UNIVERSITY OF GHANA

OPEN OCEAN BALLAST EXCHANGE: A STUDY ON THE NEED FOR INNOVATIVE APPROACH TO ELIMINATE AQUATIC INVASION

BY

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DECLARATION

While acknowledging information from various sources, I hereby declare with academic honesty that, this is my original work. This work has never been presented either in whole or in part for any purpose anywhere. I am solely responsible for any error in this research work.

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DEDICATION

I dedicate this research to God Almighty for granting me the greatest strength, love, mercy and care throughout this research. I also dedicate it to my family for their support and love.

I really appreciate all your support in prayers, moral and financially.

May the God bless you all.

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ABSTRACT

The study investigates the issues regarding Open Ocean Ballast Water Exchange (OOBWE) and propose a more innovative approach to manage ballast water.

Ships are constructed and meant to carry dry or liquid bulk cargo, containers, machinery, and people and travel on the ocean. If a ship is travelling without cargo, or has discharged her cargo in one port and is en route to her next port of call, ballast may be loaded to achieve the required safe operating conditions. This ensures that the ship's propeller and rudder operate efficiently by keeping the bow under the water, as it sails in heavy seas.

The study identified that BW is a vector of thousands of species of animals, plants and microorganisms, many of which survive temporarily in the ship's tanks and are transferred to new aquatic environment when discharged. Such species become invasive, disrupt the native ecology, and have serious impact on the economy and on human health and is one biggest threat to the world's freshwater, coastal and marine environments.

Safety is identified as the greatest challenge with the OOBWE as far as ships are concerned as potential lack of adequate stability or excessive list, longitudinal strength, dynamic loads, excessive trim, bottom slamming, propeller emergence, and poor bridge visibility which may be caused by improper planning and operation of ballast transfer or discharge.

Moreover, Ghana has a number of national regulations that deal with environmental issues, but no clear existing environmental regulation that deals with ballast discharge in Ghana and this creates difficulty for the relevant institutions to sanction vessels not complying to the requirements. The study identifies onboard treatment plant, port reception and/or treatment facility, and floating barge with treatment plant on board as most innovative ballast treatment option to ensure reduction or complete mitigation of invasive aquatic organisms.

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LIST OF ABBREVIATIONS

- ABS – American Bureau of Shipping
- AQIS – Australian Quarantine and Inspection Service
- BT – Ballast Tank
- BWE – Ballast Water Exchange
- BWM – Ballast Water Management
- BWT – Ballast Water Treatment
- CSL – California State Legislature
- EEZ – Exclusive Economic Zone
- EPA – Environmental Protection Agency
- GEF – Global Environment Facility
- GMA – Ghana Maritime Authority
- GPHA – Ghana Ports and Habours Authority
- ICS – International Chamber of Shipping
- IMO – International Maritime Organisation
- IOI – Indication of Interest
- OOBWE - Open Ocean Ballast Water Exchange –
- PP – Propagule Pressure
- SAB – Scientific Advisory Board
- TRO – Total Residual Oxidant
- UNDP – United Nations Development Program
- US – United States
- USCG – United States' Coast Guard
- UV – Ultraviolent

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Shipping alone moves about 80% of world's commodities and as ships travel from one part of world to another, the amount of BW transferred globally is about 3 to 5 billion tonnes (Tsolaki & Diamadopoulos, 2010). A similar volume is transferred domestically within countries and regions each year summing the BW movement to around Ten billion tonnes annually (Rigby, 2002).

BW is a vital part of a safe and efficient modern shipping operation, one way to achieve a safe and efficient modern ship operations is providing balance and stability to vessels not fully loaded (Andersen, 2002). BW is indispensable for bulky ocean-going vessels transporting goods and services in international shipping. This water is often carried when ships are empty or not hauling heavy cargoes. Ships require BW for stability, integrity of structure and to maintain manoeuvrability on the water during voyage operation. However, various researches have emphasized that BW is a source responsible for the spread of the globe's non-native species and pollutants into new geographical environment (Tamburri et al. 2002, Endresen et al. 2004, Jeng et. al. 2012). Transfer of certain invasive marine organisms is a major problem that adversely affect the globe ecologically and socio-economically. It is indicated that, over ten thousand (10,000) different marine species of aquatic microbes, plants and animals are carried daily in BW (Buck, 2010).

When discharged in new environments, such species may invade, disturb the natural ecology and cause massive effects on the economy and human health. The induction of these marine organisms into new environments through ship's ballast and sediments, is the greatest danger to all water bodies of the world. BW movement is identified as the most significant global pathways for the spread of certain invasive marine species (Kolzsch & Blasius 2011).

Figure 1.1: Cross section of a ship showing Ballast Tank (BT) and BW cycle

Source: (GloBallast programme 2002)

Zooplankton density in BTs depends on number of factors, such as place or season of BW uptake, the environment, dynamics in population of biota in BW, voyage length, exchange efficiency, ship and tank design (Ruiz, Murply, Verling, Smith, Chaves & Hines 2005)

The OOBWE was introduced in the 1990s and used by number of countries as a voluntary or mandatory technique to reduce risks for BW-mediated introduction of invasive organisms in coastal waters (Taylor, Rigby, Gollasch, Voigt, Hallegraeff, McCollin & Jelmert 2002).

According to Ruiz et al, (2005), the rationale for BWE is centered on two key assumptions: The assumptions that:

i. *coastal species contained in BW will be replaced by oceanic species which are unlikely to survive when discharged in coastal environment and*

ii. *oceanic communities are less diverse and abundant than coastal communities*

1.2 PROBLEM STATEMENT

According to Rigby & Hallegraeff (1994), residual water often contains many more planktonic organisms than the water from the surface of BT. In older container ships, sediment is accumulated in the base of BT. As a result, the last 1 - 5% contained in BW will contain far more species because of these sediments which still remains a potential threat for aquatic invasion (Cohen, 1998)

Although OOBWE is currently the most widely available method to mitigate spread of coastal invasion of aquatic organisms in ballast, ships may be unable to undergo exchange at mid sea due to severe weather, stability issues or benthic biota can collect in tank sediments, which are not removed during exchange. Some marine organisms can form hardy resting stages that can resist extreme changes in condition in BTs, and have the ability to also survive the left over stagnant water in BTs after they are have been fully emptied.

The residual ballast (i.e. the water remaining at base of BT after pumping) will likely contain organisms at densities higher than those in ballast discharged into the ocean which remains a potential threat for aquatic invasion, hence the study seeks to identify most appropriate and innovative approach to tackle BW problem.

1.3 OBJECTIVES

The main objective of the study is to investigate the issues regarding OOBWE and propose a more innovative approach to managing BW.

The specific objectives are:

i. To investigate the effectiveness of OOBWE in reducing coastal aquatic invasion.

ii. To identify the challenges regarding open ocean exchange of ballast.

iii. To provide appropriate recommendations on the best approach to the management of BW.

1.4 RESEARCH QUESTION

The following research questions will be asked to achieve the research objectives.

i) How effective is open-ocean BWE in reducing coastal aquatic invasion?

ii) What are the challenges regarding OOBWE?

iii) What is/are the appropriate BW Management (BWM) option (s) that will help to reduce problems associated with BW?

1.5 SIGNIFICANCE OF THE STUDY

The study seeks to provide findings which will contribute to elimination of BW problems to safe guard marine environment.

The study also intends to serve as a guide to individuals or group of persons intending to conduct research on BWM and/or in a related area.

1.6 SCOPE OF THE STUDY

The research takes a critical insight into OOBWE and its effectiveness as a measure to reducing the effects of the introduction of aquatic invasion on the marine environment.

The research also focuses on the alternative innovative approach to effective management of BW.

1.7 RESEARCH METHODOLOGY

The research uses primary and secondary sources to collect the required data. With the secondary data, the researcher used literature materials from the industry and academic journals, etc. To obtain the primary data, an interview is conducted with responsible stakeholders of the maritime industry as far as environment is concerned.

This enabled the researcher to obtain relevant information on ballast management. The analysis of findings is based on information obtained from various sources and data analysis is with respect to the objectives using descriptive method.

1.8 STRUCTURE OF THE STUDY.

The research is made up of five (5) chapters taking into consideration the following subjects.

Chapter one consist of general introduction of the study, making a background discussion on the subject, the relevance of the studies, the objectives of the research, the scope, and the organization of the research materials.

Chapter two is relatively descriptive in nature. It presents a review of literature with regards to BWM.

Chapter three (3) discusses the methods and the approaches used to obtain and analyse information used for the research. The sources being primary data and secondary data.

Chapter four presents the summery of analyses of findings with regards to the objectives and answers to posed research questions in chapter one.

Finally, chapter five provides the research conclusions, recommendations, and proposals on probable solutions to mitigate the problems of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents reviews of literature on the problems associated with BW and its management. Other reviewed areas include conventions or regulations concerning the control of invasive species being introduced into other marine environments. The chapter further provides reviews on open-ocean exchange of ballast and the processes involved, other treatment methods, the effectiveness and challenges associated with the treatment options.

2.2 DEFINITIONS OF BW

ABS, (2014) defines BW as any water that is taken onboard a vessel together with its suspended matter in order to control listing, achieve trim, attain draft, stabilize the vessel or control stresses. Ships used rocks, sand and metal as ballast sometime past but technical developments in ship building and operation makes it easier to use water as ballast. This is because it ensures the safety and efficiency of ships since it is easy to load and discharge and more economical than solid ballast (GEF-UNDP-IMO GloBallast Partnerships and IOI, 2009).

Ceyla (2009), also defined ballast as water held in tanks or cargo holds of ships to help provide stability and maneuverability during a voyage when ships are sailing free of cargo, or cargo carried is not heavy enough to provide the needed stability, or require more stability due to the roughness of seas. In order for ships to pass under bridges and other structures, BW is carried to give the ship a low draft for it to ride low. According to BWM Convention (2004), BW is defined as the form of water loaded on board ships to help maintain the stability and avoid undesirable stresses of ships. Ships operate more safely when loaded with cargo but ships need additional weight when they are sailing without cargo or when partially laden with cargo to ensure appropriate stability and manage hull stresses.

