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Effects of Discharged Effluents from Desalination Plants on Marine Living Organisms

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Abstract:

Introduction: The desalination of seawater is critical to the supply of freshwater for drinking, irrigation, and other applications in countries prone to water scarcity, prolonged droughts, high temperatures, and rapidly changing socio-economic and demographic dynamics. However, the desalination process is highly energy-intensive and generates large volumes of waste effluents, which pose significant threats to humanity and life in the marine environment. The threats are due to the brine discharges, toxic chemicals and gaseous pollutants emitted through direct disposal, entrainment, and impingement from desalination plants.

Methods: This study was done using questionnaires and interview. A google form-based questionnaire comprising 18 questions was administered via email to 30 employees who work with the reverse osmosis process of the desalination plant to examine the types of discharges, potential pollutants present, along with their effects on marine living organisms.

Results: The respondents observed that solid wastes and effluents discharged from desalination affects the soil, vegetation, and marine life (sea urchins and coral reefs) due to changes in salinity, temperature balance, chemicals concentration and toxicity of the seawater. As a result, the growth, development, and reproduction of marine living organisms is hampered.

Conclusion: It is pertinent that robust disposal techniques and management strategies are developed and implemented to curb or mitigate the discharge of brine and other waste effluents from desalination plant processes. This approach will prevent their short- and long-term effects on humans and animals in the marine environment. Furthermore, it is envisaged that the findings will contribute to the comprehensive mitigation and control measures required to address the problems associated with desalination.

Keywords: Seawater Desalination, Brine Discharges, Waste Effluents, Marine Life,

Introduction

The growing global demand for freshwater has increased over the years [1, 2]. However, the adequate supply of freshwater remains a significant problem in many societies of the world [3, 4]. Such challenges are primarily ascribed to rising population growth and socio-economic development, which has put a strain on limited freshwaters supplies across the globe [5]. This scenario is exacerbated by the fact that only 3% of the water found on the planet is designated as freshwater [6]. According to water and environmental scientists, the supply of freshwater will be further threatened by climate change in the coming years which could result in human well-being, public health, and environmental safety problems [7]. Other scientists opine that growing levels of marine and environmental pollution also influence the availability of freshwater globally [8, 9].

Given the rising challenges, the desalination of seawater has become an essential source of freshwater, particularly in nations characterised by desert lands and arid landscapes [10, 11]. In such countries, freshwater is supplied by various desalination plants that have been developed to treat and desalinate water for domestic, drinking, irrigation and other purposes [12, 13]. Many countries in the Arab region, such as middle east , that experience a severe shortage of water resources, have resorted to the establishment of desalination plants [14-16]. However, the large-scale production of freshwater generates significant solid wastes and toxic effluents during the process [17, 18]. For example, desalination produces 60% concentrated brine along with entrained chemicals such as chlorine to prevent the growth of microorganisms and sodium bisulfite which is used for dichlorination [19, 20]. Other notable chemicals used during desalination include polyacrylic or sulphuric acid which is used as an antiscalant as well as ferric chloride and polymers as coagulants [21].

The long-term use of such process chemicals and the disposal of brine discharge from desalination plants into the environment and oceans/seas presents significant challenges to marine life and ultimately to human health and safety, which remains a challenge in industrial processes [22]. The planet's seas and oceans are the basis of life because they cover more than 70% of the earth surface and contain huge biological diversity [23]. The importance of this research focuses on studying the effect of the solution resulting from the desalination process on marine living organisms such as fishes, seaweeds, coral reefs, and many other organisms. In view of

these challenges, many scientists around the world seek to examine the effects of desalination plants, their processes, and wastes streams on marine life and other living things.

Miri and Chouikhi [24] examined the ecotoxicological marine impacts from seawater desalination plants. The authors observed that the effluents from the desalination process affect the quality of seawater and living organisms due to salinity and the process chemicals. The study reported that the operation of desalination plants negatively impact seawater and aquatic communities in other ways. For example, marine organisms tend to collide with the intake screens causing death and other injuries. Similarly, the high temperature of the water lowers the level of dissolved oxygen and salinity in the water compared to the receiving water. Lastly, the desalination process releases harmful components that contain heavy metals such as Zn, Fe, Cr, Cu and Ni into the marine environment.

