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Original Research Article

Distribution of Nutrients in Surface Seawater from Red Sea Coastal Area in Hodiedah Governorate, Yemen

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Abstract: The samples of seawaters were collected during winter 2019 and summer 2020 from coasts on Red Sea at Al Hudaydah Governorate to understand the distribution of nutrients and the dynamics of the microbiological component with special reference to bacteria and find out the relationship between phsicochemical characteristics and microbiological components. The samples of nutrients (NO_3^-, NO_2^-, PO_4^{-3}, SiO_4^{-4}) were measured using spectrophotometric techniques (DR 3900, HACH, USA). The variation of the nitrates was lower during summer and higher during winter, due to the high temperature, which increases the photosynthesis process and thus the increased consumption of nitrate by phytoplankton growth. The variation of the NO_2 were less in summer and high in winter due to the high temperature, which increases the photosynthesis process. Seasonally, the high levels of phosphate in summer compared to winter because the increase the household water discharges containing high concentrations of soap and detergents. Factors analysis indicates that, the strong positive loadings of PO_4, TC. It is clear from the table (2), that the discharged water to the marine environment is characterized by a very high load of organic matter and coliform bacteria, and this is clear from the relationship between BOD and all the parameters.

Keywords: Nutrients, Red Sea, Al Hudaydah, Yemen.

1. INTRODUCTION

Marine environment is one of the most important sources for natural resources. It plays a crucial role in the world economic and social development process. The rapid development of human activities during the last decades within densely populated areas has continuously increased the risk of environmental deterioration, especially in coastal systems. The aquatic environment is being abused throughout the world by the introduction of a large number of xenophobic compounds derived from human activities in different sectors (Al-Alimi., 2008).

Many of these substances have the potential to impact on the ecosystem at relatively low concentrations. One of the primary aims of environmental quality studies is to understand the impacts of anthropogenic compounds such as organic micropollutants on the ecosystem, in order to minimize or prevent adverse effects (Zhou *et al*., 2003). The rapid industrialization along the coastal area lead to degradation in water quality particularly of brackish water and the estuaries. It is producing increased pressures leading to environmental stress or even affect public health [kumar and Anissa., 2009). These water can carry high levels of toxins and pathogenic bacteria, which may be transmitted to humans or marine organisms (Bald *et al*., 2005).

Wastewater and the lack of sewage treatment station or liquid waste are among the main causes of seawater pollution in Yemen (Schmidt *et al*., 2008). Many researchers mentioned the influence of indiscriminate discharge of untreated industrial effluent and municipal waste water on the marine environment in terms of danger to habitats such as serious risk to marine life, deterioration of aesthetic values, and limited access to coastal areas. The marine environment of Yemen is characterized by its high primary and secondary productivity making it a basic feeding and nursery ground for marine species where more than 600 species and marine organisms were recorded in Yemen waters (Al-Alimi., 2008, MFW., 2000).

The marine environment in the Republic of Yemen coastal area is subject to major contamination by persistent organic pollutants and heavy metals in largely unknown amounts from untreated domestic wastewater, industrial wastewater, and agricultural drain water, runoff during rainy periods, ship and boat traffic, oil transportation, oil spillage, and atmospheric fallout (Al-Alimi., 2008, Heba., 2000).

Bacteriological contaminations by fecal coliform and total coliform are regularly monitored to ensure that water bodies meet established surface water quality standards (Chigbu *et al*., 2004). Fecal coliform bacteria density count is the current standard for detection of fecal pollution in surface waters (Kelsey *et al*., 2003). Microbial contamination is a serious public sanitary problem in marine coastal areas, especially those located highly populated regions. The use bacterial indictors to measure water quality are widespread. There is not universal agreement on which indicator organism (s) is most useful, nor are there international regulations mandating a single standard for bacterial indicators. So, there are different indicators and different indicator levels identified as standards are used by water quality programs in different countries around the world. The most commonly measured bacterial indicators are total coliforms (TC), fecal coliforms (FC), and enterococci (EC).