2.3 WHY SHIPS USE BW

Marine transport allows economical transportation of large cargo volumes making it the most preferred transport mode for goods in large quantities. The gradual increase in the number of ships in the maritime trade becomes inevitable considering the growth in volume of the world seaborne trade. In high-volume shipping areas, the risk of shipborne pollution and marine accidents is high, therefore ship management is of great importance to minimize these probabilities. Buck, (2012) states that one most important part of ship safety is stability which can be achieved through taking on weight (BW) into the vessel.

Ships carrying less weight of cargo is vulnerable of knocking over by high sea waves and winds, which in tend increases the likelihood of "slamming" the bow or stern when riding over large waves, or raise the propeller to the level where it becomes insufficiently covered by water. Due to this, at the start of a voyage a ship may take on large quantities of water subject to the water the ship is floating in, which can either be fresh water if in a river port, or salt water when in the sea to lower the ship to a safer and efficient position. BW is pumped out of the BTs in coastal or port areas that are miles away from the source before fresh cargo is taken onboard. Ballast is also loaded or discharged for other purposes, including adjusting the ship's trim, improving manoeuvrability, increasing propulsion efficiency, reducing hull stress, raising the ship to pass over shallow areas, reducing draft, and lowering it to get under bridges or cranes reducing air draft (Cohen, 1998). According to Haruo et al, (2005), BW is important for ships to maintain stability and safety at sea when sailing without cargo. Generally, ships load BW aboard and discharge overseas before loading new cargo.

Stability is important for a ship in order to sail safely. Thus, seawater is loaded and stored in specially designed compartments located at the bottom of the ship. This practice of pumping BW not only provides stability, it also improves ship propulsion and manoeuvrability, lessens stress that exist on the hull, and compensates for weight lost because of fuel and water consumption (Alaa and Manal, 2012).

2.4 INVASION PATHWAY

Humphrey (2008) identified the invasion pathway for aquatic organisms as a multi-step in which organisms must pass through series of phases to establish itself in new environment as shown in Figure 2.1. The first phase requires that an organism utilizes natural or human-mediated transfer mechanism to move to a habitat outside its natural range. An organism will move to the second phase of establishment if it can survive the voyage in the BW carried in the ship's tank.

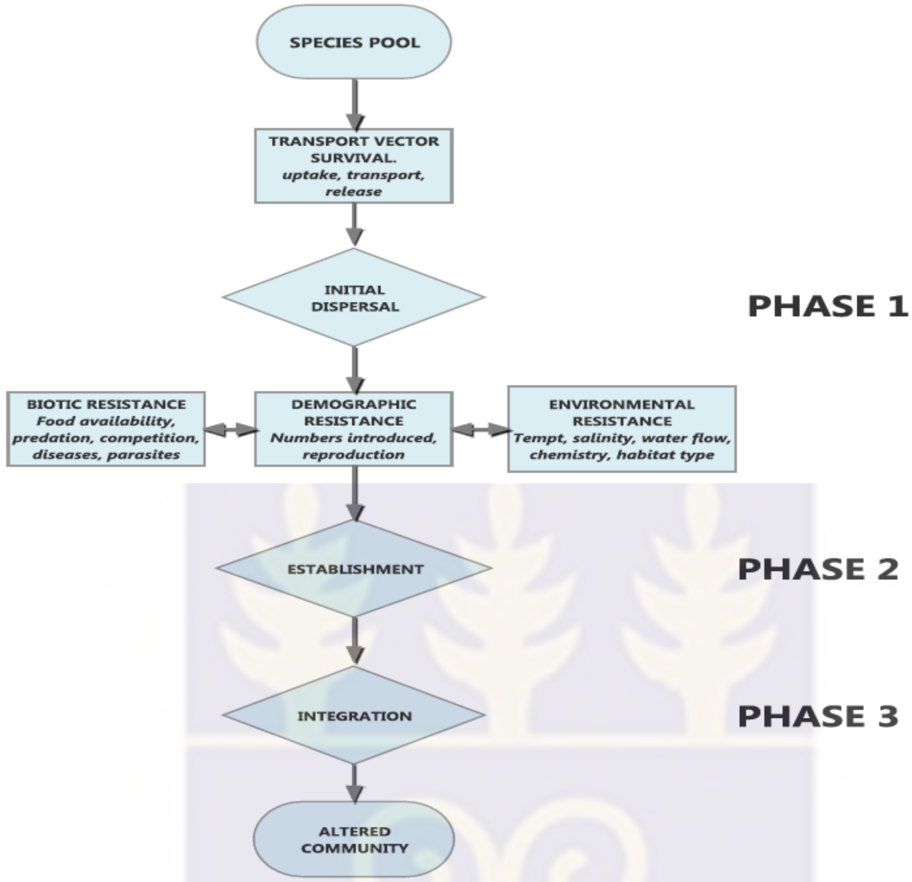

Figure 2.1: Conceptual Model of Invasive Pathway adopted from Humphrey (2008)

The second phase (establishment phase) requires that an organism establishes itself in its new environment. It has to survive through local reproduction and recruitment (Humphrey, 2008). Whether an organism can establish itself, according to Humphrey (2008), will depend on the ecological resistance of the new environment which includes: environmental suitability including temperature or salinity; biotic resistance such as prey availability, predation, competition, disease, parasites, and demographic resistance such as numbers or organisms introduced and reproduction otherwise known as Propagule Pressure (PP). According to Ricciardi, Jones, Kestrup & Ward (2011) PP is important in establishing success, which means that establishment is a game of numbers. The PP theory asserts that the ability of species to invade is contingent on the individual number introduced and the frequency of such introductions into a new environment. This assertion is supported statistically by the concept of the 'tens' rule discussed under integration.

Integration is the final phase of the invasion pathway which requires that the newly introduced species can either be self-propelled, or utilize transport vectors to spread within its new habitat (Humphrey, 2008). The release of invasive species into a new environment provides for their inoculation but not necessarily their introduction since not all organisms become, 'invasive'. Some do not survive the new environment but die off naturally, while others survive, without replacing or destroying native species (Lovell & Stone, 2006). This phenomenon was explained succinctly by the 'tens rule'.

The 'tens rule' is a generalization about invaders by Williamson and Fitter (1996) where they propounded a statistical approach to study the proportion in which organisms achieve success in new environments. The rule suggests that if the initial pool of species is transported into new environment, 10% of species become introduced, and 10% of the ones introduced become established while 10% of those established become invasive. Since the 'tens rule' have been previously adopted to successfully predict the fate of introduced birds, terrestrial plants, and insects, using the principle of substantial equivalence, the same rule can be adopted in the prediction of the fate of introduced aquatic species in a new environment.

2.5 BW PROBLEMS

In general, the global rate of the invasion of alien species is increasing especially in marine ecosystems. Scientists consider invasive species as a major danger to the marine environment, often with dramatic implications for biodiversity, natural habitats, and fishing.

In order to maintain stability and structural integrity to ensure the sinking down of propeller and rudder in the unloaded voyage, there is a need for BW. It is closely connected to safe operation in ship since ballasting help restore balance during loading and discharge operations and fuel consumption. The environmental problem here is that BW being a vector to thousands of species of plants, animals and other microorganisms (pathogens), get transferred to different aquatic environments when ballast is discharged. Polluted marine areas are more conducive to the establishment of harmful invasive species as ecosystem destabilization is caused by human activities including over-fishing and water pollution which is influential factor for successful invasion of species. In the Black Sea, over-fishing and eutrophication has contributed to massive growth of ***Mnemiopsis Leidyi*** population, a carnivorous jellyfish that found themselves introduced into the sea through ballasting in the 80s. Jellyfishes are widely known to consume huge quantities of fish larvae and zooplankton, disrupting the whole food web, and leading to the destruction of fishing stocks.

While taking on BW, organisms are inadvertently drawn into and held within a vessel's BT which are transferred from origin to destination ports facilitating the movement of many organisms from one place to another. In this regard, estimation shows that over 10,000 species are moved around the world daily (Carlton 1999). Moreover, as indicated by Minton, Verling, Miller & Ruiz (2005), each discharge of ballast has potential of releasing over 21.2 million individual live free-floating organisms. Once established, these organisms create severe ecological, economic, and human health related effects on the receiving environment.

It was further explained that all marine species have life cycles that include planktonic stages (*ibid*). Due to this species in adult's stages may not be taken in ballast because they are too large or live attached to seabed but may be transferred in ballast during their planktonic phase.

According to Nichols, Thompson & Schemel (1990), the clam account for up to about 95% of living biomass in some shallow areas of the bay floor of San Francisco. The clam is believed to be a major contributor to the loss of several pelagic fishes in the Sacramento-San Joaquin River Delta, including the threatened delta smelt (Feyrer, Matern & Moyle 2003). Worldwide, 42% of the endangered species in 2005 were listed in part because of negative interactions with non-indigenous biological organisms and one of such severe impact is zebra mussel (*Dreissena polymorpha*) which in the mid-1980s was released into the Great Lakes from the Black Sea via commercial ships. These mussels were responsible for clogging electrical generating plants and municipal water systems and resulted in maintenance and repair costs of about 1 billion dollars per year (Pimentel, Zuniga & Morrison, 2005). By dramatically reducing plankton concentrations and crowding out other species, zebra mussels alter ecological communities, causing localized loss of the natural species and reduction in expensive fish species (Martel Pathy, Madill, Renaud, Dean & Kerr, 2001).

In Volkoff (2014) submission, over 21 million dollars has been spent by California Department of Fish and Wildlife and California State Parks to control zebra and quagga mussels within California from the time of discovery of the species in 2007.

In addition to impacting the economy and environment, non- indigenous biological organisms pose risk to human health where vessels and port areas have been connected to spread of cholera epidemic in several instances including transport of toxigenic *Vibrio cholerae* serotype O1 from the Latin American region to Mobile Bay, Alabama in 1991 (Ruiz et al. 2000, Takahashi et al., 2008). This invasion during summer and fall in 1991, caused a total loss of $700,000 due to the close down of nearly all oyster beds in Mobile bay (Lovell & Drake, 2009). Other microbes found in ships' ballast include the micro-organisms that cause paralytic shellfish poisoning and coral pathogens (Hallegraeff, 1998), human intestinal parasites (*Giardia lamblia, Cryptosporidium parvum, Enterocytozoon bieneusi)* and the microbial indicators for faecal contamination (Escherichia coli and intestinal enterococci).