Lattemann and Höpner [25] investigated the effects of seawater desalination projects on marine life through environmental impact and site mitigation assessment. The findings showed that the Arab Gulf countries have the most active and effective desalination projects in the world. However, there are growing concerns about the negative impacts of these large-scale desalination projects on the environment. Among these adverse effects are the loss of marine organisms due to the process of withdrawing seawater to the desalination plant, the production of large quantities of the concentrated brine wastes, and the increase in temperature due to the heating process that is used to separate the water from salt. Similarly, the authors observed that the presence of chemical residues such as anti-scalant acids (e.g., H_2SO_4), heavy metals and other chemicals are significant concerns.

Roberts *et al.*, [26] reported that the discharges and other effluents from desalination plants affect the marine environment. The study observed that the increasing discharge from such plants increases salinity, temperature, and minerals/toxic substances accumulation are detrimental to the marine life and their environment. Ahmed and Anwar [27] carried out an environmental impact assessment of brine disposal in the marine environment using laboratory-scale investigation. The authors observed that the discharge of brine water in the marine environment increases the carbon monoxide, nitrogen dioxide, sulphur dioxide, nitrous oxide content of water, which ultimately affects the salinity, temperature, and quality of water. The change in salinity and temperatures affect the growth and development of marine living organisms, particularly benthic organisms.

Cooley and Ajami [28] reviewed the critical issues associated with seawater desalination and its impacts on marine life. The authors also reported the method of discharging wastes and effluent drainages at desalination plants and their effects. According to the study, the desalination of seawater at various plants produces large volumes of brine solution that contains chemicals such as biocides and chemicals. The use and discharge of such chemicals during the desalination process generates pollutants that are potentially toxic to living organisms even at low concentrations. The solutions resulting from the desalination process differ from seawater. Unlike seawater that contains natural calcium, magnesium, sulphate and other elements, the discharged desalination solutions contain chemical compounds such as aluminium chloride, phosphate, and other heavy metals like zinc, copper, nickel, among others. The presence of such chemicals in seawater increases the temperature imbalance, which affects marine life. In addition, the study noted that thermal-based desalination processes also produce brine water that is hotter than receiving seawater.

Missimer and Maliva [29] investigated the environmental issues associated with the reverse osmosis process of seawater desalination. In particular, the study focused on the intake and outfalls of the wastewater treatment plant and their impact on geographic position and oceanic productivity. The findings showed that the disposal of waste effluents from the treatment plants affects benthic waters and diffuser systems due to impingement. The study also showed that although the reverse osmosis process is economical and less energy-consuming, the operations related to the process result in the collision and erosion of living organisms in the marine environment. According to Elsaid *et al.*, [30] the process of desalination results in the discharge of large volumes of concentrated brine, which ultimately affects the salinity of seawater and the life of marine living organisms. Similarly, the study reported that desalination affects marine life and the environment through erosion patterns, high concentration of brine discharges, and presence of acids, anti-scalants, biological pesticides, and chemicals that are discharged into the environment with the brine stream. As a result, there is loss of diversity and abundance of organisms in the marine environment.

Overall, the review of the literature shows that the desalination of salt water is critical to the supply of freshwater to Gulf region countries like Saudi Arabia, Qatar, the United Arab Emirates, and other GCC Regions as well as Bangladesh and the United States among others [31-36]. However, the plants, processes, and by-products of seawater desalination pose significant threats to human health, safety, marine life, and the environment through the discharge of concentrated brine, chemicals, heavy metals, and other pollutant gases discharged or emitted into the air, seas, and oceans. Hence, comprehensive mitigation and control measures are required to address the outlined problems associated with desalination so as to reduce the environmental impacts of the process in nations such as gulf Region. However, the proposal requires critical studies on the effect of discharged effluents from desalination plants on marine living organisms particularly for large scale Plants. which is the core objective of this paper. This study will also identify discharges and pollutants from the plant as well as examine their effects on marine living organisms using the questionnaire method.

