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Hydrographical Studies in the Nearshore Seawaters of the Red Sea Coast of Al-Hodeida City, Yemen

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ABSTRACT

Hydrographic studies of nearshore seawaters are important because they are sensitive to both natural and human influences. The hydrographic study is very important for nearshore waters because it is very sensitive to natural and human influences. In this research, an attempt was made to study the hydrographic properties of the nearshore waters of the Red Sea coast of Hodeida city, Yemen. During the period from December 2021 to June 2022, to represent the two seasons of winter and summer. The water temperatures ranged from 30 to 34.5 °C, salinity fluctuated from 39.3 to 42.4 psu, pH varied from 7.9 to 8.2 and dissolved oxygen ranged from 4.88 to 8.54 mg/l. The higher values of temperature and salinity were recorded during summer season. In contrast, an increase in pH and dissolved oxygen were observed during winter season. The present study confirmed that salinity has a negative correlation with pH and dissolved oxygen although it was not significant and also it showed significant positive correlation between pH and dissolved oxygen (0.828). The hydrographical parameters showed significant spatial and temporal variations. The present baseline information is useful for the further ecological monitoring and assessment along the coastal beaches.

Keywords: Hydrographical Parameter; Nearshore Seawater; Hodeidah; Red Sea Coast

Introduction

Coastal ecosystems are more productive and dynamic because it receives considerable amounts of freshwater, nutrients, dissolved and particulate organic matter, sediment, contaminants and pollutants from the industries and other human activities [1]. In recent years, coastal areas have been assuming greater importance, owing to their increasing human population, urbanization and accelerated developmental activities. The quality of water is getting vastly deteriorated due to unscientific waste disposal and improper waste management and careless towards protecting the environment. Good quality of coastal water is an important part of keeping our coasts healthy for the future. Increased anthropogenic activities in and around water bodies damage the aquatic systems and ultimately the physico-chemical properties of water. The pollution of coastal water affects the marine organisms, which are at the vicinity of the coast [2]. Beaches, the most dynamic coastal landform on earth, show dynamic changes over different timescales such as diurnal, tidal, monthly, and seasonal changes. These changes can be constructive or destructive. The long-term studies on beaches help in understanding and planning for any coastal management programs [3]. The coastal ecosystems provide food and other incomes, also used for waste disposal, recreation and inspiration. Water is very essential for all Living being. It is available in different forms in our environment.

Coastal environment is vital for all human activities including industrial growth. Without the coastal environment, success of any community or nation is impossible. In the other hand coastal water is always considered as an easily available and everlasting resource for the biota. Coastal Zone is influenced by the interaction between land and sea. The environmental conditions such as topography, water movement, salinity, oxygen, temperature and nutrients characterizing particular water mass also determine the composition of its biota [4]. Thus the nature and distribution of flora and fauna in an aquatic system are mainly controlled by the fluctuations in the hydrographi-

cal parameters of the water body [5]. Coastal zone offers an important buffer zone and filtering system for the ecosystem. Generally Marine environment is a complex system and mainly influenced by various physical chemical and biological process. The open ocean is more stable compare to the near shore waters where the interaction with terrestrial and makes the variations in hydrographical properties [6]. The water quality depends on both natural processes, such as precipitation erosion, weathering of crustal materials and anthropogenic processes like urbanization, industrialization, mining and agricultural activities [7]. The coastal hydrography is much complicated due to the dynamic nature of the ecosystem. Changes in the hydrographical parameters such as salinity, dissolved oxygen, dissolved carbon dioxide; nutrients affect the activities and growth of the organisms in the ecosystem [8].

It plays a major role in forecasting, localizing, and manipulating the marine resources [9]. Coastal Water quality is an indicator which gives the necessary information about the marine waters and their ability to support the marine species to live in the marine environment. It shows how activities on land affect marine water quality. Hence the hydrological study is very much essential to understand the relationship between its different trophic levels and food webs. Usually in the coastal waters exhibit considerable seasonal variations depending on the local conditions of rainfall, tidal incursions, various abiotic and biotic processes, quantum of freshwater inflow affecting the nutrient cycle of different coastal environments [10]. Therefore, the results of these investigations are the continuation of the evaluation in these locations and could be considered as a reference for comparison for further evaluations and future studies.

