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MARINE POLLUTION AT KARACHI COAST: ENVIRONMENTAL IMPACTS AND STRATEGIC SOLUTIONS FOR THE MARINE ECOSYSTEM

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Abstract
Marine pollution in Karachi Harbor has been on the rise for decades and has had a toll on the aquatic ecosystem. These have led to the occurrences of toxicity and an increase in the concentration of toxic heavy metals and organic pollutants. Working towards the environmental problem of the Karachi coast, which is home to Karachi Harbor, needs a comprehensive control strategy that is coherent as well as intersectoral. However, the present study aims at presenting a current picture of the state of Marine Pollution in the outskirts of Karachi coast, the effects it has had and the possible measures for its future control.

INTRODUCTION

Maritime litter refers to any solid waste that is intentionally or unintentionally thrown out, disposed of, or left behind in the maritime and coastal environment (Ali et al., 2021). The United Nations has been adopting various resolutions regarding the management of marine debris (Ahsanullah et al., 2021). Marine litter has the additional consequence of causing a significant amount of discarded material to eventually be carried onto beaches, so degrading the visual appeal of the beaches and negatively impacting beach environment and tourism.

Pakistan shares a border with the Arabian Sea, encompassing a coastline that extends over one thousand kilometers along the Sindh and Balochistan regions (George & Ghaddar, 2018). Nevertheless, the problem of marine pollution and its detrimental effects have not been completely acknowledged in Pakistan, and there is currently no dedicated organization responsible for taking the lead in addressing this issue (Gillani, 2019).

The unsecured and untreated garbage in rural regions and large cities along the coast are the primary cause of marine debris. Pakistan must formulate a policy to effectively regulate the influx of untreated trash into its coastal waters, including a robust monitoring system (Shahzad, 2020). In addition, it is necessary to implement awareness efforts at both the national and provincial levels to address the problem of marine litter. They should be aimed at beach cleanup and the development of SOPs that should be followed during any fun activity or carriage of boats into and out of the harbors.

To some extent, the current institutional arrangements facilitate the detection of the problem by KPT, NIO and Maritime Security Agency. As for now, there is no legal provision that mandates that one organization, often time a single ministry, to be

responsible for addressing marine trash across the coastal and marine parts of Pakistan.

The primary objectives of this study are (a) to briefly discuss the status of marine pollution along the coast of Karachi city, (b) enumerate the various forms and sources of pollution, (c) describe why preserving this coastline must be done, (e) assess sources of marine pollution and (f) analyze effects on the marine environment.

LITERATURE REVIEW

Marine pollution is another problem that must be solved immediately. Over the world, marine ecosystems are fighting hard to contain several challenges including oil, land pollution, POPs, heavy metals, radioactive materials, overfishing, marine debris and the rate at which marine species are going extinct (Aronson et al., 2011). The areas such as the Arabian Gulf region contain extremely high levels of heavy metals because of electronic wastes and mining residues. Marine habitats of the coastal area are affected by the increase in coastal constructions and the releasing of raw sewage to the water bodies. They also cause the over issuance of nutrients in such places (Chen et al., 2021). Such factors, coupled with warming of oceans, reduction in sea ice and prognostications for the alterations in ocean currents in the future, may pose a large influence on marine communities (Bergqvist et al., 2015).

Marine pollution can be categorized into physical pollution, thermal pollution, chemical pollution as well as biological pollution and the pollutants can reside in the ocean in form of solid/liquid or gaseous substances (Wilhelmsson et al., 2013). The source of pollution can be a direct result of human activities; hence the marine environment has many divisions, based on the group of pollutants (Matthies-Wiesler & Fleming, 2019). Chemical pollution of the ocean affects the marine habitats and the organisms that inhabit it. While biological pollution can affect all three parts namely physical, chemical and the populations or species (Macleod et al., 2016).