Many areas along the coast are used as recreation areas by the public. It is successfully used for commercial fish cultivation with a significant market in Yemen. The present study aims to understand the dynamics of the microbiological component with special reference to bacteria and find out the relationship between phsicochemical characteristics and microbiological components in the coastal area of Red Sea of Yemen.

2. MATERIALS AND METHODS

2.1 Study Area

Al-Hodeidah Governorate is located on the western part of the Republic of Yemen and extends on the western coastal strip overlooking the Red Sea coast between longitudes (42^o – 43^o) east of Greenwich and between latitudes (14^o – 16^o) north of the equator, it has approximately about 13,500 Km, with the estimated population of 979.000 in 2013 (Statistical Year Book)., 2010). About 18000 cubic meters of municipal sewage is discharged daily into a series of eleven oxidation ponds. The system of treatment serves nearly 35% of the residential population. The municipal sewage contains several types of liquid waste such as industrial liquid effluent and animal waste. About 70% of the municipal sewage is used for agriculture purposes. The remainder (30 %) is discharged through a small open channel north of the city into the seawater area close to khawr Al Kathib (Al-qadasy *et al*., 2017).

2.2 Sample Collection and Preparation

Eight water samples were collected during two periods in December 2019 and June 2020 from eight sites in the coastal region of Al Hudaydah Governorate / Yemen. Samples were collected in 1 liter colored glass bottles. It was previously autoclaved in a sterilizer at 120 °C and 15 ATM trays were used to collect surface water samples for biological samples. It was immediately preserved in Ice Box 4 (°C) and transported directly to the laboratory of the Local Water and Sanitation Corporation in Al Hudaydah City. Likewise, the period between taking the sample and arriving at the laboratory should not exceed (three hours), and the period between taking the sample and analyzing it should not exceed on 24 hours (Figure 1). Water temperature, pH and Salinity were measured directly in situ using graduated thermometer, pH-meter (HQ40d multi/HACH) and hand-held Salinity refract meter respectively. A turbidity meter (2100Q HACH) was used to measure turbidity of the water samples. Dissolved oxygen was fixed immediately after collection and then determined by Winkler's method, two samples were considered for this analysis. DO was determined for the first sample immediately. The second sample was incubated for five days and then the DO was determined. Total Dissolved Solids were measured by the following equation (TDS mg/l = EC*0.67. The BOD was determined using the relation, BOD = DO before incubation - DO after incubation. The oxygen requirement was determined for samples using spectrophotometer (model DRB 200, HACH, USA) at 620 nm after digesting it for 2 hours at 150 ^oC using COD Reactor (DRB 200, HACH, USA). 100 ml of the sample was filtered by a sterile filtration device and 0.7um pore film filter paper, then the membrane filter paper was taken with sterile forceps and placed in a petroleum dish containing 2 ml of food medium (M-Fc Broth), and the dish was transferred to the incubator at a temperature of 44 f ºCor 24 hours after the incubation period passes, and if colonies are formed, they are counted either with the naked eye or by using the colony counter (APHA., 1999). The samples of nutrients (NO_3^-, NO_2^-, PO_4^{-3}, SiO_4^{-4}) were measured using spectrophotometric techniques (DR 3900, HACH, USA) according to methods described by at wavelengths of 500, 507, 890 and 452 nm on straight. The Samples of SiO_4 determination were analyzed by using UV-Spectrophotometer DR 3900 HACH (APHA., 1999). 100 ml of the sample was filtered to test Fecal Coliform (FC) with a sterile filter device and 0.7 µm porous membrane filter paper, then the membrane filter paper was taken with sterile forceps and placed in a petroleum dish containing 2 ml of food medium (M-Fc broth), and the dish was transferred to the incubator at Temperature 44 F or 24 hours after the incubation period has passed, and if colonies have formed they are counted either with the naked eye or using a colony counter (APHA., 1999). 100 ml of the sample was filtered by a sterile filtration device and 0.45um pore film filter paper to test Total Coliform(TC), then the membrane filter paper was taken with sterile forceps and placed in a petroleum dish containing 2 ml of food medium (M-Endo Broth), and the dish was transferred to the incubator at a temperature of 37 f ºCor 24 hours after The incubation period passes, and if colonies are formed, they are counted either with the naked eye or by using the colony counter (APHA., 1999). Various quality control and quality assurance measures were adopted during the data collected and processing to ensure reliability of the results. All materials and equipment were cleaned, and the instruments were calibrated daily before starting work, to ensure the validity and reliability of the results, and the work was repeated three times for each sample.