2.6 BWM REGULATIONS

BWM refers to the mechanical, physical, chemical, and biological processes used either singular or in combination to remove or render harmless the effects of pathogens and aquatic organisms in BW and its sediments. The International Convention used to control and manage ship's BW and its sediments was adopted by IMO in 2004 with the aim to provide global applicable regulations to prevent, minimize or eliminate risks to human health, property, environment and resources resulting from the induction of harmful marine organisms. After the entry into force of the convention, all vessels will be required to carry out a BWM system that complies with specific standards depending on the capacity of their BTs and year of built. These standards are the BWE Standard and the BW Performance Standard (IMO, 2004).

Although the Convention has not entered into force several coastal states have already established national standards on BWE procedures and have specified the necessary documentation centred on IMO Resolution A.868 (20). Though BW is very helpful in maintaining the stability and avoiding ship stress, it may contain some marine organisms or pathogens. These organisms when introduced into the sea, fresh water course and estuaries may affect human health, the environment and properties which can cause impairment of the biological diversity or interfere with other legitimate uses of such areas. As of June 25, 2014, 40 countries representing 30.25 percent of global commercial tonnages has ratified the Convention (California State Lands Commission, 2014). Until the convention is ratified and entered into force, it cannot be enforced (IMO, 2007).

With concerns from the shipping industry about the implementation of the Convention, the IMO Marine Environment Protection Committee, during its 65th meeting in May 2013, discussed a sub-committee proposal and agreed in principle with establishment of a 2-3-year trial period after the Convention enters into force. During this trial period, methods of assessing discharge compliance with the D-2 standard would be tested and reviewed to ensure they are fit for purpose. Furthermore, nations would "refrain from applying criminal sanction or detaining ships, based on biological sampling" (California State Lands Commission, 2014).

2.6.1 The International Management Convention requirement

According to the IMO (2004) the requirements in the International Convention for the Control and Management of Ships' Ballast and Sediments (2004) regulations B-3 includes the following;

1. A ship that was constructed not later than 2009: this kind of ship must be equipped with ballast capacity that is between 1500 and 5000 cm3. It must be able to manage BW onboard according to the standards set out in regulations D-1 or D-2 up until 2004. After 2004, the ship should be able to meet up fully with the standards in regulations D-2.

2. The BW capacity of not be less than 1500 or more than 5000 cm3 to conduct BWM according to the standard in regulation D-1 or D-2 until 2016 and subsequently must at least achieve the standards set in D-2
3. A ship that applies in paragraph 1 shall conform to paragraph 1 and the period must not be a period after its first intermediate or renewal survey (whichever applies first), subsequent to the delivery date of such ship in the year of compliance to the standard applicable to the ship
4. Ships built in or after 2009 having a capacity of 5000m3 and over are expected to undertake BWM to meet at least the standards prescribed in regulation D-2
5. Sips built in or after 2009 but before 2012, having a capacity of BW of 5000m3 and over are expected to undertake the management of BW to meet the standards highlighted in paragraph 1.2
6. Ships built in or after 2012 having a BW capacity of 5000 m3 and above shall undertake BWM to meet the standards stated in regulation D-2.
7. However, requirements in the regulation does not apply to ships that discharge its ballast to reception facilities considering the guidelines that govern such facilities as established by the organization
8. So far as other approaches of BWM will ensure efficient treatment that bring protection to the environment, human property, resource and are also approved in principle by the committee, they will be accepted as alternatives to the requirements prescribed in paragraphs 1 to 5

2.7 BWM OPTIONS

BW that is taken onboard vessels may contain different organisms, bacteria and viruses including those in the larval and the adult stages of many marine and coastal plants. While a large part of these organisms may not survive by end of voyage, some may survive and boom in their new environment. There are serious economic, ecological and public health implications for the receiving environment when the non-native species become established (Lloyds' Register, 2007). The management of BW onboard vessels include measures that aim to prevent unwanted marine species from being transferred between ports in the ballast. Seaports stand the risk of invasions when they engage in daily ship BW exchange (Buck, 2012).

Even though there exist many treatment technologies for municipal and industries applications, none of them has been able to achieve the capabilities to attain the treatment standard required by the BWM Convention under D-2. However, the entry into force of the treatment methods for BW under the convention is expected to provide a major boost in treatment technologies worldwide (David & Gollasch, 2008). While there exist some challenges in ship types and the ability of shipyards to modify, many of the BWM systems are already on the market whiles others are still in the development stages

Presently, various maritime sectors and suppliers are making significant efforts to propose and develop more Ballast Water Treatment technologies.

Studies indicate that these treatment technologies exist in either primary or secondary separation methods (Tsolaki & Diamadopoulos, 2010). The primary method also known as the solid-liquid separation technique consists of physical processes such as filtration and hydocyclones (Tsolaki & Diamadopoulos, 2010). The secondary separation method consists of both physical and chemical disinfection technologies, (ultraviolet, cavitation, ozonation and coagulation MICA (P) 039/02/2012) as explained in figure 2.2 below.

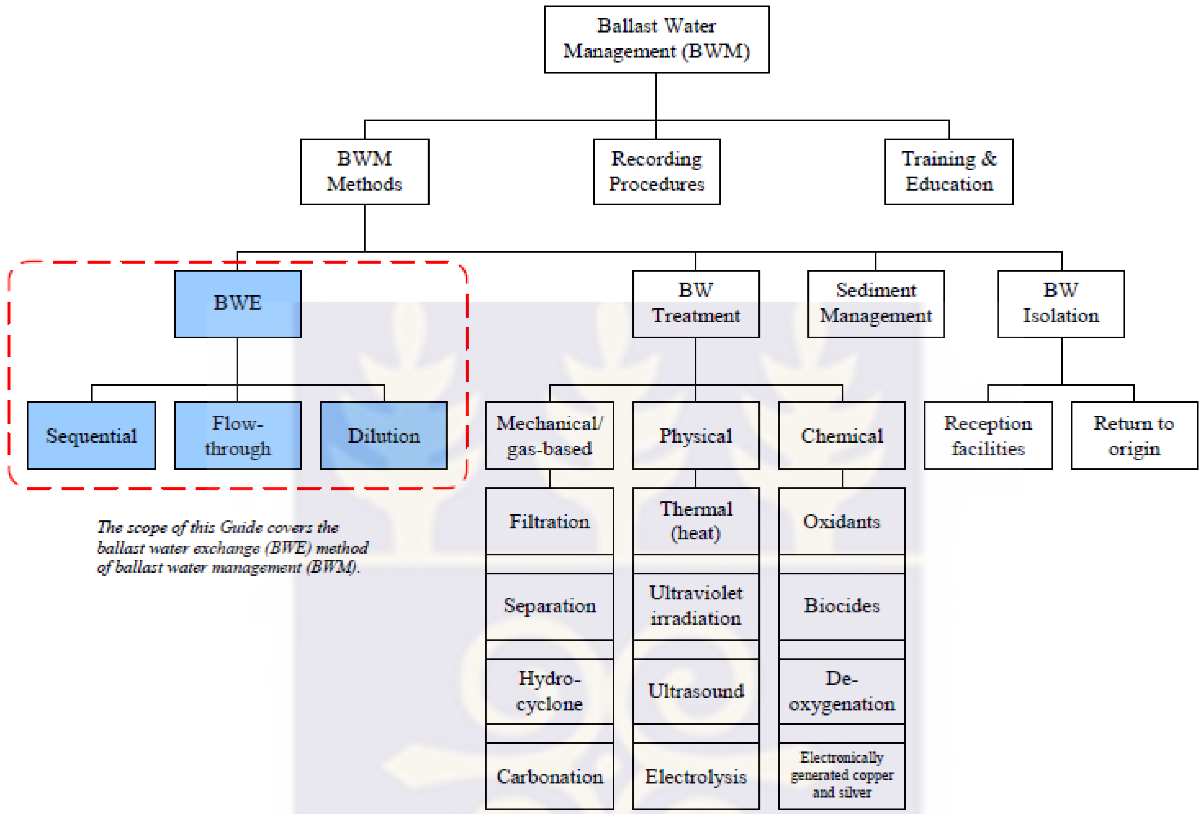

Figure 2.2 Diagram illustrating BWM options (Source: ABS guide for BW exchange 2010)

2.8 OOBWE

BW exchange (BWE), the process of exchanging port water with ocean water, is presently the most broadly applicable method of reducing risks of Aquatic Invasive Species introductions (USCG, 2003). It is typically conducted using a flow-through or empty-refill technique. Flow-through involves flushing the BW tank containing coastal or port water with water from the ocean from bottom up. Although efficiency varies, pumping the tanks volume three times is the operational standard.

After adopting the BWM Convention, there were no approved methods of achieving prescribed operational performance standards. The only mode of ensuring that harmful alien aquatic species are not transferred from one area to another was to exchange the BW while the ship is en route within the deep ocean. BWE is not considered an ideal answer as it only reduces, but does not eliminate the risk of transfer of living organisms. The design and construction of BTs affect the effectiveness of the BW exchange in the ocean.

Furthermore, BWE on the high seas exposes the ship to potential dangers of both physical stresses on ship's hull and potential loss of stability. Naturally, the procedure must be carefully performed and monitored, but for human errors there are recorded incidents where ships have come close to foundering due to loss of stability during a BWE procedure. There are no records available regarding structural damage or increase of metal fatigue caused by stress forces due to BWE procedures but they are almost certain to have occurred (Cordell, Lawrence, Ferm, Tear, Smith & Herwig, 2009).