Ahsan et al. (2013) discussed how the direct discharge of primarily untreated municipal sewage into coastal waterways via the Lyari and Malir Rivers through storm water drains is a key contributing factor. According to the data, around 75% of Karachi's sewage is improperly dumped and ends up in the harbor and nearby seas. According to Akhtar (2023), a variety of pollutants, including as plastics and other non-biodegradable wastes, end up in coastal water during monsoon seasons in metropolitan areas by storm water drains, rivers, or direct shoreline placement. Solid garbage, microplastics, and chemical pollutants are introduced as a result. Lead, cadmium, chromium, nickel, copper, and mercury are among the most prevalent organic contaminants detected in Karachi Harbor.

Zafar et al. (2020) elaborated that high nutrient inputs from sewage discharge, including phosphorus and nitrogen, promote the development of microalgae and eutrophication processes. Some of the roles that coastal ecosystems play may thus shift because of this. According to the research, bacterial pathogens, like coliform bacteria, are still present in Karachi Harbor at increased levels, especially in regions near the sewage outfalls. Drinking water contaminated with fecal materials puts people's health in danger.

Yousuf et al. (2022) reported that there is enough evidence of litter, specifically plastics, glass, medical waste, and other sharp items, in the surface sediments and coastal waters around Karachi. The ecosystem and way of life of marine species are negatively impacted by this solid waste. Ali (2024) found that one of the main factors affecting the well-being and habitation of marine species is the buildup of pollution in the waters of the North Arabian Sea, especially the Karachi Harbor. According to published research, industries, plastics, and pesticides all pose serious risks to ecological and marine life by contaminating water supplies. According to Barbier (2023), pollution in marine environments, such as Karachi Harbor, affects not just the animals that live there but also the surrounding organisms, with repercussions felt across the entire biological system. Their possible effects as a pollutant of the health of organisms found in the marine ecosystem, as a contributor to the decline in genetic variation leading to a decline in overall species heterogeneity, as a reduction in the ability of the species to act as a carbon sink, as well as their potential for loss of life, incapacitation, and reduced reproductive capacity, may also be investigated. All the world's seas and oceans are home to microplastic

pollution, which poses a threat to marine animal populations and other highly trophic creatures.

MATERIAL AND METHODS

The researchers have sought to establish the fact with a view to assessing the salinity level of sea water around Karachi where sea water sample was collected systematically. The researchers obtained samples at random intervals of geographical expansion and at different hierarchal standings across the coastal region within a four-day period to capture most of the studied region. The researchers then ensured that the samples were carefully collected in a bid to avoid any contamination while ensuring that the samples would be as they were for the next tests.

The testing was conducted with the help of the Central Testing Authority under controlled environmental conditions, setting the temperature at 28 °C and the humidity at 60%. The purpose of the uniformity was to eliminate all and any biases that could be pre-existing in the testing process.

Table 1. *Test Specifications*

Temperature	Humidity	No. of Samples	Duration
28 °C	60%	4	4 Days

Using the American Society for Testing and Materials (ASTM) guidelines and methodology for everything measured was also part of the protocol. To be more specific, the pH value was determined by adopting ASTM D1293-12 standards; however, chloride, calcium, alkalinity, sulfate, magnesium, sodium, and potassium were detected by employing ASTM D512, D5463, and D1428-11 methodologies accordingly.

Table 2. *Test Methods and Standards*

Test	*Method*	*Standard Value/Data*
pH Value	D1293-12	8.2
Chloride (ppm)	D512	19350
Calcium (ppm)	D5463	413
Alkalinity (ppm)	D5463	142
Sulphate (ppm)	D5463	2712
Magnesium (ppm)	D5463	1294
Sodium (ppm)	D1428-82	10760
Potassium (ppm)	D1428-82	387

After attaining the results, the data was compared with the defined parameters and standard values to check whether the water samples meant good-quality seawater or not. If the numbers are not normal, it could mean a lot of different things, from pollution and contamination in the water. The subsequent procedure of assessing results was systematic and involved an accuracy and reliability analysis of the Marine Pollution Index of Karachi coast.