Materials and Methods

The objective of this study was to examine the effects of discharged effluents from the desalination Plant on marine living organisms Typically, desalination plants generate large quantities of solid wastes, wastewater effluents, and toxic chemicals, which pose considerable risks to human health, safety, and the environment. Therefore, this study seeks to examine the effects of such effluents using the mixed method of questionnaires and interviews. The questionnaire consisted of 18 questions on the types of discharges, potential pollutants present, along with their effects on marine living organisms. The google form-based questionnaire was

subsequently administered via email to the entire 30 workers who work with the reverse osmosis process in the plant. In addition, interviews consisting of formal meetings among the reverse osmosis workers were performed via internet video calls (Microsoft Teams) to deduce further information and clarifications to the questionnaire questions. The resulting data was analysed and presented diagrammatically using various types of charts.

Results

Figure 1 presents the demographics of the respondents that were administered the questionnaire during the study based on gender. The data is based on the responses of the 30 staff working at the desalination plant As observed, 85.7% of the workers who responded to the questionnaire are male, whereas females account for 14.3% of the respondents. The findings are to be expected due to the nature, drudgery, and working hours associated with industrial plant tasks. This is also due to the physical risk and toxic hazards associated with such tasks, which also plays a critical role in determining the gender of workers. As such, industrial roles and jobs are typically filled by men rather than women around the globe [38, 39].

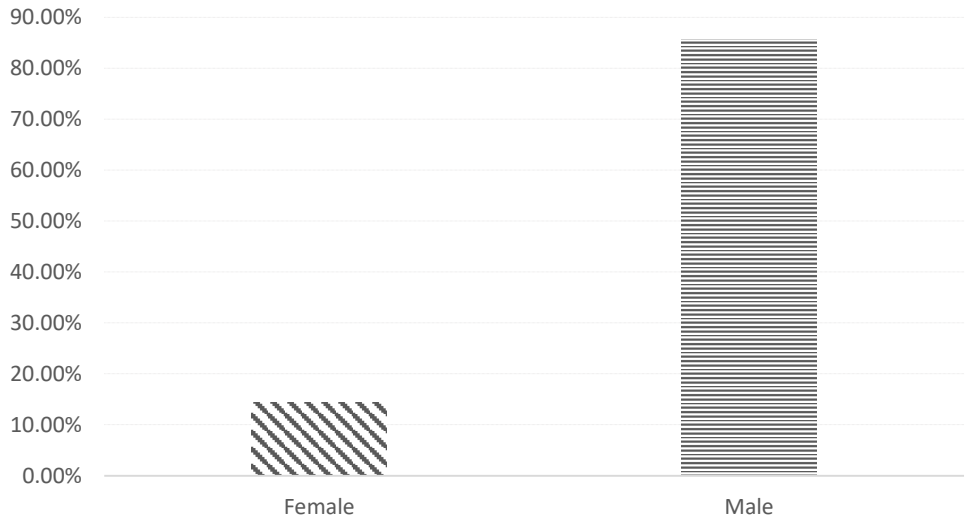

Figure 1 Gender of the respondents

The age distribution of the respondents of the study is presented in Figure 2. Age is considered a critical factor in employability, employment time, and capacity to fulfil roles at any workplace. Likewise, age affects the level of risks and effects of occupational hazards to employers. Hence, the age distribution of workers at the Desalination plant was examined using the administered questionnaire.