2. RESULTS &DISCUSSION

3.1 Physicochemical characteristics

Table (1) shows the annual mean of the results of various characteristics and elements in the study area, including the maximum value, minimum value, rang and annual average, as well as the standard deviation and other statistical accounts. The results of physicochemical parameters of the samples of seawater for winter and summer seasons are displaying in figure 2. Seawater temperature plays a vital role in the metabolism of aquatic ecosystems. When the water temperature rises, the toxicity of heavy metals becomes more dangerous for marine organisms.

3.1.1 Seawater Temperature

The temperature values of seawater ranged between 26.00 °C and 27.30 °C during December of winter 2019 with an average value of 26.69 °C, and 32.10 and 33.70 °C in June of summer in 2020 with an average value of 32.88 °C and annual mean (29.73 °C). The variation that recorded during the seasons of study period in normal rate but above the Limits of WHO 2011 (26.00-30.00 °C) (WHO., 2011).

3.1.2 Salinity

The Salinity values ranged between 37.3 % and 38.4 % during December of winter 2019 with an average value of 37.86 %, and 39.10 and 41.10 % in June of summer in 2020 with an average value of 40.16 %.) and annual mean (39.01%). The highest values of salinity were recorded at ST4 which affected by waste waters. The average salinity values showed limited changes with an average (1.24) PSU in winter and summer seasons.

3.1.3 pH

The pH value of seawater is an important parameter for the biological activities in the marine environment. It is reflecting of the state of pollution and productivity. The pH values ranged between 7.9 and 8.33 during December 2019 with an average value of 8.08, and 7.52 and 8.60 in June of 2020 with an average value of 7.86 and annual mean value (7.99). The significant differences in surface water pH value where decreased in ST1 (7.9) in winter season related to degradation processes of the dead organic matters by aerobic and anaerobic bacteria, releasing more CO_2 into the water column where increased pH value in ST8 (8.60) this is probably related to the photosynthesis of many algae and sea grasses in this area leading to uptake of CO_2 from seawater and consequently pH increases. This was confirmed from the positive relationship exists in the pH values of water with dissolved oxygen ($r = 0.81$: $p < 0.01$), where the two parameters were used as good indicator for the production level.

3.1.4 Dosolved Oxygen

DO is one of the most important variables in the marine environment. It uses to determine the different water masses and the role of distribution of domestic production and consumption to a large extent. In Al Hudaydah coastal area, the absolute DO values ranged between 4.2 mg /l at ST1 and 7.0 mg/l at ST8 (with an average value of 5.17 mg/l) during December of 2019 and 4.00 mg /l at ST1 and 6.8 at ST8 (with an average value of 5.06 mg/l) during June of 2020 and annual mean value (5.12 mg/l). The high values of DO in surface water can be attributed to the exchange of O_2 from the air to the surface water as well as to algal photosynthesis (Al-qadasy *et al*., 2017).

3.1.5 TDS

The results of TDS varied from 39.73 g /l at ST8 and 41.47 g/l at ST1 (with an average value of 40.51 g/l) during December of 2019 and from 40.736 g /l at ST8 to 41.54 g/l at ST1 (with an average value of 41.213 g/l) during June of 2020 and the annual mean (40.86 g/l). The annual mean of TDS is 40.86 (Table 1). The elevated in values of TDS related to electrical conductivity values, as they increase and decrease with increasing and decreasing electrical conductivity as shown in Figure (2).