Analytical results of a pollution test offer factual data for evaluating the situation of today's aquatic environment and for developing a plan of enhancement. In other words, the study intends to give a specific solution to the issue by mapping strict sampling as well as testing guidelines.

RESULTS AND DISCUSSION

Analysis of sample sea water collected from different areas of Karachi coast is beneficial to understand the health status of marine ecosystems in this area. Thus, these results should clarify the pollution and contamination rates, the state of the marine environment, and the efficiency of the existing measures of protection.

Table 3. *Test Results*

Test	*Method*	*Standard Value/Data*	*Results*			
			NB-1	*NB-14*	*WHISKY WHISKY*	*ECHO WHISKY*
pH Value	D1293-12	8.2	5.73	7.23	7.38	6.66
Chloride (ppm)	D512	19350	20400	19800	19400	16400
Calcium (ppm)	D5463	413	340	355	335	325
Alkalinity (ppm)	D5463	142	105	135	145	128
Sulphate (ppm)	D5463	2712	2010	1980	1950	2010
Magnesium (ppm)	D5463	1294	1225	1230	1245	1240
Sodium (ppm)	D1428-82	10760	10400	9840	9520	8680
Potassium (ppm)	D1428-82	387	370	360	320	310

Using the pH scale, the samples had measurements of between 5.73 to 7.38. Since the figures obtained are within acceptable thresholds for freshwater and marine ecosystems, the variations from the ideal pH of 8.2 provides a clue to the nature of one of the causes like acidity or alkalinity. The study's water samples had chloride concentrations ranging from 16400 to 20400 ppm, indicating no pollution of the groundwater. The calcium level was at a rate of 325 to 413 ppm, which was in line with typical marine environmental ranges.

The researcher found that the alkaline level in some samples ranged abruptly from 105 ppm to 145 ppm, suggesting that these brief changes might indicate probable causes of either localized acidity or alkalinity. Sulfate readings decreased within the expected limits, with 1950–2010 ppm. levels. In addition to calcium, there was a difference of 69 ppm in the magnesium levels, with values ranging from 1225 to 1294 ppm, which shows that the conditions did not change much and may have been acceptable for marine life if not ideal.

Sodium variation was in the range of 8680–10760 ppm, an approximate value for the marine environment. The potassium concentrations at the experiment site fell within the expected range, specifically from 310 to 387 ppm. Most parameters fall within the given ranges, but abrupt deviations from the prescribed values demonstrate the need for continuous monitoring and an alarm system in Pakistan's maritime infrastructure to safeguard against marine pollution and contamination threats.

