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Abatement of bilge dumping: Another piece to achieve Maritime Decarbonization

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ABSTRACT

The release of bilge water into the oceans presents a high environmental risk and poses a serious threat to marine life, which are already affected negatively by climate change. Nowadays, technologies like satellite allows to real policing of the oceans. Adequate port reception facilities combined with comprehensive crew training and improved oil-water separation technologies can facilitate the recovery of bilge water and its use in on-shore waste-to-energy power plants to generate electricity and heating. This paper presents several proposals to effectively reduce oily water discharges at sea categorized under three drivers: technological, behavioral, and managerial measures. Ensuring the proper maintenance of the equipment, promoting awareness of the legal and environmental consequences of bilge dumping, and providing suitable facilities for the disposal of the water-oil mixture in ports are essential. The reduction of bilge dumping in the ocean provides a three-fold benefit to society: first, it enhances marine conservation by improving the health of the oceans and preserving their biodiversity. Secondly, by transforming waste into an energy source, it contributes to the recovery of useful energy, which benefits humankind. Finally, it reduces the pressure on ships' crews to avoid accidental discharges while operating bilge treatment machinery.

SPECIFICATIONS TABLE

Subject area	2212 – Ocean Engineering
Category/categories of societal impact	Environmental Societal Technological
Sustainable Development Goals (SDGS) the **research contributes to**	*GOAL 7: Affordable and Clean Energy* *GOAL 13: Climate Action* *GOAL 14: Life Below Water*
Resource availability [optional]	
Related research article OR Related supporting **information** **Please provide a link to the webpage if relevant**	*None available* *This is a type 1 article: papers which provide* *information on how authors are planning to* *generate societal impacts, focusing on the* *methodology which will be applied*
Stage of research	*In Progress*

1. Social impact

The use of fossil fuels as the primary source of energy for maritime transportation contributes to human-induced climate change [1]. The air pollution derived from the maritime industry accounts for 2.89 % of total anthropogenic CO_2 emissions [2]. In terms of decarbonization, the application of measures to monitor and reduce air pollution are crucial to achieve a net zero maritime transport. However, energy losses and pollution derived from the shipping industry are also impacted by other factors, often overlooked, like bilge dumping. Developing abatement techniques for all these issues is crucial because projections on global trade forecast an increase in the demand for maritime transport in the mid-term future. Energy wise, illegal bilge dumping also presents consequences: It is estimated that ships could be dumping 1.8 million barrels of oil per year into the ocean [3].

Illegal bilge dumping consists of the discharge of contaminated bilge water into the oceans. Bilge water can be defined as a mixture of engine room liquids like fuel and lubricant oil, cleaning solvents and metals which are collected at the bottom of the vessel and should be transferred into an appropriate treatment facility, approved by MARPOL

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Convention [4]. Onboard treatment of bilge water is possible with adequate oily water separator devices, and contaminated water must be treated to be less than 15 ppm before being released. But treatment can be costly and time consuming, which leads to wrong practices like bilge dumping, particularly after sunset to evade detection [5]. Carić estimated that a 3000-guest cruise vessel would produce between 3.3 and 10 liters of bilge water per person per day. This resulted in a total generation of 9900 to 30,000 liters per day that, which could cost between 2178 and 6600 euro per day of vessel operation at a treatment cost of 0.22 euro per liter [6]. According to the European Maritime Safety Agency (EMSA), illegal discharges of oil and other polluting substances still regularly occur in European waters. Zhang et al. stated in 2019 that operational discharges were the most relevant source of oil pollution in the oceans, accounting up to 45% of total [7]. Dong et al. detected a cumulative area of 1.51 * 10^6 km^2 in a study that analyzed satellite images from 2014 to 2019 [8]. The release of contaminated water into the oceans presents a high environmental risk and poses a serious threat to marine biodiversity [8–10].

