast water has had its traditional systems for testing and monitoring that have been part of the shipping industry however now that the standard is raised for the management of ballast water discharges it is clear that a customer, shipowner who buys into the popular new technologies in **Table 1** will have a great chance of being able to prove ballast water management compliance.

Innovators in the ballast water management space have shown us according to the table above that technologies in the market are capable of achieving regulatory compliance for IMO and Port State control, therefore let us consider how these methods have been technically and operationally advanced to provide ballast water treatment shore side or by barge as an example of the latest developments. It is important to

consider how this innovation is contributing towards a greener ship, port and ballast water management system. Green shipping is the future because without a stable environment there is no life, commerce, or trade to sustain. This cannot be ignored because it leads to devastation. We must applaud, support, and encourage those who use modern technologies for greener safer shipping [27].

The leading innovators on barge and port-side ballast water management are the company, Freedom Ballast [28]. The technology used is illustrated in the company's patented system which works as follows before ballast water is discharged from a ship it passed through the patented and patent pending UV and pasteurization technology of Freedom Ballast. This technology without the use of active substances and chemical compounds treats the ballast water before it is discharged. The system itself works with high throughput at 1000 M_3/hour, this would please the shipowners seeking that just-in-time speed for port operations.

Upon the author of this paper is granted an interview with the CEO of Freedom Ballast, it was clear that the CEO was focused on technologies to stop invasions before the technology to deal with current and existing invasions is discussed. In his discussion, the CEO discussed a world where ship hulls can be repurposed to provide logistical possibilities for this system to be available at ports throughout the globe. This means that there is much research and development behind this company to make these green ideas of not toxic, effective, recycling ballast water management to reach their full potential. The Freedom Ballast system is accepted in North America with concessions to operate in the lower Mississippi. What will be interesting to see is whether or not this technology is suitable for the mega-size class vessels and if it were to be used in ultra-sensitive marine environments like the Arctic region whether or not it would be one of the most acceptable methods. Considering the non-toxic nature of the technology, this system might be one of the latest applications that may be most suitable.

It is submitted that the spirit of environmental protection and innovation in marine environments should continue as shown with the barge port side ballast water treatment system demonstrated above. In US law, which we may use as a significant example of a global benchmark for regulatory compliance on ballast water management, new innovations in ballast water management, whether local or foreign are supported. In the case of foreign innovations and other unique methods, a request to pass these under the United States Coast Guard (USCG) is encouraged. This mean that practically it is required that a formal request is made to the USCG to decide on any new Ballast Water Management Systems (BWMS) approved by a foreign administration. This is why it can be said that standards for BWM in the US are high, see the Code of Federal Regulation particularly, Title 33 CFR, '§ 151.2026. It is submitted that governments around the world should as research grows and data becomes available in the area of ballast water management that an innovatively open mind to even better technologies be kept to continue to encourage the finding and investment in the best technologies.

In the US, again, for example, to illustrate this innovation encouraging the best solution for ballast water management strategies, when a shipowner wants to use or is using an Alternate (ballast) management systems (AMS), as long as such a system is in agreement with the aims of the BWM 2004 Convention and request to use it in writing is made to the USCG, that system can be approved and usable in the USA subject to the discretion of the port authority, of course. This means constant research and development is being encouraged in the USA, this is the commitment to the environment. It is submitted that the same commitment that is shown in stopping

new invasions should also be applied in finding solutions to current invasions. For, example, can we use plasma solutions on zebra mussel infestations in the great lakes by demarcating certain areas and treating them with this application or more effective ones? This is a question that innovators and research and development can answer but the encouragement of these ideas is called for by this paper.