According to Regulation A-3 in the Annex to the BWM Convention, the requirements will not apply in some situations. For example, in an area where the BW is taken, that same area cannot be allowed for discharge or to uptake and discharge of the same BW on the high seas. This is perfectly logical as there would be no transfer of aquatic animals in these cases from one location to the other. Furthermore, the requirements will not apply where there are incidental discharges from ship damage or its equipment or where it is necessary to prevent or minimize pollution from the ship and are considered as easily justifiable exceptions (IMO, 2004). Finally, the requirements do not apply to uptake or discharges of BW and its sediments that are done to ensure the safety of the ship and life at sea. Consequently, one could argue that if adverse weather conditions prevent a ship from undertaking BWE on the high seas without prejudicing the ship and crew safety, it would, at least, be exempted in principle from the requirements of the BWM Convention. This makes sense, but one can easily imagine that Port State Control inspectors and other "desk drivers" involved in the implementation and execution of the convention might second guess the Captain's judgment and question the decision not to engage in BW exchange. However, the BWE procedures is not a completely effective approach for the prevention of the movement of harmful organisms. This is because it is unable to remove all organisms, making it, in any case a temporary solution allowed for some ship types, but only until 2016. Presently, OOBWE is the only approved BWT strategy that can be used to fulfil the United States' (US) Coast Guards (USCG) BWM required by federal regulation. Until fresh treatments methods and strategies are available and approved, ships that have operated outside the US Exclusive Economic Zone (EEZ) must either retain their ballast on board or undergo BW exchange. In open-ocean BWE ships flush BTs in the open ocean, thereby replacing ballasted coastal water with ocean water. If the exchange occurs far from the continental margin, the probability that there is reciprocal introduction is low. The open-ocean BWE has some potential disadvantages as much as the possibility of organism translocation is concerned. Assuming that the efficiency of removal of organisms is the same as the water replacement efficiency during ballasting then, more of dangerous organisms may remain in the water that is discharged into the receiving port. This is especially true when ballasting occurs during an algal bloom in the ballasting port (Bax, Williamson, Aguero, Gonzalez & Geeves, 2003).

2.9 Methods of OOBWE

2.9.1 Sequential Ballast Exchange

The sequential ballast exchange also known as empty/refill method requires pumping out of water out of tanks taken in ports, estuaries, or territorial waters until the tank is empty, then refilling it with open oceanwater (MEPC, 2003). 100 percent of the BW must be emptied from the tank before refilling the tanks to complete an empty/refill exchange. Even though the whole volume of water is replaced with open ocean water, Vinograd & Sytsma (2002) believe that despite flushing of BTs with open ocean water, pockets of unexchanged water and associated organisms may remain. Remaining layers of sediments may serve as hideouts through which organisms can escape being flushed during the BWE.

The effectiveness, merits and demerits of this possible mitigation measure is presented below:

Table 2.1: Efficacy of sequential BWE

Effectiveness	Original estimates of exchange efficiencies resulting from the empty/refill approach was as high as 99%. However, field tests and investigations have revealed different efficiency values.
Advantages	Sequential BWE is the most cost-effective method of BWE and can safely be accomplished
Disadvantages	BWE methods can put the safety of crew and the vessel at risk baring its effectiveness at removing nearshore organisms from BTs.

Source: Author

2.9.2 Flow-Through Ballast Exchange

The method employs the pumping of open ocean water to the bottom of the tank to flush out BW and ensure a continuous overflow from the top until sufficient water is exchanged. The aim of the process is to reduce the number of organisms left in the tanks (MEPC, 2003).

In the flow-through method of exchange, open ocean water is pumped to full tank or hold from below while the existing coastal water is forced out an opening at the top. The capacity of water needed for a complete flow-through exchange is 3 times the volume of the BT with capacity of

(300%). Correctly completed flow-through BWE can replace up to 99% of initial coastal waters with ocean waters and can remove over 90% of the coastal zooplankton trapped within the BT, depending on ship type and BT design (Ruiz et al, 2005). Minton et al, (2005) further assert that tank configurations, such as the double bottom and peak tanks, could be difficult to flush through effectively and may need pipe work to enhance mixing. Care must be taken during the process because, a number of things can happen including enlargement of pumps owing to increased resistance and workload, fixing new pumping and piping systems, over-pressurization leading to structural damage and icing on deck especially low temperature conditions. The efficacy of this possible mitigation measure is presented below in table 2.2

Table 2.2: Efficacy of Flow-through BWE

Effectiveness	The efficiency of replacement of original water will depend on design of the ship's BTs, safety requirements of the ship, sea conditions, quantity of water pumped and the design of the pumping system. The effectiveness is limited to some classes of organism.
Advantages	The continuous flow-through system, in contrast to BWE at high seas at bad weather does not impose excessive bending moments or shearing forces and minimizes stability problems.
Disadvantages	This flushing method would turn over the complete BW, but requires specially designed piping system and time to undertake the entire process.

Source: Author, 2017

Figure 2.3: Ship undergoing OOBWE

Source: Globallast, (2002)

2.9.3 The Challenges with OOBWE

Although open-ocean BWE is currently the most widely available method to mitigate spread of invasive species through BW, it is stopgap measure. In some circumstances, ships may be unable to undergo exchange at sea due to severe weather or stability issues. Furthermore, the technology is not 100% effective at getting rid of all coastal organisms from BTs (Ruiz et al, 2005). According to Ruiz and Carlton (2003) as cited by Ruiz et al (2005), percentage reduction of zooplankton by BWE depends on initial planktonic densities inside the tanks. A number of factors will determine the density of zooplanktons and they include place and season of ballast uptake, biota population dynamics, the length of voyage, the environment, exchange efficiency, and the ship and tank design.

The greater the starting density of zooplankton in ballast and the shorter the voyage, the more likely some survivors remaining inside the tank. Additionally, there is accumulation of benthic biota in tank sediments, and they may not be necessarily removed during exchange. Some marine organisms can form hardy resting stages that can withstand extreme temperature changes in tanks, and can still exist in small water volumes even after BTs are fully pumped out. At best, the least risky water discharged into port areas is one that are organisms are eliminated.

There are however several safety issues to consider when using the open-ocean exchange method and the obvious is the potential loss of adequate stability or excessive listing of ship due to poor ship planning and implementation of BW transfer or discharge (Countryman & McDaniel, 2006). Along with increased workload on piping and pumping systems and ships' crew, there are risks imposed in respect of longitudinal strength, dynamic loads, excessive trim, bottom slamming, propeller emergence, and poor bridge visibility. Karaminas (2000) also identifies additional risks that are associated with the flow-through method, the replacement of the ballast by allowing tanks to overflow to replace the tank volumes enough times.

The BW Convention makes provision for possibility of poor weather and sea states, and it would be expected that the discreet mariner would factor in these conditions when determining when to undertake the operation. The effective implementation of such process may be jeopardized by the ship design or configuration. Care is required where icing is encountered so that vents would not get blocked and to address stability concerns due to possible accumulations of ice on deck and over pressurization leading to structural damage.

2.10 OTHER MANAGEMENT METHODS

In order to limit, eliminate or cause to be harmless the effects of BW and its sediments in marine environments, several technologies are available. These technologies and their extent of use are defined in the BW performance standard. Treatment processes could be mechanical, physical, chemical, or electrical as discussed below.

2.10.1 Shipboard BWT Systems

These are water treatment systems that are integrated into a vessel's BW system designed to aid in the treatment of BW to reduce invasive species that may, during the discharge activities be released together with BW into marine environment.

Shipboard systems are considered more appropriate due their flexibility to manage BW simultaneously as normal ship operations. The system is even more important in the case of vessels that undertake cargo discharge operations in offshore lightering zones (EPA SAB 2011).

2.10.2 Solid-Liquid Separation

This main approach here is a separation technique where large particles and microorganisms (>40-50 μm) are separated from BW using mechanical systems such as filtration, hydrocyclone and flocculation (Bureau Veritas, 2011).

2.10.3 Filtration System

During uptake, this is the common method that is employed to treat BW (Tsolaki & Diamadopoulos, 2010). A filtration method is often carried out during ballasting where discs or screen filters and automatic filter systems with sizes ranging from 20 - 40 μm are used to effectively block particles and organisms. The filter technology operates through a back-washing cycle by removing organisms and particles which are captured by the filters to be discharged adequately at port (CSL 2013). In general, since the filtration system involves specialized equipment for removing smaller particles and sediment from BW, it is expensive to acquire and install on ships (Corrina et al. 2002). Another major set-back of this system is that the filters used prone to clogging and needs replacement with new filters and back flushing frequently (Germanischer Lloyd, 2010).

2.10.4 Hydro Cyclone

Hydrocyclone is another option that is used to separate larger solid particles from the BW through centrifugal forces and gravity (Hofer et.al 2012). When ballast is forced into tank with high velocity of centrifugal rotational motion, the velocity of the particles contained in the water is increased to allow the particles to be separated from the water. As indicated by Taylor & Rigby, (2001) and Balaji &Yaakob (2011), the hydroclone separation technique is seen to be cost-effective compared to the filtration method. A rather big challenge to the hydrocyclone system is that aquatic organisms with small sizes are difficult to separate since they have almost the same density with the seawater (CSL 2013).

2.10.5 Flocculation System

This technique involves the use of electro-mechanical separation to help enhance the efficiency of the treatment system (Bureau Veritas 2011). During treatment process, coagulants are supplied to the existing particles in the water to generate more particles that are of large density which ensures effective removal of flocculated particles by applying filtration separation technique. The effectiveness of electro-mechanical separation method depends on time residence (Bureau Veritas 2011). The flocculation system is known for high efficiency in removing large particles during treatment of large flows of ballast. A limitation to this method is the volume of coagulant that must be applied during a said process as the volume of coagulant determines the amount of time expended to remove the desired pollutants.

2.10.6 Disinfection

This treatment process is used to remove smaller organisms existing in the BW (Bax *et al*, 2003). It consists of two main kinds of treatment processes involving physical and chemical disinfection. The technique is where physical treatment technology requires use of non-chemical method to eliminate organisms existing in BW. Technologies used in this process consist of ultraviolet irradiation, cavitation, and de-oxygenation methods (CSL 2013).

2.10.7 Ultra-Violet Irradiation (UV)

The U.V method operate by generating protons in the form of active substance to breakdown cell walls of organisms present in water (ABS, 2014; Bureau Veritas 2011). This technique functions by surrounding a quart sleeve with combined lamps to generate UV light at various wavelengths to kill micro-organisms such as viruses and cysts (Lloyds' Register 2010). Studies has shown that the ultraviolet irradiation technique may not be effective if suspended matter is present in BW, therefore it is necessary to filter off the water before treatment (Germanischer Lloyd, 2010). UV treatment systems may also efficiently perform better during treatment of BW if combined with mechanical separation methods, but the limitation with this combination is that more space and financial cost will be incurred (EPA-SAB 2011). Figure 2.4 below illustrates a model UV system.