This study is in line with the Sustainable Development Goals 7 (Affordable and clean energy), 13 (Climate action) and 14 (Life below water). With the appropriate measures, this quantity of oily water can be recovered and used in waste-to-energy power plants to produce electricity and heating. By doing this, several benefits to society could be achieved: first, ocean pollution will be diminished, which directly affects the marine ecosystem and biodiversity [11]. Avoiding the dumping of hydrocarbons into the sea aligns with SDG 14, target 14.1, which aims to reduce marine pollution by 2025. In addition, preventing bilge dumping will also contribute to target 14.3 as ocean acidification is linked to the marine biodiversity's ability to absorb carbon. Secondly, the conversion of waste products into commodities promotes circular economy and alleviates the use of new fossil fuels, extending its decline. This second benefit is in line with SDGs 7 and 13, in particular with targets 7.3, as the recovery of previously discarded residues is now transformed into a source of energy; 13.2, given that some proposed measures would need to be integrated into national policies; and 13.3, since part of the behavioral measures suggested aim to educate and raise awareness about the problem.

The rest of the paper is structured as follows: Section 2 presents the methodology, which outlines proposed measures to address the issue of bilge dumping. Section 3 reports the results of each proposal and highlights the benefits they offer to society.

2. Methodology

The abatement of illegal bilge dumping into the oceans presents a difficult challenge, as many times these activities occur in the high seas. According to the United Nations Convention on the Law of the Sea (UNCLOS), the high seas are open to all States, but no State may validly claim any part of the high seas to its sovereignty. This leaves the high seas without a task force to ensure IMO rules and regulations are met. Even if there was such enforcement, the area to cover is tremendously vast and vessel patrolling would not be enough.

Instead of relying solely on a law enforcement program in the field, several proposals are presented to effectively reduce the discharge of oily water into the sea. These measures are categorized under three different drivers: 1.- Technological; 2.- Behavioral; and 3.- Managerial.

Technological measures are those related to existent or new technology that can be implemented onboard in order to ease out the water treatment process. Currently, oily water separators (OWS) that implement a 15-ppm device are utilized onboard. These devices process bilge water, delivering a relatively clean effluent that can be discharged overboard, meeting the criteria set forth in the IMO MEPC.107(49) resolution [12]. The simplest OWS is a gravity-based parallel plate system whereas more sophisticated systems incorporate a membrane with a centrifugal pre-treatment unit. The main issue with the simplest method is its inability to effectively treat non lubricating oil products, such as fuels and cleaning detergents. Gravity-based systems are unable to break down the emulsions, making it difficult to meet the mandatory 15-ppm requirement. Shipowners and crews need to be aware of how each of these technologies work since, for example, the speed of the pump used on the OWS will vary the grade of emulsification of the oil, altering the performance of the entire system. Other technologies that can complement the required OWS are the White Box System and physicochemical methods. A White Box System would be implemented at the outlet of the OWS and contains a recorder that stores start and stop time of each discharge cycle, the oil content of the effluent and the total amount of water discharged. The system can be further enhanced with a network connection to the navigation devices of the vessel, which allows to record ship's position and course as well. Additional physicochemical methods include biological treatment and absorption / adsorption processes. The biological treatment technology uses a bioreactor to facilitate a biological reaction in which microorganisms eliminate, or at least reduce, the organic and inorganic compounds present in the bilge water before being released overboard. The combination of biological treatment with an OWS will reduce the oil content of the effluent since the emulsified oil droplets present in the effluent delivered by the OWS are very difficult to remove by physical or chemical treatment but can be degraded by the microorganisms present in this biological reaction [13]. Absorption and adsorption systems require a sorption media that retains the oil contained into the bilge water when this is pumped through the device. These systems are relatively small in size but the sorption media saturates frequently and needs replacement in order to maintain operational effectiveness [14]. Lastly, high-speed centrifugal separation is an appealing option to maximize the separation of bilge water emulsions. Comparable to a fuel purifier, these systems rotate at very high speeds, enabling to operate with gravitational forces of up to 6000 G. This system poses the advantage of already being familiar to marine engineers, resulting in a shallow learning curve for operation and maintenance. Additionally, manufacturers of centrifugal separation systems claim that it is not affected by fluctuations in oil concentration within the emulsion [5]. Further improvements in oily water separation technologies would help reduce discharges even further as the typical separator does not have the ability to properly separate chemical emulsions formed by water and other fluids like fuels and detergents.