3.1.6 Turbidity

The turbidity values in the study area ranged between 1.5 NTU and 16.0 NTU during December of winter 2019 with an average value of 8.48 NTU, and from 3.0 to 20.0 NTU in June of summer in 2020 with an average value of (13.1 NTU) and annual mean (10.80 NTU). ST1 recorded the highest value in both winter and summer seasons and ST8 recorded the less content in the two seasons. The seasonal values showed that the turbidity values were higher during summer compared to winter. This variation may be due to the abundance of phytoplankton, massive contribution of suspended solids from sewage and the influx of rainwater carrying suspended soil particles via wadies and other substances to sea in summer. The increase in stations 1,4 and 6, may be due to increase sewage discharge and soil particles into sea water. The statistical analysis in figure 3 shows the positive strong relation between turbidity and TDS (r^2:0.96) and negative relation with the DO (r: -0.91).

3.1.7 Electrical Conductivity

The electrical conductivity values ranged between (59300 µs/cm to 61900 µS/cm) with a mean of 60462 µS/cm in winter season as shown in (Figure 2). Whereas it ranged from 60800 µS/cm to 62000 µS/cm with a mean of 61512 µS/cm in summer season and annual mean (60987.50 µS/cm). The maximum value of electrical conductivity in summer season was at ST1 and ST4 which was (62000 and 61900 µS/cm). This increasing related to increase sewage discharge that contains ions such as chloride, nitrates, and phosphates that contribute to increase electrical conductivity as well as an increase temperature in these two stations. It is also an indicator of pollution which shows the presence of more inorganic ions in the effluent discharges received by the water (Dar et al., 2012). The minimum value of electrical conductivity in winter season was finding at ST8 and ST7 which was (59300 and 59400 µS/cm). This related to rainwater runoff which mixing with seawater and decreasing electrical conductivity. Total dissolved solids values ranged from 39.731 g/L to 41.473 g/L with a mean value 40.509 g/L in winter season **(**Figure 2**)**. The maximum value of total dissolved solids e was recorded at ST1(41.473 g/L) and ST4 (41.339 g/L). Whereas it ranged from 40.736 g/L to 41.540 g/L with a mean of 41.213 g/L in summer season. The maximum value of electrical conductivity was at ST1 and ST4 which was (41.473 and 41.373g/L).

3.1.8 Biochemical Oxygen Demand

BOD concentrations ranged from (0.3 to 2.95 mg/L) with an average of (1.76 mg/L) in winter season as shown in figure 2. The obtained BOD data showed that the maximum values recorded in ST1 and ST4 were (2.95 and 2.81 mg/L) respectively. The BOD values in the seven stations were higher compared to the reference station. In summer season, BOD recorded the highest levels from 0.50 to 3.20 mg/L and an annual mean value of (1.98 mg/l). This elevation in BOD content may be related to the high temperature, sunshine and their effect on the activity of living organisms in seawater. The results of the statistical analysis showed that the mean values of biochemical oxygen demand for each station were significantly different at $p < 0.05$ between the eight stations. The increasing the contents of BOD in ST1 and ST 4 comparing to other stations, this may be due to the abundance of nutrients associated with wastewater which are ST1 and ST4 closely to the sources of wastewater discharge. This leads to an increase in the number of microorganisms, and therefore the demand for dissolved oxygen in this water increases, while the lowest concentration (0.30 mg / L) was in ST 8 (the reference station) which was far from the sources of pollution. As shown in figure 2. Figure 4 shows the strong relation between DO and BOD (r^2:0.90).

3.1.9 Chemical Oxygen Demand)

Chemical oxygen demand concentrations as shown in figure 2 ranged from 1300 to 2300 mg/L, with mean of (2025 mg/L**)**. The obtained COD data showed that the maximum values recorded at ST 3 and ST 6 which were (2300 mg/L) while the lowest concentration was (1300 mg/L) at ST 8 (the reference station) that was farther from pollution sources. As shown in (Figure 2) COD values in the seven stations were higher compared to the reference station in summer season, COD recorded the highest levels from 1500.00 to 2700.00 mg/L with an average 2206 mg/L and the annual mean (2115.63 mg/L). The results of this study were less than those observed by (Mohorj and Khan., 2006) in the red sea coast near Jeddah, Saudi Arabia found COD values ranging from (88 to7680 mg/L). The results of statistical analysis showed that mean values of chemical oxygen demand for every stations were significantly different at $p<0.05$. Figure 4 shows the good positive relation between DO and COD (r^2:0.62).