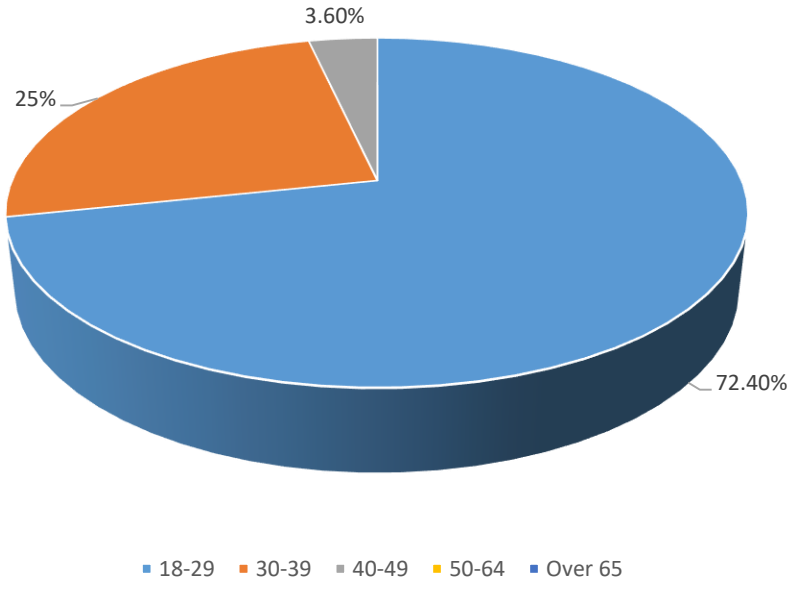

Figure 2 Age distribution of respondents

Figure 3 shows the results of the respondents' views on whether the plant follows the necessary procedures to avoid harming marine living organisms. From the chart below it can be seen that 64% of the workers affirmed that the plant follows the necessary procedures required to avoid harming marine life.

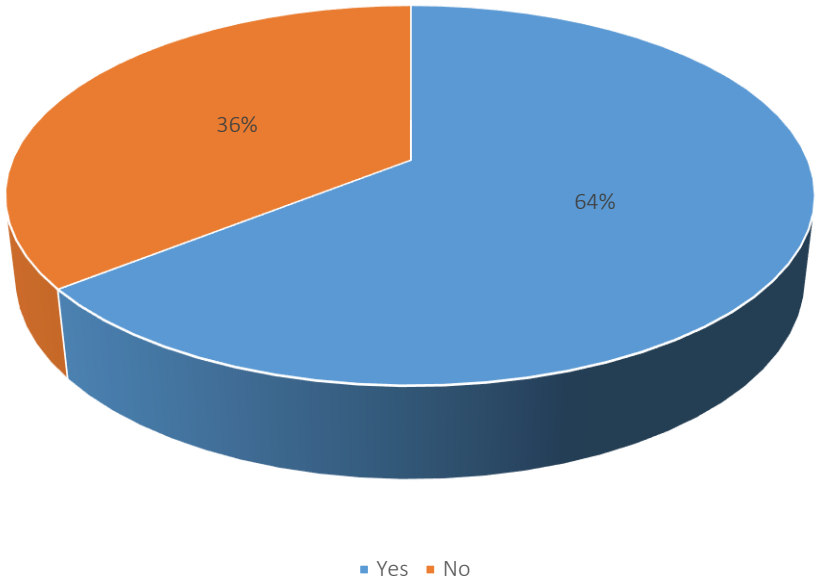

Figure 3 Adherence of desalination plants to marine life preservation procedures

Respondents were asked about the effect of the desalination process on seawater quality. Based on the responses, 60% of respondents avowed that desalination process affects quality of water. Whereas 39% responded otherwise. The results are shown in Figure 4 below.