Materials and Methods

Study Area

The area under investigation is laying from the south eastern part of the Red Sea in the coast of Yemen, Hodeida City. It extends from Hodeida power plant which is located at latitude 15° 00' 20" N and longitude 42° 56' 02" E to Fishing port in the south at 14° 46' 54" N latitude and 42° 56' 50" E longitude. The distinctive areas are namely Al Hodeida port, Hodeida power plant, Fishing port and The Corniche of Al-Hodeida (Figure 1) and (Table 1). The sampling stations were fixed by the global position system (GPS).

Table 1: Geographical locations of the sampling stations.

		Location of Station	
Station No.	**Description**	**Latitudes (North)**	**Longitudes (East)**
St-1	Al Hodeida port	14° 49′ 58″	42° 56′ 02″
St-2	Hodeida power plant	15° 00′ 20″	42° 55′ 15″
St-3	Fishing port	14° 46′ 54″	42° 56′ 50″
St-4	The Corniche of Al-Hodeida	14° 46′ 49″	42° 56′ 33″

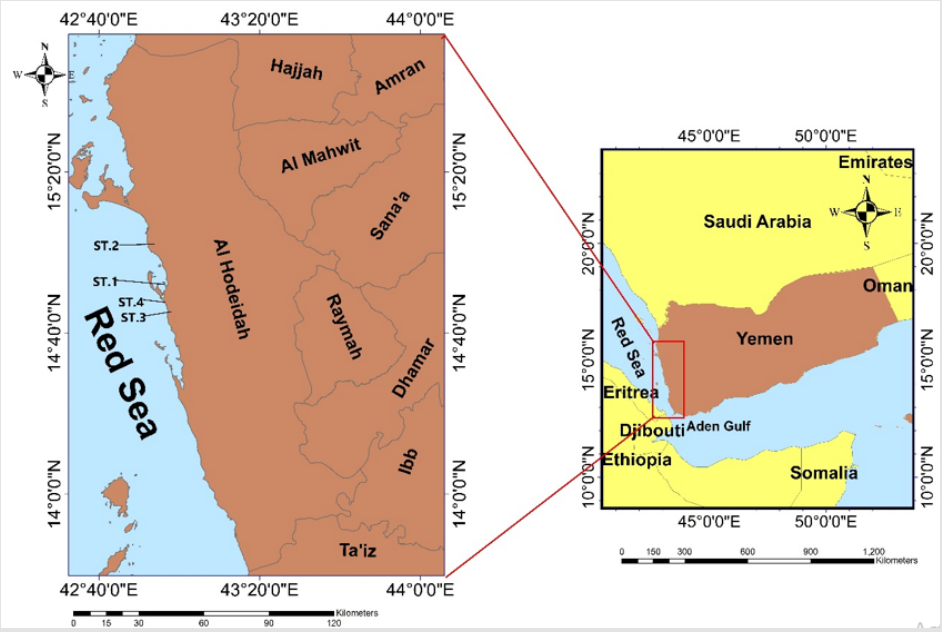

Figure 1: Sampling stations of the study area.

Water Sample Collection and Analysis

The surface seawater samples were collected at the nearshore seawaters of the Red Sea coast of Hodeida city, Yemen. During the period from December 2021 to June 2022, to represent the two seasons of winter and summer, to assess the various hydrographical parameters. The surface water temperatures was recorded at the sampling site using standard mercury centigrade thermometer, pH was measured using pocket pH meter (Hanna), whereas the analyses of salinity and dissolved oxygen were done in the laboratory as per the standard methods [11]. For analysis of dissolved oxygen, water samples were collected by glass bottles of 125 ml capacity and fixed on the field using Winkler's reagents. Statistical analysis: the simple correlation was determined between various hydrographical parameters: water temperature, pH, salinity, dissolved oxygen.