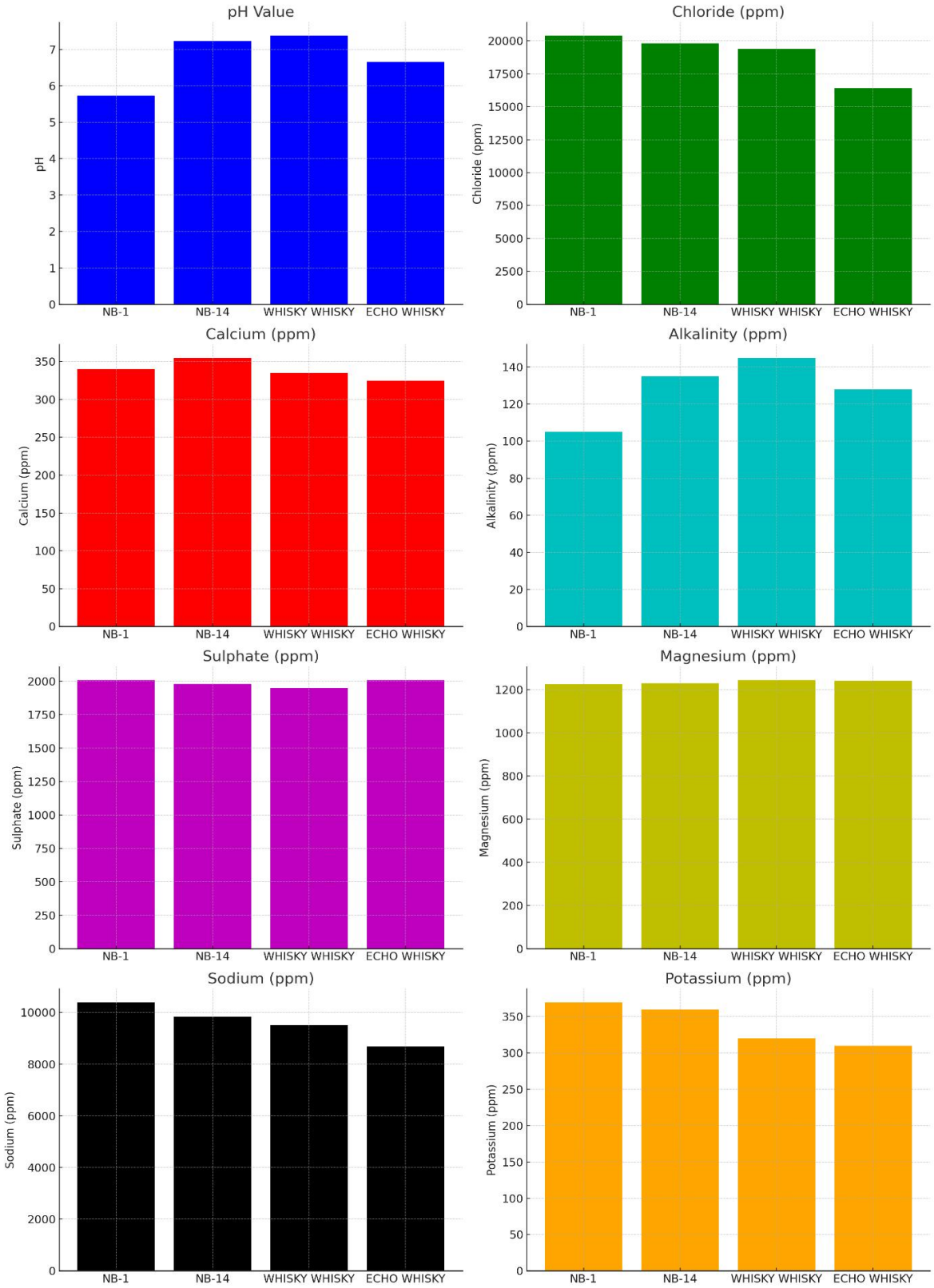

Figure 1. *Comparison of values across the different samples*

Consequently, the seawater examination, executed in the close neighborhood of the Karachi Sea, reveals the environmental conditions that beset Pakistan's maritime infrastructure. Most of the data revealed the measured parameters as being within permissible limits. However, the results revealed the presence of marine pollution in the form of deviations from standard values and slight variations among samples, necessitating prompt action for remediation.

One of the important things that will reveal the possible extent of pollution is the change in pH levels in the seawater, which is analyzed. Although the measured pH values fall within the limits of what is acceptable for marine environments, the fact that they differ from the standard 8.2 indicates either that there are acidic or alkaline sources in the sampled water, which means that we should be cautious when writing about the sampled water's state. When biosolids deviate from their normal composition, they may have significant impacts on marine life and biodiversity, demonstrating that pollution assessment and minimization are essential in such cases.

Furthermore, the testing of chloride contents in seawater samples exemplifies no contamination, and this suggests that chloride sources may not be a considerable contributor to pollution in the studied areas. Nevertheless, such parameters as alkalinity and sulfur are not completely steady across all the mentioned samples, suggesting that there could be some local sources of pollution that necessitate extended exploration.