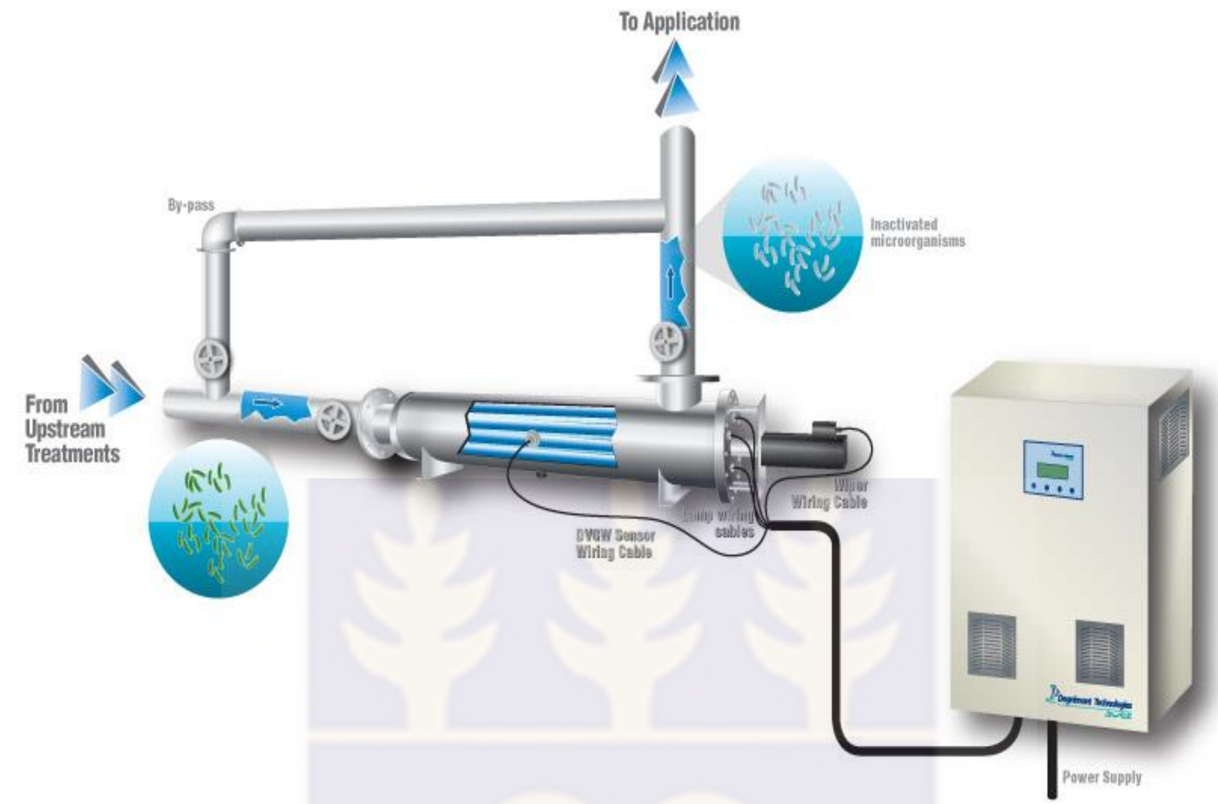

Figure 2.4: UV System (Image Credits: degremont-technologies.com, 2016)

2.10.8 Cavitation System

The technology employed destroys the cell walls of organisms in ballast through the use of venturi pipes by generating bubbles. The system is considered a physical treatment method (Bureau Veritas 2011). The ICS (2011), indicate that cavitation system sometimes displays inconsistent result during treatment process as the venturi pipe create bubbles for the breakdown of cell walls of organisms, high energy is produced in the process, however a challenge about creating a control mechanism for the energy generated is experienced.

2.10.9 De-Oxygenation Technology

De-oxygenation technology is deployed to remove oxygen that is present in the BW, and with subsequent substitution with inert gas such as nitrogen to produce a condition not favourable for existing aquatic organisms (Lloyds' Register, 2010; Bureau Veritas 2011). A weakness of this technological process is that it requires much time between one to four days to effectively get BW treated from organisms (Balaji *et. al* 2011).

2.10.10 Chemical Disinfection

Chemical disinfection technique involves the use of chemical disinfectants such as oxidizing and non-oxidizing biocides (bromine, chlorine, and ozone) to attack and kill the cell membranes of different organisms existing in ballast (Tsolaki & Diamadopoulos, 2010). While ozonation process generates hydrogen and chlorine gas when ozone is added to BW, decomposition of chlorine gas in the presence of chlorine ions leads to oxidization of existing organisms (Bureau Veritas 2011). Depending on the temperature, PH level and the kind of organism, different types of disinfectant like chlorine, bromine and ozone can treat BW. However, studies show that the use of these disinfectants to treat water has several associated weaknesses. For instance, the ozone treatment process can lead to corrosion of vessel equipment (Balaji *et. al* 2011). The oxidizing qualities of ozone makes it hazardous to the eyes and the respiratory system due to its primary irritant nature even at low concentration. Moreover, if treated BW is pumped out into fresh water, the ozone remains active for up to 30 minutes, thus having potential of harming sea life (Michael Lloyd, 2012).

2.10.11. Combination of Treatment Technological Process

A combination of different shipboard treatment technologies (i.e. physical, mechanical, and chemical) can be applied to achieve more effective results (CSL 2013). Depending on the kind of system, each treatment technology varies in terms of advantages and drawbacks. Studies suggest the mechanical and physical method is mostly combined during uptake and discharge to eliminate both macro and micro-organisms. For instance, Albert et. al. (2010) suggest the filtration system and UV irradiation could be combined to treat BW. Deployment of these approaches can be done during both ballasting (uptake) and deballasting (discharge). During uptake of BW, back-flushed solids or sediment is retained in the filter, and in the discharge process UV irradiation is applied to kill organisms that may exist. Electro-chlorination and ozonation can as well be paired together to complement each other. For example, electro- chlorination may not be appropriate for treating sea and fresh water because it has the potential of generating explosive gases e.g. (H2) and radioactive substances, hence ozonation can get rid of this problem by employing sodium bisulfite (Na2HSO3) to regulate the value of Total Residual Oxidants (TRO) that may exist in ballast (MICA (P) 039/02/2012).

2.10.12 Heat Treatment

The use of heat to treat indigenous organisms that exist in ballast is known to have been potentially cost effective. Subsequent to this, there are several proposals that have been made on potential shipboard ballast treatment options (Gregg, Rigby & Hallegraeff,2009). In treating ballast, one proposal is the use of waste heat from the ships engine cooling system and exhaust, which significantly reduces costs (Perkovic and David, 2001). Disadvantage with this system is accelerated corrosion of Ballast Tank internal surfaces of pipes.

2.10.13 Electrocution

Electrocution is considered as a potential technique to treat ballast during ballasting and de-ballasting and was first proposed by Montani et al. (1995). The de-activation of bacteria by generating pulsed electric fields has been demonstrated by Blatchley and Isaac (1992) and Aronsson et al. (2001).

2.10.14 Mechanical Damage

Through mechanical abrasion, high velocity pumping during ballasting can have the effects of lethal damages to some organisms in the oceans (Gregg et al. 2009). Taylor et al. (2002) believe that the installation of these systems is difficult and the cost for installing additional infrastructure to create high velocity jets of water in BTs or pipelines would be prohibitively expensive.

2.10.15 Magnetic Treatment

Magnetic treatment has been used to eliminate the growth of bacteria in diesel fuel over the years.

In this process, magnetic field is pulsed along fuel lines generating very low frequency and de-ionizing electromagnetic radiation. The system uses a technology in which a mixture of magnetic powder and coagulants is added to BW. The mixture produces a magnetic floc that contains marine organisms and magnetic discs are applied in order to separate the magnetic flocs from the water (Gregg et al. 2009).

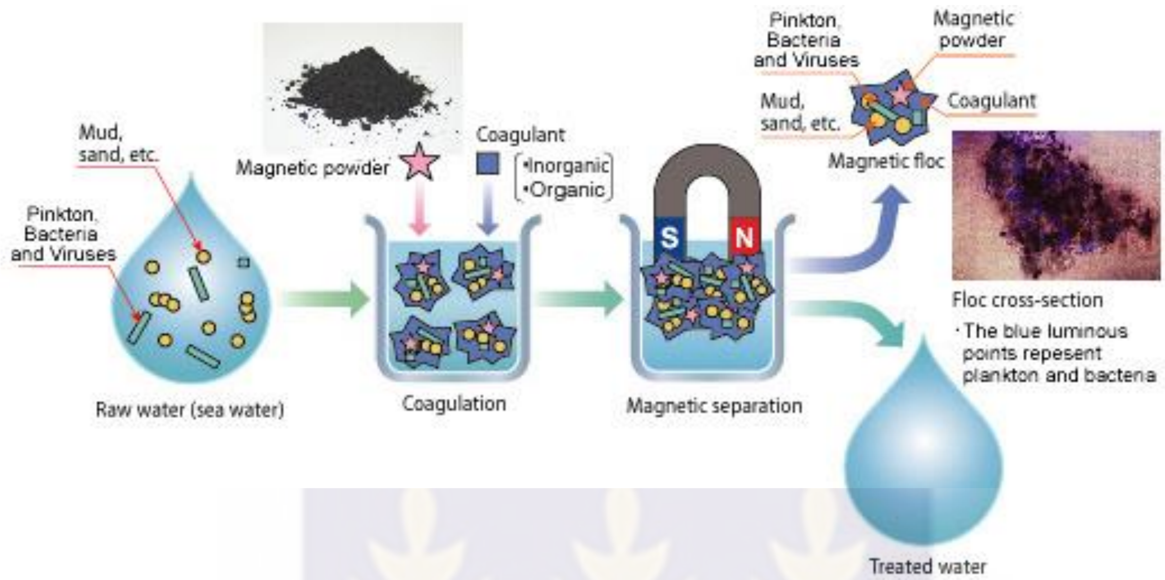

Figure 2.5: Magnetic BWT System

(Image credits: hitachi-pt.com)

2.10.16 Reception Facilities

BW reception facility in ports would be an excellent solution for small ports or harbours with limited amount of short sea traffic. A closed and well controlled system of water recycling assures a safe water quality. The advantage will be absence of accumulation of sediment in the bottom of the BW tanks in such a closed cycle (Marcel, Cato, Etienne, Rivière, Frank, Jan, Peter, Isabel, Cees, 2010). A small land-based treatment unit in the harbour would be enough to clean ballast and to guarantee water quality and free of organism. In areas with sufficient drinking water also standard tap-water could supplement the pool of BW. This water is already free from organisms and sediment. As chemical water qualities are nearly as strict as those for drinking, this water source should at least be acceptable. Moreover, reception facilities require a completely new logistic service in ports *(ibid)*.