Results

Hydrographical Parameters in Surface Sea Water

The hydrographical characteristics of surface seawater were meticulously examined during both the winter and summer seasons across four designated locales along the coastal expanse of Al-Hodeida city on the western periphery of Yemen. These locations spanned from the Fishing Port situated at 14° 46' 54" N latitude and 42° 56' 50" E longitude to the Hodeida Power Plant positioned at latitude 15° 00' 20" N and longitude 42° 56' 02" E, encompassing the Strait. The subsequent section presents the findings concerning the hydrographical parameters delineated in the course of this investigation (Table 2) and (Figure 2).

Table 2: Seasonal average of temperature, salinity, pH and dissolved oxygen in surface seawater of the study areas.

	Hydrographic Parameter (Winter 2021)				Hydrographic Parameter (Summer 2022)			
Location	**Temp.**	**S**	**DO**	**pH**	**T**	**S**	**DO**	**pH**
	°C	**PSU**	**mg/l**		**°C**	**PSU**	**mg/l**	
Fishing-Port	30.2	40.8	4.3	7.9	33.5	42.4	4.4	7.6
Al-Hodeida Corniche	30.2	39.3	6.7	8	33.1	42.2	6.3	8.1
Al-Hodeida Port	30.1	39.4	6.3	8.04	34.5	41.3	6.1	8.1
Al-Hodeida Power Station	30.6	40.6	7	8.03	34.4	41.6	6.9	8.2
Average	30.2	40.2	6.8	7.99	33.8	41.8	5.8	8,0
Maximum	30.6	40.8	7.1	8.04	34.5	42.4	6.9	8.2
Minimum	30	39.3	4.3	7.9	33.1	41.3	4	7.6