Besides, the high saline content in the samples that sustain Na+ and K+ levels suggest the parameter may be in the process of stabilizing; however, other sources of pollution could not have been ruled out. The very small change in magnesium concentrations found demonstrates likewise the significance of ongoing assessment and security of the marine environment against any possible polluting threats.

While the results of the analysis of seawater are a sign of hope for the quality of the marine ecosystem along the Karachi coast, they also challenge the need for concern about marine pollution and should be taken as a call to undertake actions that can address the issue. Pollution from a whole spectrum of different sources, such as industrial effluent, sewage, and shipping activities (Qari & Khalid, 2018), remains the main threat to the planet's marine ecosystems and to the health of the people who interact with the oceans.

Efforts to suppress marine pollution demand a multi-dimensional strategy that involves tougher regulations, effective waste management methods, and raising public awareness of the danger (Shahzad, 2020). All the agencies from the government side, representation of the business community, and participation of civil society in this concern are the only sources to get an efficient solution to this problem (Ali et al., 2021).

Marine pollution is a multifaceted issue in the case of Pakistan and has national and international implications. Pakistan's domestic laws, as well as the international conventions acknowledged by the global and regional community, are capable to address the issue of sea-borne pollution but they are ineffective as they failed to implement the laws (Javaid & Shahzad, 2016). The Karachi port is one of the causes through which the water is filled with so much trash and the impacts can also be seen in other regions. Over the past few years, the government of Pakistan has sent out statements of reducing the pollution rate of marine areas due to ease in following the international as well as regional rules. The Marine Pollution Control Department was set up in 1996 to efficiently tackle all types of air, water and noise pollution and effluents originating from both the land and sea within the sixty-two sq.km area of Karachi harbor. Besides, it involves working waste and emissions from cargoes, as well as other industrial and commercial waste from other establishments adjacent to the Karachi harbor.

CONCLUSION AND RECOMMENDATIONS

This is a descriptive study of pollution in Karachi Sea water; therefore, its focus is on appearance of water samples analyses for various parameters such as, pH, chloride, calcium, alkalinity, sulphate, magnesium sodium and potassium concentrations, the standard method of measurement was adopted. The outcome specifies the difference between standard values and non-standard ones, showing the marine pollution situation and the resultant need for prompt actions to ensure no further pollution. The work of reducing marine pollution must be multifaceted, which means introducing tighter regulations, an adequate waste management strategy, and public awareness

programs. Coordination among the government institutions, industry participants, representatives of nongovernmental organizations, and civil society stakeholders is vital for efficient dealing with marine pollution and the protection of maritime resources and resorts in Pakistan. Fast responses are required to search out and address sources of contamination, preserve biodiversity, and keep marine assets for future generations. Based on results and discussion, authors have drawn the following recommendations:

- Improve laws relating to effluents discharge from industries and sewage outfall into marine waters. Improve enforcement and monitoring.
- Upgrade sewerage treatment facilities and make industries pre-treat their effluents before discharging them into the systems.
- To address the issue of waste disposal, the community should be educated on the importance of reducing the use of plastics and using the right methods of disposing of waste. It may include practices such as encouraging the recycling process or conducting cleaning campaigns.
- The stakeholders must encourage sustainable practices to minimize cases of destruction of aquatic habitats.
- Develop and designate marine sanctuaries along the coastal margins. Coastal resource management planning is the best tool to be utilized.
- Promote more focused effort on the collection of data and studies on the state of the marine ecosystem for policy-making purposes.
- Develop partnerships between the government, business and industry, communities, non-governmental organizations, and academic institutions to ensure that everyone has a role to play and is accountable for the outcome.
- Engage with various local and global organizations with the aim of implementing standards as used in other countries to produce successful models of sustainable coastal management.

DISCLOSURE

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