2.10.17 Onshore BWT Facility

The treatment of ballast on land demands a complex facility to ensure a thorough cleaning. When the ship berths, ducts are laid up with the tanks to remove BW, store the water in tanks and ensure that treatment happens. On-land stations were originally proposed by AQIS (1993).

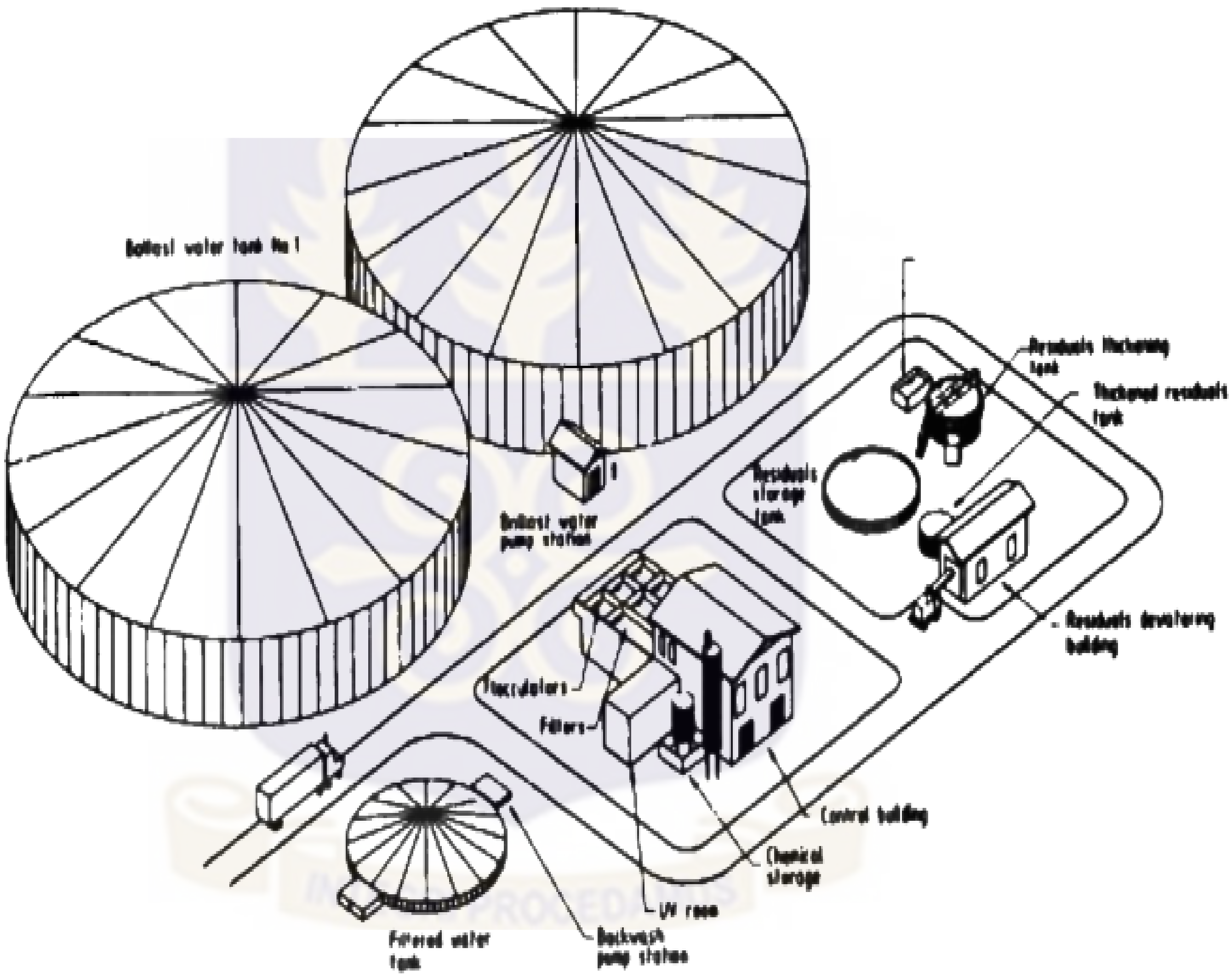

Figure 2.6: Lay-out of hypothetical on-land treatment facility

Source: (AQIS 1993)

In Brown and Caldwell (2006) & Greenman et al. (1997) submission, the US' government commissioned feasibility studies on land treatment for ports of Baltimore and Milwaukee and the terminal for cruise ships in San Francisco (Bluewater network 2005).

Figure 2.7 On-land treatment station for BW

Source: OASIS Environmental Inc, 2004

NRC (1996) mentions that the main advantages of onshore treatment are that operation, maintenance and monitoring of the facilities could be done by ports authority routinely to ascertain the extent of treatment and effectiveness. There is a better control of treatment in onshore operations in comparison to potentially difficult operating conditions on board the ship. Management of wastes coming from the treatment process is relatively better due to the presence of environmentally accepted standards and the presence of appropriate authorities. Furthermore, onshore treatment plants can merge the treatment alternatives to ensure better efficiency in the process, and may be done on board ship.

Cohen (1998) cited the following advantages of this system. It says that sewage disinfection station near the port or of the municipality can easily be treated with the ballast. Methods like filtration can be integrated into on-land stations to remove many tough life stages (cysts and spores), in addition to organisms and inorganic sediments and can combine methods as biocides, UV that are cheaper and efficient; Higher safety for the crew, since there is no contact with toxic components of treatments on board, lower corrosion problems and structural stress resulting from temperature variations in some methods. Additional room in the vessel (especially in the engine room) is not required, the ship energy consumption is not increased, and there are no new facilities or modifications of original design. The method can provide an economy of scale in the design, building and the operation of onshore stations in contrast with number of devices required on ships to handle BW of the same amount. Gollasch, et al (2007) mentioned that the treatment of ballast onshore in tankers is an example of the possibility of developing a standardized system in ports. Pumping systems in all petroleum terminals are standardized, so that any ship can load and unload. Thus, the same concept of standardized oil pipelines can apply in the development BW systems and these stations on-land can supply treated water, for ports and vessels that require to carry clean water.

However, the main disadvantages of treatment facilities on land, is the high demand of pipe connection between the treatment plants and all the berths, and each ship would have to change its own BW pumping system, especially where hoses cannot be connected to BTs (AQIS 1993). The largest ports would need multiple units to receive BW and thus, delay in shipping may occur when the capacity of a ships' BT exceeds the capacity of treatment plant (including storage tanks). The cost of land acquisition for implementation of storage systems is another limiting factor. Moreover, where vessels discharge untreated BW to reduce its draft while entering an access channel may contribute to bio invasion.

Despite these drawbacks, the treatment on land remains a feasible alternative compared to a variety of options available for treating BW, if the criteria for safety, environmental acceptability, and technical feasibility, practical and profitable operations are considered.

2.10.18 Barge Based Reception and Treatment Systems

This type of treatment system is located either on the barge with or without propulsion or barge accept ballast from vessels and transfer to land-based facility. The study by Brown and Coldwell (2007), using cost and access to determine various technological options for convenient port-based BWT system identified that, the best ones uses barge with plant installed onboard. King and Hagan (2013), also investigated economic and logistical viability of shore-based BWT at the port of Baltimore (USA). The authors assumed that potential users of this facility would be ships without a USCG approved on-board BWT system and concluded that economic viability of shore-based systems significantly depends on circumstances prevailing in a particular port varying from very positive to very negative outcomes.

The advantages of barge-based systems are the flexibility of operation at different locations even at anchorage. It is also flexible to integrate with systems that are not readily viable on the land (e.g. insufficient power supply on land or limited space on land), possibility of use without land-based pipelines, employment of qualified personnel to operate the barge and the BWT system.

The main disadvantage of the barge system comes from the number of ships and the frequency of ship ballast discharges per terminal which may be below economically viable thresholds.

Additional costs are also needed to fuel barges and ensure proper maintenance. There can be less optimal operations if low capacity systems are installed and delays may be encountered by high ballast dependent ships with high capacity systems. Delays may also result from concurrent requests from ships or in the case where there is barge failure.

Figure 2.8: Barge-bsed ballast treatment system

Source: Damen Shipyards Group, 2016

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the various methodology or techniques used by the researcher in collecting, collating and analyzing the necessary data for the study. It describes sample size and sampling procedures, research instruments and procedure for collecting data. Kumekpor, (1999), defines methodology as the processes, methods, techniques used to discover what we want to know. The data for this research work was collected from two sources; primary and literature review. Primary data collection is done through unstructured interviews and secondary data comprise of journals, internet, and articles.

3.2 RESEARCH DESIGN

Burns and Grove (2003) defined research design as the *blueprint* for undertaking a study in which there is a control mechanism to result into valid findings. Many researches also explained that it as a master plan that lays out all the necessary means by which data is to be collected and analysed This research adopts qualitative approach which according to Baker & Edwards (nd) is a method that seeks a subjective consideration of a phenomenon amongst a given population. They further explained that a qualitative approach is usually aimed at identifying similarities between the sampled populations' experiences, perceptions, interactions, etc and to draw conclusions based on the commonalities for the larger whole.

3.3 AREA OF THE STUDY

The study was performed at Tema port, one of the two main seaports in Ghana. The port handles the greater part of vessels calling to Ghana, which are relatively about 85% and approximately 1000 ships call at the port annually Tema port was chosen because of vessel traffic flow through it throughout the year.