Behavioral measures comprise those related to how shipowners and especially crews operate the abovementioned technologies. Due to the relevance of the issue, and since the engine room crew is composed not only by officers but also by ratings that operate and maintain the systems as well, questionnaires and interviews about the awareness of the risks associated to illegal bilge dumping shall be conducted. This survey shall not be limited to operational questions but also cover legal affairs, as bilge dumping violates international pollution regulations. Upon completion of the survey, and derived from the obtained results, a capacity-building program shall be developed and delivered so awareness is risen between shipowners and crews. In addition to educational measures, nowadays the prevention of marine pollution can be done via satellite imagery. The European Union's Space programme provides data from the Earth observation via its component Copernicus. This component is formed by several Sentinel satellites. Specifically, the satellite Sentinel-1 supplies day-and-night synthetic aperture radar imagery where oil slicks can be distinguished. Since the images are fabricated from the amount of radar's energy reflected back after interacting with the different fluids, no light is needed to detect an oil slick so illegal discharges at night can be detected and monitored. The identified oil slicks can be correlated with the vessels in the area by using ship's Automatic Identification System (AIS). The EMSA is currently using this technique in their CleanSeaNet Service programme, helping to prosecute criminal offenses for environmental crimes. As an example of the results derived from the CleanSeaNet Service, in 2021 an oil spill was detected northwest of the Canary Islands. Satellite data combined with other pertinent information helped the authorities to identify a tanker as the likely source of the spill. The Spanish authorities later confirmed the involvement of this vessel in an illegal discharge, resulting in a 55 km^2 spill. The bond for the vessel's release was set at 580,000 euro, marking a record high in Spain [15]. The imposition of fines and other economic measures also impacts the behavior of the stakeholders involved in bilge dumping but authorities shall be aware that the sanctions must exceed the costs of implementing good practices onboard. Port States related to the oily water spill can also take action to promote correct behavior of crews. Several States reward crew members who alert of inadequate practices. In the case of United States, the Act to Prevent Pollution from Ships (33 USC Section 1908(a)), which was passed in 1980, allows to allocate up to half of the imposed fine to the person giving information that led to conviction. This initiative has proven effective, with two notable cases: in 2004 the U.S. District Court for the District of New Jersey imposed a $4.2 million fine on OMI Corporation for a string of unlawful discharges over a five-month period in 2001. Additionally, the Captain and the Chief Engineer were sentenced to spend several years in probation due to their involvement, encouraging the crew to lie to the U. S. Coast Guard and asking engineers to conceal illegal discharge bypass pipes. The whistleblower received half of the fine, $2.1 million, which was the highest reward in history [16]. Two years later, in 2006, Overseas Shipholding Group, Inc. was judged by several U.S. District Courts for 33 felony convictions and received a criminal fine of $27.8 million from which $9.2 million were dedicated to marine environmental projects and $5.25 million given to the group of twelve whistleblowers who brought attention to the unauthorized practices [17]. The implementation of the suggested behavioral measures might face impediments. Pertaining to educational initiatives, a prominent entity such as the International Maritime Organization ought to oversee curriculum development, in order to establish a unified knowledge base. Moreover, simplification of certain topics, notably legal aspects, is advisable to enhance comprehension by each and every crewmember, regardless of their academic background. Furthermore, consensus among all States and ports regarding the implementation of diverse measures applied, such as incentives and levies, would need to be achieved. Otherwise, vessel operators may divert their routes to dock in more lenient locations where bilge dumps are not taken seriously.