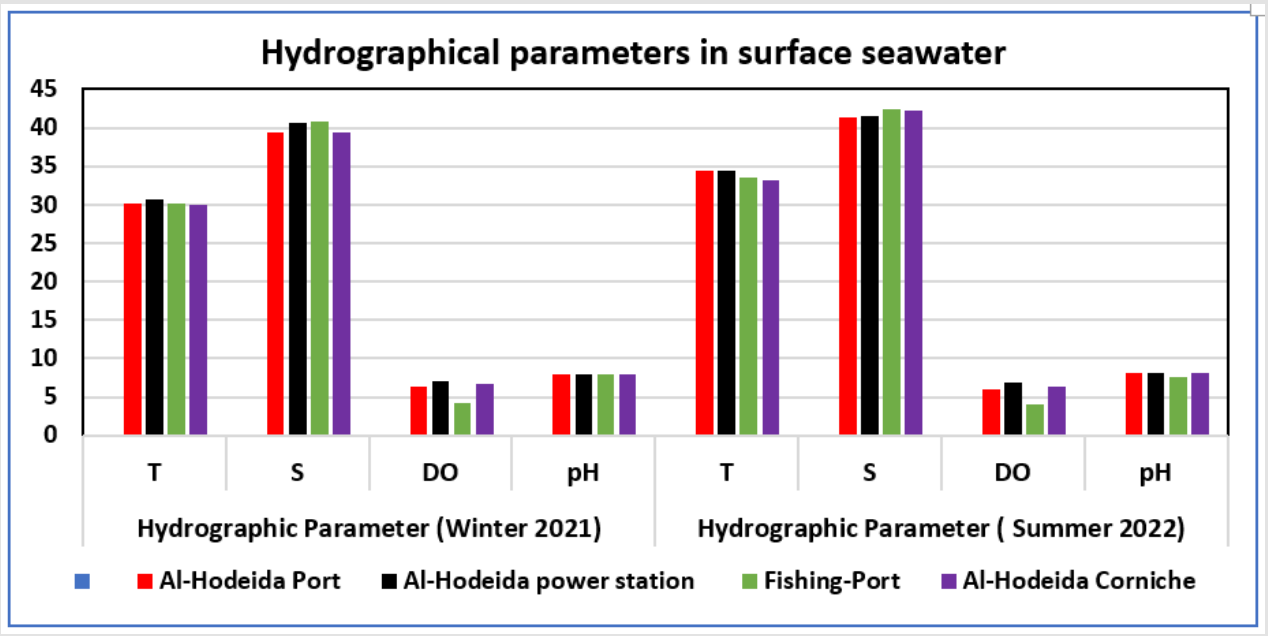

Figure 2: Seasonal average of hydrographical parameters in surface seawater of the study area.

Discussion

Surface Seawater Temperature (°C)

It is well known that water temperature influences the nearshore organisms directly by effecting on their physiological parameters and indirectly through change in the hydrographical properties of nearshore seawater. It influences the chemical processes such as dissolution-precipitation, adsorption-desorption, oxidation-reduction and physiology of biotic community in the nearshore habitat. Therefore, water temperature becomes an important factor in the environmental studies. Water temperature during the sampling of different seasons was found to vary from 30°C in December at Al-Hodeida Corniche to 34.5°C in June at Al-Hodeida Port. These observations unveil an augmenting average surface water temperature throughout the summer, culminating in its zenith at Al-Hodeida Port, and a subsequent decrement during the winter months, reaching its nadir at Al-Hodeida Corniche. Comparatively, the recorded surface water temperatures during this study align harmoniously with those observed in analogous tropical waters and conform to acceptable ranges conducive to aquatic life within tropical ecosystems. The fluctuations in water temperature are primarily orchestrated by the intricacies of the heat budget, which encompasses radiation influx, interplay with atmospheric temperature, radiative return, and latent heat of evaporation. Additionally, the prevailing wind direction and the introduction of cold water from the Gulf of Aden into the Red Sea, compounded by the temporal dynamics of sampling, engender variations reflective of the warm subtropical zone endemic to the southern Red Sea (. Notably, the apex of surface seawater temperatures was discerned during June, attributed to intensified solar radiation, atmospheric warmth, and humidity. Correspondingly, the nadir of surface water temperatures in December could be ascribed to diminished solar radiation, diminished atmospheric warmth and humidity, augmented by brisk winds and waves, and the influx of cold Gulf of Aden waters into the Red Sea [1,12].

Salinity

Salinity is a dynamic indicator of the nature of the exchange system. Salinity is one of the important factors which profoundly influence the abundance and distribution of the animals in estuarine environment and inshore waters. Salinity levels in coastal water vary because of river inputs, tidal and oceanic currents and influx of ground water, variable evaporation rates and freshwater runoff with rainfall. Surface water salinity in the present study was fluctuated from 39.3 practical salinity units (psu) at Al-Hodeida Corniche in December to 42.4 psu at Fishing Port in June. Evidently, the survey portrays an overarching predominance of elevated salinity values across the study area throughout the year. The zenith of salinity was distinctly registered at Fishing Port, potentially influenced by waste seawater discharges. Of significance is the upsurge in salinity during the summer months compared to the winter months, which corresponds to elevated temperatures. The temporal and spatial variability in salinity manifests an echo of the prevailing warm subtropical conditions inherent to the southern Red Sea. These variances find their origins in a confluence of oceanographic circumstances, encompassing shallow seawaters, semi-isolated shorelines, intense evaporation, meager fresh seawater influx, constrained circulation, and the cadence of sampling [12,13].