3.4 TARGET POPULATION

Sam (2011) discussed that target population is a well-defined collection of individuals or objects known to have similar characteristics and often referred to as the number of persons or objects covered by the study or with which the study is concerned.

The target population for the study was ship Masters, Chief Pilots at the Port of Tema, Senior Staff of the Environmental Protection Agency (EPA), and Port State Control officers of Ghana Maritime Authority (GMA).

3.4.1 SAMPLE SIZE

A sample size of 4 industry players including ships master, Chief Pilot, Senior officer of EPA, and GMA representative (Port State Control officer) of Tema port were selected from the population. The sample of 4 is to ensure a fair representation of respondents to enable the researcher to obtain accurate information or data for analysis. Baker & Edwards (nd) stated that qualitative researchers usually study fewer people, but delve more deeply into those individuals, settings, subcultures, and scenes to generate a better standpoint about the subject under review. The sample size is restricted to the above due to limited time for the completion of research. Baker & Edwards (nd) indicated that in selecting a sample size, variety of factors will influence amount of data researchers gather and this includes the presence of participant observation, where applicable. And when researchers are faced with time constraints, a fewer sample is selected.

3.4.2 SAMPLING TECHNIQUE

The purposive technique was adopted to select the respondents from the target group. Purposive sampling is synonymous with qualitative research. Purposive sampling is non-probability sampling technique which is sometimes referred to as selective sampling. This technique relies on the judgement of the researcher during the selection of research units to be studied.

The interviewees selected for this study were based on their experiences regarding BWM practices. Respondents were purposively chosen upon the recommendations of mainly the organizational heads or top management who are believed to be in the best position to recommend a more knowledgeable person. According to Karmel & Jane (1987), the use of this purposive method of sampling is more appropriate for social studies than the random sampling which is highly prone to selecting a respondent who may not be adequately experienced in the field of the research. Purposive sampling can therefore be more realistic than randomization in relation to time, effort and cost needed in finding informants.

The participants were purposively selected due to the qualities the participant possessed since the researcher decides what needs to beknown and sets out to find people who can and are willing to provide the information by virtue of knowledge and experience. The researcher identified and selected individuals that are proficient and well-informed with ship operation, environmental and ballast management. In addition to knowledge and experience, emphasis was placed on availability and willingness to participate, and the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner. The idea behind use of purposive sampling is to concentrate on senior management of relevant institutions who will better be able to assist with the research.

3.5 SOURCES OF DATA

Data was gathered mainly through literature reviews such as researches conducted by certain renowned researchers from the internet, books from the libraries, articles, and brochures. The other data was obtained from interviews, conducted with individuals in the target population, which include selected stakeholders of the shipping industry

3.5.1 METHOD OF DATA COLLECTION

The research data collection technique adopted was one on one interview by the researcher using interview guide to sort the views of the target group made of ships masters, Chief Pilot, Senior officer of EPA, and GMA representative (port state control officer). Information gathered from the respondents included their background, and knowledge on ship operations.

3.5.1.1 Interview Technique

The researcher conducted personal interview with participants using interview guides as illustrated in appendix I. Cooper & Schindler (2003) described interview guide as a set of questions covering relevant topics under research that is used by the researcher to guide the scope and direction of a personal interview.

The use of grand and mini tour questions was also employed on the field to elicit information from participants. Grand tour questions were broad questions asked to introduce the topic such as "What is your opinion of BW?"

The interview techniques of probing (verbal) were used. These included probing or "exploring", silence, prompting and summarizing. The researcher used phrases such as "Could you elaborate more on that point?" maintained eye contact to encourage participants continue speaking. The researcher summarized the last statements of the participants and encouraged more talk.

There was flexibility and consistency throughout the interviews. The researcher asked if there are more comments. This helped in closure of the interview. The researcher summarized the interview proceedings by restating in his own words the ideas and opinions of the participants, to ensure understanding. The participants were told of the need for follow-up interviews should there be any aspects that were not clear.

3.5.1.2 Background of Interviewees.

The interviewees were aged between 35 and 60 years with varied years of experience in ship operation and environmental management ranging from 10 to 25 years. The participants are senior management of the selected institutions.

3.5.2 Data Process and Analysis

This is where data collected on the field involving personal interviews is concerted into information so that it can serve as the real and factual basis for adducing conclusions, recommendations and advising policy directions.

The analysis of data in this research was mainly based on the grounded analysis approach. According to Gray (2004) as cited by Radwan, Jones & Minoli (2008), there are two main approaches to analysing qualitative data, namely context and grounded approaches. The context approach is linked to a deductive approach in which the researcher identifies specific categories and criteria of selection before beginning the analysis process whilst using the grounded theory, no criteria are prepared in advance of the analysis processes and is also called the inductive approach. In regards to this study, using the grounded theory, the researcher used the constant comparative system which comes from the grounded theory.

The analysis of data began with the coding or identification of persistent phrases, words, themes and concepts within the data as obtained from the interviews into various categories relating to the research questions they address. The various categories of the data was finally integrated according to their relations.

Since the study is qualitative in nature, the simple deductive analyses were followed immediately by description in words.

3.6 DATA COLLECTION AND FIELD CHALLENGES

As much as possible, some measures were put in place to minimise the adverse effects of some of the challenges faced by the researcher. However, some of the following challenges were beyond the solution of the researcher.

It was realised that some of the respondents were very reluctant to give out in-depth information as they probably doubted the true purpose of the interview for whatever reasons.

It also became very challenging to obtain some other information which the researcher felt could enrich this research. For instance, there was no literature available on the subject of research that directly relates to Ghana to give evident-based linkage to the Port of Tema in the initial chapters. No interviewee provided any additional information during the personal interviews.

In spite of all the field challenges encountered, the purpose of this research was adequately achieved.

3.7 ETHICAL CONSIDERATIONS

Ethics are moral principles which ought to be considered to be good enough in every community of people. According to Abdallah (2014), they are standards used to measure how right or wrong an action or behavior is, especially of researchers. In this research, ethical issues were carefully prioritized in way that did not exposure confidentiality of the researcher - data integrity was the hallmark of this research. Hence, the researcher considered the following ethical issues in data collection. As indicated in the introduction of the interview guide, the research sought the voluntary participation of all the interviewees before proceeding with the interview. Besides, confidentiality was not only assured to the interviewees but a strict effort was made to keep the identity of same away from the content of this research.

CHAPTER FOUR

DISCUSSION OF FINDINGS

4.1 INTRODUCTION

This chapter illustrated the findings from data collected from both secondary and primary sources. The purpose for the analysis is to identify the innovative way of BWM that will help reduce introduction of aquatic invasive organisms into the marine environment. Much emphasis is laid on the open ocean exchange currently practiced worldwide by ships.

4.2 BACKGROUND INFORMATION OF RESPONDENTS

Interview questions were posed to specific respondents with wide experience in ship operation, port operations and officers in charge of environmental issues in ports community. Respondents were purposively selected from the Ghana Ports and Harbours Authority (GPHA), GMA, Ships Masters, and EPA. The general knowledge of respondents was assessed on ship operation and BWM regulation.

4.3 BWM IN GHANA

According to Port State Control Officer of GMA, Ghana as a state uses the open ocean exchange as a method of managing BW for vessels calling our ports for loading and discharging of cargo. The Chief Pilot at the GPHA confirmed that bulk carriers such as tanker vessels are required to undertake open-ocean BWE before arriving for loading. A ship Captain indicated that as part of IMO rules on BWM, many ports do not allow vessels to ballast and de-ballast in port. Thus, the exchange carried out on the high seas where BW taken from a departure port is pumped out into the sea and replaced by the mid ocean water before entering ports of Ghana. The researcher wanted to know the respondent's knowledge on the practice of the open ocean BWE. All the respondents displayed knowledge and awareness of the practice. They indicated that open ocean BWE usually takes place in the open sea some miles away from the coast where organisms may not survive the conditions in those waters and may end up dying. The flow through method, is used mostly by ships calling at Ghana ports. In this process, the water is completely flushed out by pumping in ocean water to the bottom of the tank. This causes continuous overflow of the BT until greater portion of water has been changed and thereby leading to the reduction of the number of organisms left in the BT. The EPA indicated that using the Jubilee offshore terminal as an example where vessels arriving for loading from the terminal are required to exchange with clean BW prior arrival, and should be prepared to "load-on-top" of slops if so required in line with the standards set by the International Conventions. Vessels arriving with unsuitable ballast for dumping into the sea will be denied the right to load and those discharging contaminated ballast overboard shall be subject to anti-pollution laws of Ghana.

4.4 EFFECTIVENESS OF OOBWE PRACTICE IN GHANA

This practice according to GMA's respondent has been effective to some extent as majority of active organisms are removed during exchange process. This can be seen in literature by USCG, (2003) and International Association for Great Lakes Research, (2002) which states that open ocean is most broadly applicable method for mitigating risks of Invasive organisms' introduction. He indicated that the method does not guarantee 100 per cent effectiveness due to its inability to completely remove the aquatic organisms likely to remain in sediment on tank bottom. This is confirmed in the literature review by Ruiz et al, (2005) where they said open ocean BWE is not 100% effective at removing all coastal organisms in BTs. This still pose danger to marine environment when discharged within port environment. There are issues of safety of crew and vessel which is of primary concern to Maritime Administration as ships stability might be compromised during the exchange putting crew in danger.

The chief Pilot at the GPHA is of the view that it is sometimes difficult to determine effectiveness of this system most especially when the institutions like GPHA, EPA lack required testing equipment or systems to check whether vessels do the exchange before arrival. Moreover, it is not guaranteed as to whether there exist some organisms on the tank bottom which could affect our environment. Cordell et al. (2009) explanation support the above that BWE does not offer ideal solution as it only reduces, but does not mitigate risks of transfer of living organisms.

Regarding BW content prior to discharge, the chief Pilot at GPHA says due to unavailability of required resources such as testing equipment, contents are not checked before discharge. GMA also does not conduct any form of checks or inspection on ballast content before discharge because of lack of logistics and needed equipment for testing. Meanwhile, the chief pilot at GPHA further states that vessels are prohibited from discharging any oily water or substances suspected to have been mixed with engine room oil into the waters within the port.