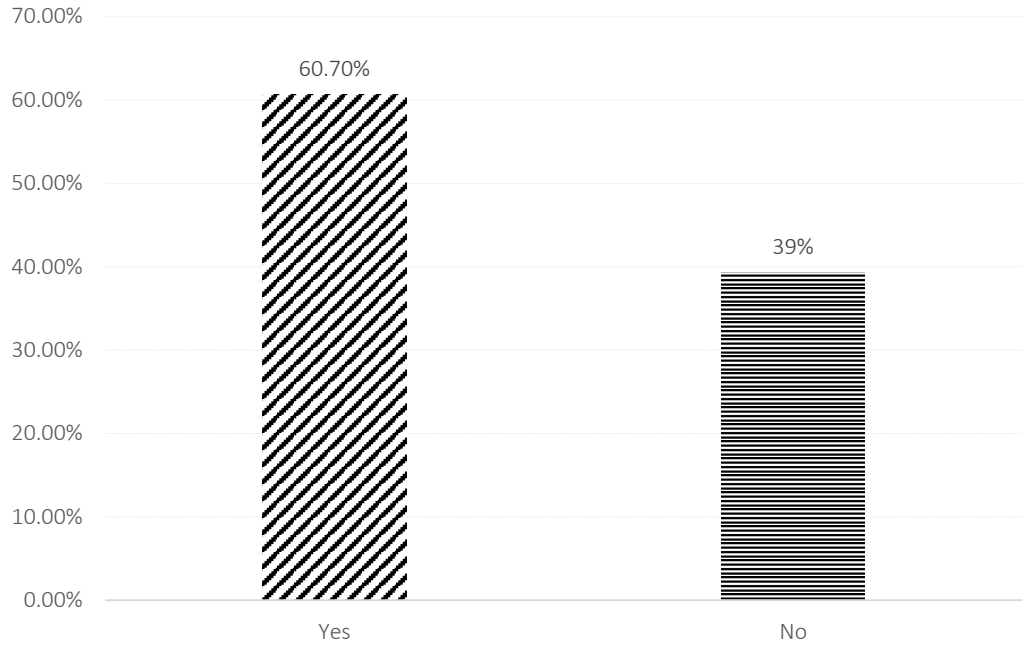

Figure 4 Effect of desalination process on seawater quality

Respondents were also queried about the types of marine animals affected by brine discharges from desalination plants. Based on the responses received, 71% alluded that fishes were mostly affected by brine discharge. The second most affected species are molluscs and the phytoplankton with 17.9% and 10.7%, respectively, based on the views of the respondents in this study. Figure 5 shows the responses of the respondents.

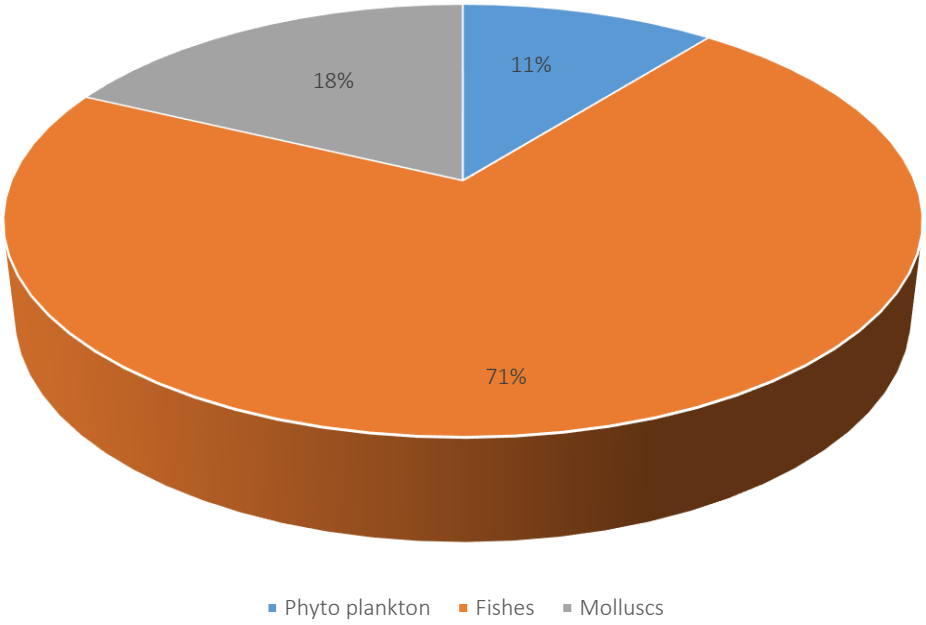

Figure 5 Marine animals threatened by desalination discharges

Respondents were queried about the potential effects of the plant, processes and wastes on the surrounding environment as shown in Figure 6. As observed in Figure 6, 39% of the respondents stated that the desalination plant affects the vegetation, whereas 36% responded affirmatively. However, 17.9% confirmed that the desalination plant processes cause soil erosion, whereas 7.1% stated that the discharges enable soil fixation.