5. Ballast water in the Arctic region

The Arctic Region is regulated by the Polar Code developed by the IMO [29]. According to the Polar Code, The Ballast Water Convention (BWM Convention, 2004) and its Regulations D-1, regarding ballast water exchange (a method that requires foreign ballast water carried on a ship to be exchanged with local water before the ship enters the region's marine environment), an exercise that may prove dangerous in adverse weather but accepted to be effective and an acceptable practice, and D-2, regarding ballast water performance standards, are methods currently considered to be appropriate for the Arctic region [30]. The fact that Polar Code so clearly encourages compliance with the treatment of Ballast Water in that region by providing as follows:

"4 **Additional Guidance Under Other Environmental Conventions And Guidelines** 4.1 Until the International Convention for the Control and Management of Ships' Ballast Water and Sediments enters into force, the ballast water management provisions of the ballast water exchange standard, set out in regulation D-1, or the ballast water performance standard, set out in regulation D-2 of the Convention should be considered as appropriate. The provisions of the Guidelines for ballast water exchange in the Antarctic treaty area (resolution MEPC.163 (56)) should be taken into consideration along with other relevant guidelines developed by the Organization. 4.2 In selecting the ballast water management system, attention should be paid to limiting conditions specified in the appendix of the Type Approval Certificate and the temperature under which the system has been tested, in order to ensure its suitability and effectiveness in polar waters."

The Polar Code is a strong risk management and safety instrument mandated and applied together with the Safety of Life at Sea (SOLAS) [31] IMO instrument as well as the environmental protection law in the form of The International Convention for the Prevention of Pollution from Ships (*MARPOL*) [32]. This means that ballast water laws must be effective in the Arctic to protect that region (**Figure 2**).

In a paper, simulating ballast mater movements and management in the Arctic region authors Rosenhaim et al. use a ballast water tracer as a pathway to highlight through their experiments that ballast water accumulation in the Arctic is strongly linked to seasonality, this essential data for environmental protection and planning. Through their experiments, the authors demonstrate that conditions linked to summer, winter, and autumn conditions affect ballast water accumulation in the region. Most importantly, the authors through experimentation show that there is a risk of contamination of the environment through ballast water accumulation [11]. Here is a ballast water management warning from the experiment of the authors in the Arctic:

"In winter, due to the small number of vessels navigating the Northeast Passage, the amount of ballast water tracer released in the model was small. Following the increase in the number of vessels towards spring and especially in summer, the amount of ballast water tracer increased, and thus the risk of environmental contamination (e.g., by nonindigenous species, anthropogenic contaminants, pathogens, and toxins) [11]."

Figure 2.
Extent of Arctic waters as per IMO polar code, source: (IMO, polar code, 2017).

The authors above are telling us that when the Arctic waters open up more as a result of trade, ballast water methods on ships should be updated to comply with the BWM 2004 Convention, so that environmental contamination is a smaller risk for winter months (trades and voyages significantly shrink), or whether the contamination is more significant in the summer months, their tracer experiments should be able to (with the right ballast water technologies on board vessels trading in the Arctic) show that in general employing such technologies actually through the proof

of data decreases contamination through ballast water. This is a powerful experiment to test for the success of ballast water management technologies.

6. The loss of Russian scientists in Arctic research

Protection of the environment is a global effort, where experts through effective and established and hopefully ethical methods put forth efforts to collaborate on sharing information on keeping environments safe whether it is space, land, or sea. This is why it is concerning that reports such as, "Russian and Western scientists no longer collaborate in the Arctic" [33] are quite disturbing. This situation is one of the direct results of the Russia-Ukraine conflict. It is submitted that from an international perspective policies ought to be developed concerning matters where the common interests of mankind are not abandoned to the extent of ignoring environmental protection since it is in the immediate interest of all, whether in conflict or not to continue collaborating on threat prevention efforts to protect the environment. For conflicting nations, basic survival takes precedence over all other interests that are understood however it is submitted in this paper that such situations should be treated in a special manner at the international level.

The maritime world is a global, interlinked one therefore having considered the impact of war on scientific minds, it is essential that we briefly consider ballast water management and impacts of other trade regions as a way of random global sampling in order to have a clearer perspective on some of the latest issues around ballast water management in the world. We will be considering Ballast Water management around Antarctica and the ancient trade route of the Mediterranean Sea, all areas where scientific minds globally have contributed.