4.5 THE CHALLENGES OF OPEN OCEAN BWE

The Chief Pilot asserts that although BWE is the most available method to eradicate introduction and spread of invasive species, it is not the ultimate solution because there are circumstances, where ships are cannot conduct exchange at sea due to severe weather conditions and stability issues. He thinks that even after exchange at the deep seas it is likely there will be some survivors of organisms remaining inside the tank which can affect the coastal environment. This is also stated in the literature review by Ruiz et al, (2005) that although open ocean BWE is currently the most widely available method to mitigate spread of invasive organisms in BW, it is stopgap measure as in some cases, ships may not be able to undertake exchange at sea due to severe weather or stability issues. Verling et al, (2005) noted that the benthic biota can accumulate in tank sediments, which are not removed during ballast exchange where some organisms can form hardy resting stages that can resist extreme changes in condition of BTs, and can survive in small volume of water that might be left after BT is fully pumped out which is likely to be discharged into ports.

A ship captain cited on some safety concerns as far ships officers are concerned, that the obvious danger is the potential lack of adequate stability or excessive list, longitudinal strength, dynamic loads, excessive trim, bottom slamming, propeller emergence, and poor bridge visibility. As identified by Countryman & McDaniel, (2006), the dangers of open ocean exchange of BW are potential lack of adequate stability or excessive list by poor planning and execution of BW transfer or discharge.

4.6 REGULATIONS DEALING WITH BWM IN GHANA

The study revealed that though Ghana is signatory to the BWM convention, the legal frame work is yet to be formed and implemented to ensure enforcement. The interviews conducted at the port, revealed that there was no clear existing environmental regulation that deals with ballast at the port. The marine pollution bill yet to be passed by parliament, will be an act which shall give mandate to GMA to promulgate laws that will deal with the treatment and control of ballast carried by vessels calling Ghana's ports. This bill if passed into law shall provide specific requirements needed by vessels regarding the treatment and managing ballast before entering any port in Ghana. The officer responsible for marine environment at EPA, indicated that Ghana has a number of national environmental plans formulated to address the areas of coastal management which includes the coastal zone management indicative plan (1990), the national environmental action plan (1994), the integrated tourism development plan (1996-2010), the draft integrated coastal zone plan (1998) and the national oil spill contingency plan (2002, revised draft 2009) but no specific regulation on BWM.

4.7 OTHER BWM OPTIONS

GPHA indicated the following as better management options. Onboard treatment for all vessels calling our ports. With this system, ballast is treated on board ship before discharge in which case we are sure that it is free of harmful organisms. Similarly, ship captain proposes that the on-board treatment plant will be more appropriate and efficient as it allows flexibility for managing ballast while on normal operations discharge can as well take place while vessel is underway. Onboard treatment plant as indicated by EPA SAB (2011), is important for vessels that need to discharge at offshore lightering zones during cargo transfer.

It is possible that some vessels may not allow for installation of such equipment because of their designs, so in that case, the point is considering the feasibility of providing for reception facility in port for discharge of ballast and sediment for shore treatment. GMA believes that establishing port reception facility to receive ballast from vessels will help check aquatic organisms introduced into the coastal waters. Marcel et al, (2010) reiterates this point stating that BW reception facilities will reduce accumulation of sediment in BTs in such a closed cycle which would guarantee water quality free from organisms.

The other alternative is having floating barge to receive ballast from vessels within the anchorage area which may not enter the main port for operation. To support this point, King and Hagan, (2013) stated advantages of barge-based systems that include the ability to use on different locations, like anchorage, possibility of using systems that are not viable on land example, insufficient power supply on land or limited space on land, possibility of use without land-based pipelines, engagement of qualified crew members to operate the barge and the Treatment (BWT) system. EPA as an institution responsible for the environmental issues share with the idea of using floating barge to ensure proper treatment and disposal of ballast free of harmful organisms.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter summarizes the overall conclusions of the survey results and discussions based on research objectives. The chapter also makes recommendations on the most appropriate approach to managing ballast to reduce introduction of aquatic invasive species.

5.2 SUMMARY

The study reveals that Ghana as a state allow open ocean ballast exchange by ships calling Ghana's ports for loading and discharging of cargo. The bulk carriers such as tanker vessels are required to exchange ballast in open-ocean before arriving for loading.

The study further identifies that mid-ocean BWE is most broadly applicable method for reducing risks of Aquatic Invasive Species introductions though not 100 percent guaranteed at removing all coastal organisms from ballast and pose danger to aquatic life at coast when discharged within port environment.

It was highlighted in the findings that Ghana as a state has no specific regulation or legal framework that can deal with ballast management and give the relevant institutions the mandate to enforce such requirements on vessels.

Finally, the study identified that onboard treatment system, port reception or shore treatment facility and floating barges are best alternatives and the most appropriate ballast management options for the reduction or elimination of invasive species as these systems can effectively remove all organisms present in ballast before discharge.

5.3 CONCLUSION

The principles of managing BW are like the basic principles of quarantine science. The process should prevent introductions of non-indigenous species including bacteria, viruses, algae, protists, invertebrates, and fish. An important corollary is that no control methods practiced today totally avoid unintentional introduction of non-indigenous aquatic organisms through ships' ballast operations. Technologies to achieve this goal must be safe for ships and crew, demonstrate effectiveness of destroying potential invading organisms, environmentally acceptable, practicable in application, compatible with normal ship operations and cost effective. Currently there are available means of mitigating risks of non-indigenous organisms being introduced to new marine habitat. The control method currently in use for ships in international trade involves exchanging ballast loaded in port (or taken on board while transiting inshore waters) with ocean water loaded during passage between ports of call (USCG, 2001).

5.3.1 BWM in Ghana

The research establishes that most practiced methods in Ghana by ships, is the mid - ocean exchange as indicated by the respondents. The flow through method, is used mostly by ships calling Ghana ports where ballast is completely flushed out by pumping in mid-ocean water to the bottom of tank and continuously overflowing the tank from top until significant amount of water is exchanged to decrease number of organisms in tank. This is as per standards set by the International Conventions for the Management of BW (2004).

5.3.2 Effectiveness of OOBWE Practice in Ghana

BWE is not ideal solution because it only reduces, but not eliminate risks of transfer of living organisms. Apart from the fact that BWE is not 100 percent effective at removing all coastal organisms there are issues of safety of crew and vessel which is of primary concern to Maritime

Administration as ships stability might be compromised during the exchange putting crew in danger.

5.3.3 The Challenges of OOBWE

The challenge established from the research with open ocean ballast exchange stems from the fact that benthic biota can accumulate in tank sediments, which cannot be removed during ballast exchange and some species of marine organisms can form hardy resting stages that can resist extreme changes in BTs, condition and can survive in small volume of water that might be left after BT is fully pumped out and discharged into ports. There are safety concerns with ships including potential lack of adequate stability or excessive list, longitudinal strength, dynamic loads, excessive trim, bottom slamming, propeller emergence, and poor bridge visibility which may be caused by poor planning for ballast transfer or discharge.

5.3.4 Regulations Dealing with BWM in Ghana

The study revealed that though Ghana is signatory to the BWM convention, the legal frame work is yet to be formed and implemented to ensure enforcement. Though Ghana has a number of national regulations dealing with environmental issues, no clear existing environmental regulation deals with BW in Ghana. The marine pollution bill yet to be passed in parliament, will be an act which shall give mandate to GMA and other relevant institutions to promulgate laws that will deal with the treatment and management of ballast by vessels in Ghana's ports. This bill if passed into law shall provide specific requirements needed by vessels regarding treatment and management of ballast before entering any port in Ghana.

5.3.5 Alternative BWM Options

Firstly, the study identifies On-board Treatment facility for vessels as one of most appropriate ballast treatment option to ensure reduction or total removal of invasive aquatic organisms. With this system, ballast is treated on board ship before discharge in which case we can be sure that water is free of harmful organisms. The shipboard treatment systems allow flexibility for management of ballast during normal operations because the systems allow vessels to discharge ballast while underway and are also important for vessels that need to discharge at offshore lightering zones during cargo transfer. However, the possibility that some vessels may not be capable of installing such equipment is high because of their designs in which case, port reception and treatment facility at the shore will be an ideal management option. The other alternative is having floating barge to receive ballast from vessels within the anchorage area which may not enter the main port for its operation in the Ghanaian waters. The advantages of barge-based systems are the ability to use in different locations including anchorage, possibility of use of systems not viable on land (e.g. insufficient power supply on land or limited space on land), possibility of use without land-based pipelines; engagement of qualified personnel operating the barge and the BWT system.

5.4 RECOMMENDATIONS

The researcher recommends that GPHA, GMA, Ghana EPA including other relevant institutions form a joint force in establishing, inspecting and testing BW carried by ships to ensure strict compliance to the international standards and requirement set out in BWM convention 2004.

Efforts be made to enact required legal framework in Ghana which shall cover pollution issues from the intake to discharge of BW including management and treatment. This will help the port and relevant institutions address challenges that may arise from BWM. This legal framework shall provide specific requirements needed by vessels regarding treatment and management before entering any port in Ghana.

The port Authority and Ghana government should consider establishing reception and treatment facilities in port for treatment of BW from ships which may not have Ballast Water Treatment plant on board.

Floating barge facility is also ideal solution to ballast problems that should be considered by the port. This can be used in different locations, including anchorage, and possibility of using systems that are not viable on land.

Adequate resources should be provided to stakeholders with oversight responsibility to check visiting ships that they are complying with required national as well as international standards.

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APPENDIX I

INTERVIEW GUIDE FOR SHIP MASTERS, PORT OFFICIALS, GMA AND EPA

i. Could you describe in detail how you undertake BW exchange?

ii. What BWM method do you use when ballasting and de-ballasting?

iii. Do you engage in open ocean ballast exchange?

iv. What is your opinion about OOBWE?

v. What do you think is the effect of this BW exchange on ships?

vi. How effective is OOBWE in reducing coastal aquatic invasion?

vii. What are the challenges regarding OOBWE?

viii. What regulation deals with BWM in Ghana?

ix. In your view, what will be the appropriate BWM option (s) to eliminate BW problems?