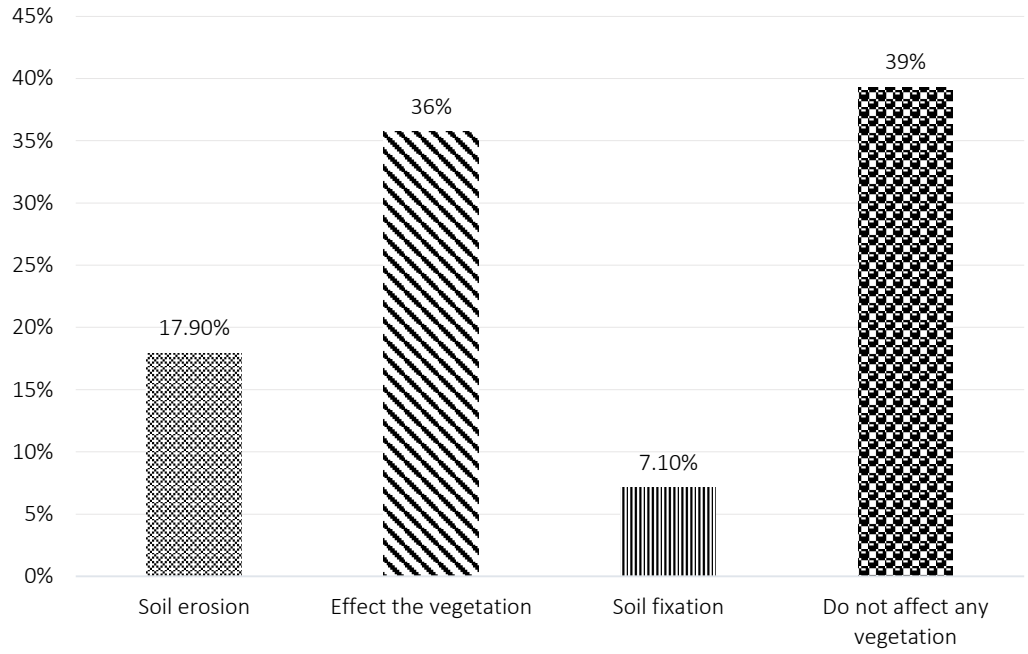

Figure 6 Effect of a desalination plant on the environment

Figure 7 shows that mangroves, coral reefs, and sea urchins could also be adversely affected by the desalination plant. The findings revealed that sea urchins (75%) are the most affected by the brine discharges and effluents from the desalination plant, followed by coral reefs (14.3%), while the least affected are mangroves (10.7%).

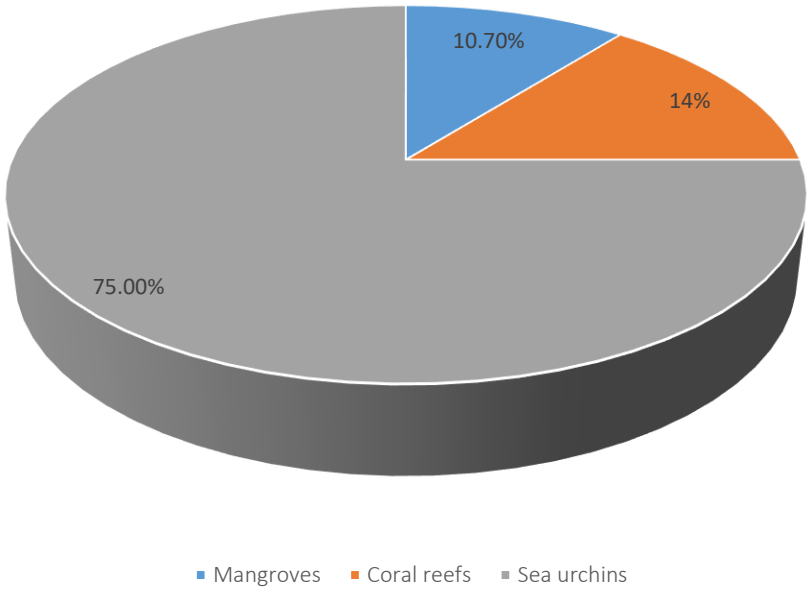

Figure 7 Threatened species affected by the disposal of desalination brine

The respondents were also asked on the effects of impingement and entrainment on marine life. 71.4% of the respondents affirmed that the impingement and entrainment processes affect marine organisms. However, 28.6% responded that impingement does not unduly affect marine organisations.