6.1 Ballast water in the Antarctic region

It is important to note that the BWM 2004 Convention applies to the Antarctic region. There is also an important document in the form of the Antarctic Treaty, 1959 which guides the use, exploration and exploitation of the Antarctic. While dynamics of Antarctica are different from those of the Arctic in that the Antarctic is not a populous area with attractive shipping lanes for trade. However, due to untreated ballast water being introduced in the area, researchers also warn of the dangers of foreign waters being introduced together with AIS into the Antarctic Treaty region [34]. Authors, Dulière et al. in a scientific experiment running along a 9-year period conducted along the location of the Western Antarctic Peninsula, evidence of the introduction of AIS from ballast water can be overcome by encouraging ships to exchange foreign ballast water at least 200 nautical miles from the Antarctic region. This is the observance of the D1 standard of the BWM 2004 Treaty. This clearly means that the risk is extremely serious for the environmental future of the region and it will be essential for international parties to tighten sanctions for offending parties who traverse this region and pollute with impunity.

6.2 Ballast water in the ancient trade route of the Mediterranean Sea region

In a cutting-edge, very first study of its kind in the Mediterranean Sea conducted by Matej et al. [35], a sampling of 15 ships calling at the Port of Koper, Slovenia showed that ballast water management and the sometimes irreversible effects and

damage on the environment are still very serious issues, particularly for a trade rouse as busy as the Mediterranean Sea shipping lanes. The results of the experiment showed that invasive species were being introduced with shipping as a vector, however, this was prior to the compliance and technological methods introduced by the coming into force of the BWM 2004. As part of ongoing research and monitoring, it would be very interesting what a repeat of this experiment might produce following the coming into force of the ballast water treaty.

7. Monitoring in environmental protection efforts

One of the concerns as to the effectiveness of ballast water management efforts and other environmental protection methods is the issue of monitoring. Monitoring helps in establishing a record of the success of the environmental protection innovations that we are using. In terms of innovation and technological developments, there have been impressive monitoring systems by various innovators. In this paper, the author highlights systems for monitoring by CEMTEK [36]. Without proof of data for compliance, even showing and measuring regulatory compliance is difficult. It is therefore proposed that ballast water management systems should also be equipped with tried and tested monitoring techs that will make it easier to reach standards and regulatory compliance while supporting ship management efficiency and protecting the environment.

8. Conclusion

Ballast water management has created excellent results in encouraging research and development as well as international cooperation on environmental protection to keep bio-invasions in the marine environment at bay. However, more data needs to be collected in order to measure the true effectiveness and human/biosafety of the more popular and now existing technological innovations to treat ballast water. The use of chlorine on the scale that it is being used to treat ballast water and the concerns raised about it must encourage even better solutions. This is true progress.

Further, taking special care for the ballast water management of a sensitive regions like the Arctic, the Antarctic, and the ancient traditional routes of trade around the world such as the Mediterranean Sea will need to continue. Collaborations to use science to create sustainable and bio-safe maritime activity must be the inspirational goal through which scientific studies for innovation, monitoring and record-keeping must be done while protecting sustainable maritime commerce.

The best and most environmentally sound ballast water management systems must be encouraged for that region to protect the environment and directly the communities of that region. In terms of the loss of Russian scientists because of the Russian-Ukraine conflict, cutting-edge research, ground-breaking findings of scientists should not be so easily abandoned, negotiation, and respect for scientific answers should still be protected, conflicting nations also have a vested interest in the environment and this must be protected. Finally, since the surveys conducted and experiments discussed in this paper have demonstrated where the strengths and weaknesses are (for example, consider the experiments in the Arctic and Antarctica, there are still problems with lack of compliance with the BWM 2004 Treaty that seriously threaten those environments), this should be very useful to guide different budgets

to be prepared by governments, business entities, and various commercial interests to invest in making sure that ballast water management is taken very seriously.

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