Hydrogen Ion Concentration (pH)

The effect of pH on the chemical and biological properties of liquids makes its determination very important. It is one of the most important parameter in water chemistry. The pH concentration gets changed with time due to the changes in temperature, salinity and biological activity [14]. The pH values across the study area, varied from 7.6 in June at Fishing Port to 8.2 in June at Al-Hodeida Power Plant. Evidently, substantial deviations in pH values emerged at Fishing Port, attributed to the decomposition of organic matter via aerobic and anaerobic bacterial activity, thereby escalating the release of CO2 into the seawater column. This phenomenon chiefly emanates from anthropogenic activities, runoff from proximal land, and sewage discharge at the specific site. Conversely, marginally elevated pH levels in June may be attributed to photosynthetic activity during that season, facilitating CO2 uptake from sea seawater and consequently engendering an elevation in pH levels. This relationship was substantiated by a positive correlation between seawater pH and dissolved oxygen, underscoring their utility as dependable indicators of production levels. The increased atmospheric levels of CO2 due to anthropogenic factors such as the combustion of fossil fuels—including coal, oil, and natural gas—prompt an augmented uptake of carbon dioxide by the ocean, instigating a decline in seawater pH and giving rise to a suite of chemical perturbations collectively recognized as ocean acidification [15]. Although the long-term ramifications of ocean acidification remain enigmatic, its anticipated impact on diverse ecosystems and their attendant services to society are irrefutable. The pH value of seawater stands influenced by carbon dioxide concentration, dissolved oxygen levels, salinity, seawater temperature, sewage discharge, land runoff, organic matter decomposition, photosynthetic activities, and the temporal facet of sampling [15,16].

Dissolved Oxygen (DO)

Dissolved oxygen is an important parameter of water and its concentration in water is an indicator of prevailing water quality and ability of water body to support a well-balanced aquatic life. Two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity. The dissolved oxygen levels assessed in the study area were generally found moderate to high. This may well indicate a high primary production level in seawater shallow in these sites. It ranged from 4.0 mg/l in June at Fishing Port to 7.0 mg/l in December at Al-Hodeida Power Plant. The variation of dissolved oxygen in sea seawater ecosystems may be attributed to several hydrographical and biological conditions prevailing at various locations, organic wastes, seawater shallow, amount of gases (carbon dioxide

and dissolved oxygen) in air, discharge of the sewages outfalls, altitude, dissolved or suspended solids, turbidity, seawater circulation, amount of nutrient in the seawater, seawater inflow and the sampling period. In addition to, type and number of organisms in the seawater body [17,18].

Correlation Analysis of Environmental Parameters

[Al-Hagibi, et al. [15]] reported a positive correlation between surface water temperature and salinity. This study also confirmed a positive correlation between these two parameters (0.852). High temperature and salinity cause the oxygen to be relatively low [15]. The present observation also confirmed that salinity has a negative correlation with pH and dissolved oxygen although it was not significant. [Al-Hagib, et al. [12]] found a positive correlation between pH and dissolved oxygen; this study also showed positive correlation between these two parameters (0.828). These correlations of environmental parameters of the study area have been illustrated in (Table 3).

Table 3: Correlation coefficient between various environmental parameters.

Variable	Temperature	Salinity	pH	Dissolved Oxygen (DO)
Temperature	1			
Salinity	0.852	1		
pH	-0.118	-0.283	1	
Dissolved oxygen (DO)	-0.049	-0.388	0.828	1

Note: Correlation is significant at (< 0.05 and < 0.001). High correlation (r=0.7-0.9)

Conclusions and Recommendations

The hydrographical parameters in the nearshore seawaters of the Red Sea coast of Al-Hodeida city, Yemen; showed clear seasonal patterns. The knowledge of nutrients, related to their sources, availability and the utilization levels gives us the information about the productivity potential and health of the coastal ecosystem. The study revealed that all the selected stations are in a good state of health as they reflected water quality is in normal condition. The present study provides a good outline on the prevailing condition of the surface seawaters and baseline information for better management and conservation of the Red Sea coast of Al-Hodeida city inshore waters. The difference between mainly due to local Hydrographical condition for example semi-closed shores: intensive evaporation and several biological conditions prevailed at various locations. It is recommended that, continuous programme for the Red Sea Cost of Yemen should be formulated and conducted to ensure that the values of hydrographical are within this study.

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