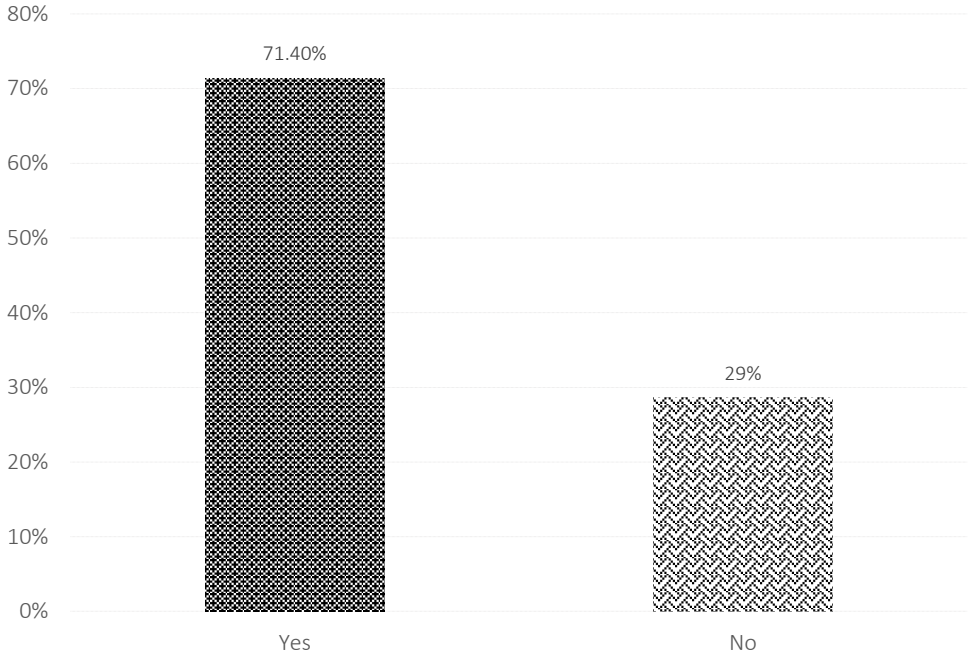

Figure 8 Effects of impingement and entrainment on marine life

Discussion

As observed from figure 2, the most significant percentage of workers (> 70%) fall within the age group 18-29 years, whereas the group 30-39 and 40-49 account for 25% and 3.6%, respectively. According to the United Nations, the term youth is used to describe people between the ages of 15 and 24 in any society [40].

According to the results from Figure 3, 64% of the workers affirmed that the plant follows the necessary procedures required to avoid harming marine life. The examples of procedures put in place include checking the amount of chemical dosed by taking samples through intake filtration. Others include maintaining a safe number of parameters such as temperature and chemicals in the outfall and ensuring that the hypochlorite dosed in the inlet suction is below 10 ºC. The workers also mentioned that the pH of the waste effluents is periodically checked before discharging to prevent harm to marine life. Studies have shown that the poor treatment

of wastes before discharging into waste bodies could result in significant risks to marine life due to high levels of hazardous materials. As a result, the temperature, turbidity, nutrient availability, pH, as well as chemical oxygen demand and biochemical oxygen demand of the water bodies could be adversely affected causing suffocation or death of aquatic living organisms [41, 42].

The findings from Figure 4 showed that the desalination process somewhat affects the quality of seawater, as confirmed by over 60% of the respondents. The results are to be expected due to the large quantities of waste materials generated by the desalination process., the process of desalination in various plants around the world produces over 90 million cubic meters of freshwater daily for drinking, irrigation, and other applications. Similarly, the process generates large quantities of brine amounting to over 110 million cubic meters daily or 60% solid wastes. As a result, large quantities of brine are piled up at desalination plants, thereby posing significant waste disposal and management challenges. Studies have shown that the direct disposal of the brine into the ocean, open dumping or landfilling could pose significant risks to humans, marine life, and the environment at large. Therefore, the respondents were queried about the types of marine animals affected by brine discharges from desalination plants [41].