Managerial measures can be related to several stakeholders: in first place, internal procedures to enhance communication between the crews and shore staff can be developed by the shipowner. If the company promotes and maintains a culture of compliance between their employees, they will feel less pressure to commit inappropriate or illegal actions in order to ensure the continuation of ship's operations. The company shall foster a culture of bilge water reduction at source as well, by promoting correct maintenance practices like leak monitoring and repair programs. In the case of port facilities, umbrella organizations like European Sea Ports Organization (ESPO) classified "water quality" and "ship waste" as two of their top ten environmental priorities for 2023 [18]. The ports can contribute reducing inappropriate discharges at sea via inspections or promoting their shore facilities. Port State Control inspectors shall have the appropriate training to detect suspicious T-connections, blanked flanges in the bilge water treatment system, or hoses that divert the contaminated water to either other systems or overboard. Detection during an inspection can be challenging due to their location, as they can be positioned far away of the system or exit it from below the floorplates. Moreover, flexible, temporary hoses are often used. In older vessels with bilge water separators that do not comply with MEPC.107(49), closing the sample supply valve of the oil content monitor and leaving open the flushing water valve has been done to prevent alarms. Port State inspectors should be aware of this and inspect the configuration of the system thoroughly. Since this became a common practice, currently all oil content monitors that comply with the in-force MEPC.107(49) will sound an alarm if clean water is used for cleaning or zeroing. Also, scrutinization of the related documentation is crucial. The Oil Record Book, used to record machinery space operations involving the transfer, discharge or disposal of bilge water, must be a reliable document. Its veracity can be assessed by checking for continuity in recorded bilge tank levels and comparing relevant changes against the times the OWS was in use. These observations led to the U.S. Coast Guard in late 2021 to identify a vessel involved in illegal discharges, and to imposing a $1.5 million fine on the shipping company [19]. This was also the hint that convicted a Chief Engineer in 2022: the fail to accurately log transfers in the Oil Record Book revealed that the bilge water tank's content was being transferred to the sewage tank and later discharged directly into the ocean. To give the impression that pollution prevention equipment had been used, the Chief Engineer instructed the crew to fill the bilge water tank with seawater and then process it. The U.S. Coast Guard detected the issue, resulting in a $1.1 million fine for the shipping company and a term of 12 months in custody for the Chief Engineer [20]. An additional measure implemented in some ports is the use of divers to examine the OWS discharge from the seaside. In this case, no visible traces of oil should be present. In order to alleviate the financial burden related to the bilge water treatment, ports shall include the usage of onshore reception facilities into their fees. Finally, on-land recovery facilities play a key role in converting bilge water residue into a usable product through waste-to-energy strategies. Achieving this last step requires collaboration between ships and port operators, is required. The MEPC.1/Circ.834/Rev.1 outlines the list of obligations and good practices for both stakeholders [21]. Ships and crews should rely on advance planning, follow appropriate procedures of the ship's Safety Management System and request the Waste Delivery Receipt to document the quantity of bilge water received by the on-land facility. Reception facility operators should be able to provide sufficient and efficient services to the ships calling at port without causing undue delay. They must have the adequate connection arrangements for the discharge of bilge water, stated in Regulation 13 of MARPOL Annex I and, at least, offer facility services at a reasonable cost. Once the vessels are able to discharge their bilge waters in port without any difficulties, the residue can be transferred to a recovery plant.

3. Results and implications

The results of the project aim to influence several society problems that are present at the moment: in first place, marine pollution will be mitigated, which will help to preserve oceans biodiversity. The mixture of water, oil and surfactants derived from cleaning products and contained in the bilge water increases the risk of planktonic species as they usually have limited capabilities to avoid certain regions. For fish, different studies have shown that a combination of water and oil enters the animal through the gills, resulting in the impairment of vital internal organs such as the liver and the heart. [22–24]. Another problem presented by bilge water discharges is that contamination occurs almost instantly and affects large areas [25]. The preservation of phytoplankton and seagrasses indirectly reduces Earth's greenhouse effect, through the Blue Carbon deposits. The impact of bilge water on seagrass meadows causes sediment erosion and loss of carbon sink capacity in the ecosystem [26]. Phytoplankton photosynthesis converts CO_2 into organic matter that moves from the surface of the ocean to deep waters. Increasing oceanic CO_2 capture could aid in mitigating the excess of anthropogenic pollution released on shore.

Secondly, the recovered bilge water can be used in inland waste-to-energy facilities to produce valuable power. While the net calorific power of bilge water is not comparable to that of conventional fossil fuels', the energy extracted comes from a waste product that now is reused, extending its life cycle and slightly reducing the reliance on raw fuels. Although the volume of bilge water to discharge is minor in well maintained vessels, other abatement technologies like scrubbers also generate residual waters that can pollute marine ecosystems if released, putting more pressure in bilge treatment systems but increasing the amount of possible waste to reuse. Air pollution resulting from the combustion of bilge water in waste-to-energy power plants can be treated with the already installed systems such as filters, adsorption techniques, and electrostatic smoke precipitators.

The transfer of bilge water from ships to waste-to-energy facilities on shore can also alleviate crews' job since bilge water processing is time-consuming and can be stressful as an accidental discharge can also have severe consequences.

Ethics statements

The author declares that this submission follows the policies of Societal Impacts as outlined in the Guide for Authors and in the Ethical Statement.

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Luis Alfonso Díaz-Secades: Conceptualization, Project administration, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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