As observed in Figure 5, fishes are the marine life most affected by the processes and discharges from the desalination plant, with over 70% of respondents confirming this position. The second most affected species are molluscs and the phytoplankton with 17.9% and 10.7%, respectively, based on the views of the respondents in this study. The discharge of brine and other pollutants derived from some chemicals used during desalination in the plants could poison seawater, which adversely affects the growth, development, and reproduction of marine species such as fish.

For example, the process of desalination involves the use of chemicals such as chlorine (prevents microorganism growth), sodium bisulfite (dichlorination), polyacrylic/sulfuric acid (anti-scalants), ferric chloride and polymers (coagulants) [21, 42]. Despite the efficiency of desalination, the elimination of toxic and chemical pollutants from discharges and effluents remains challenging for the industry. As a result, large quantities of solid wastes are discharged into the land, seas, and oceans through causing various problems for flora and fauna alike. To examine the extent of these challenges, the workers at desalination plant were queried about the potential effects of the plant, processes and wastes on the surrounding environment, as shown in Figure 6. As observed in Figure 6, 39% of the respondents stated that the desalination plant affects the vegetation, whereas 36% responded affirmatively. This indicates that the location of the desalination plant and or its processes and discharges do not unduly affect any vegetation. This finding may be due to the geographical landscapes, which is characterized by deserts and arid lands that lack susceptible vegetation [41, 42]. However, the respondents (17.9%) confirmed that the desalination plant processes cause soil erosion, whereas 7.1% stated that the discharges enable soil fixation. According to the respondents, other species and parts of the ecosystem are also affected by activities at the desalination plant.

Figure 7 shows that mangroves, coral reefs, and sea urchins could also be adversely affected by the desalination plant. As observed in figure 7, the findings are to be expected as sea urchins and coral reefs are considered either endangered or delicate animal species that are susceptible to the slightest changes in their environment. As stated earlier, the disposal of untreated brine discharges or waste effluents from the desalination process can alter the pH, salinity, BOD, COD, and toxicity of seawater in the vicinity of marine life. On the other hand, mangroves are salt-tolerant trees or shrubs characterised by numerous tangled roots that grow in the tidal and coastal swamps of tropical regions. The dense thickets of roots and characteristic nature of mangroves make them well adapted to life in harsh conditions such as low/high tides, toxic chemicals, and other environmental pollutants. Therefore, it can be reasonably surmised that the tolerance of the mangroves reported in this paper is due to their salt-tolerant nature, also typically reported for other halophytes in the literature.

The study also observed that the discharge of brine and other effluents is caused by impingement and entrainment processes that occur during desalination, as illustrated in Figure 8. As observed, 71.4% of the respondents affirmed that the impingement and entrainment processes affect marine organisms, particularly during the process of withdrawing seawater for desalination. However, 28.6% responded that impingement does not unduly affect marine organisations. Overall, the findings of the study show that the proper management of brine discharges and solid waste effluents should be handled appropriately through monitoring, recording, and remediation. Furthermore, such waste streams must be kept away from vulnerable ecosystems like wetlands, coral reefs, and benthic areas. It is envisaged that such measures will prevent the short- and long-term effects desalination plant discharges on human health, safety, as well as marine life, and the environment.

Conclusions

This paper examined the effects of discharged effluents from the desalination plant on marine living organisms. The paper observed that the desalination of seawater provides an abundant supply of freshwater for drinking, irrigation, and other applications in drought-stricken areas. However, the process of seawater desalination poses significant long-term threats to humans, marine organisms, and the environment due to the brine discharges and toxic chemical pollutants due to direct disposal, entrainment, and impingement. According to the respondents' responses from the administered questionnaire, the soil, vegetation, and marine life such as sea urchins and coral reefs have been affected by the wastes discharged by desalination plants. Overall, the study finds that disposal and management of brine discharges and other waste effluents from desalination plant processes should be handled appropriately to prevent the short- and long-term effects on human health, safety, along with marine living organisms and the environment.

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