3.2.1 Fecal Coliform

The Fecal Coliform (FC) values ranged between (0-120 MPN/100ml) during December of winter 2019 with an average value of (46.265 MPN/100ml), and (0 – 165 MPN/100ml) in June of summer in 2020 with an average value of (57.5 MPN/100ml) and annual mean (51.94 MPN/100ml). The seasonal variation of the Fecal Coliform was higher during summer and lower during winter. This variation due to the huge amounts of untreated sewage which discharge into seawater, as well as other various human activities during summer season and the absence of environmental and regulatory controls. The results of the microbiological analyzes showed high levels of microbiological counts in the study area, especially in ST 1 and ST 4, as well as ST 2 and ST 5 compared to other stations, this is considered a dangerous indicator of the water pollution and its dangerous impact on living organisms. The results of this study were lower than those observed by Mok., *et al*. (Mok *et al*., 2016) in the seawater Korea found the FC concentrations of pollution sources ranged from (17 to 790,000 MPN/100 mL) and Bhat and Danek (2012) found FC values ranging from (86 – 583 MPN/100 mL) in town of Suwannee, a coastal area in southeastern USA. Figure 4 shows the positive relation between DO and FC (r^2:0.54).

3.2.2 Total Coliform

The Total Coliform values ranged between (120-1125 MPN/100ml) during December of winter 2019 with an average value of (613.8 MPN/100 ml), and (180 – 1244 MPN/100ml) in June of summer in 2020 with an average value of (696.3 MPN/100ml) and annual mean (653.814 MPN/100ml). The seasonal variation of the content of Feale Coliform during summer and winter, due to the huge amounts of untreated sewage which discharge into seawater, as result of increasing the consuming of water in different sectors during summer season. The high levels of microbiological counts in the study area, especially in ST 1 and ST 2, as well as ST 6 and ST 3 is considered a dangerous indicator of the water pollution and its dangerous impact on living organisms. Figure 4 shows the positive relation between DO and TC (r^2:0.54).

3.3. Nutrients

Nutrients are dissolved forms of inorganic matter, such as Sulphate, Nitrates, Phosphates that are utilizing by photosynthetic organisms in the formation of organic matters (Saha *et al*., 2001). The nutrients distribution in the costal sea water depends upon rainfall, land run-off, tidal action, and the biological activities of the flora and the fauna. An increase in nutrients impacts the organism by eutrophication like processes (Kuma., 2012).

3.3. 1. Nitrate

The Nitrate (NO_3^-) values displayed in figure [2] ranged between (0.4 – 7.1 mg/l) during December of winter 2019 with an average value of (3.36 mg/l), and (0.3 – 6 mg/l) in June of summer in 2020 with an average value of (2.85 mg/l) and annual mean (3.11 mg/l). The seasonal variation of the nitrates was lower during summer and higher during winter, due to the high temperature, which increases the photosynthesis process and thus the increased consumption of nitrate by phytoplankton growth. The results of this study were higher than those observed by Al-Amara., et al (2008) in the Red Sea coast of Yemen, that found NO_3 values ranging from (0.249 -2.31 mg/L) in winter and (0.224- 2.16 mg/l) in summer and Madkour and Dar (2007) who found the range for NO_3 was (0.019 -3.132 mg/L) in the Red Sea coast at Hurghada, Egypt, but it was less than that reported by Mohorjy and Hussein (2006) who found the range for NO_3 was (6.90 -26.61 mg/L) in the Red Sea coast near Jeddah, Saudi Arabia.

3.3.2 Nitrite

The Nitrite (NO_2^-) values ranged between (0.009– 0.15 mg/l) during December of winter 2019 with an average value of (0.06 mg/l), and (0.005 – 0.06 mg/l) in June of summer in 2020 with an average value of (0.03 mg/l) as shown in figure [2] and annual mean (0.040 mg/l). The seasonal variation of the NO_2 were less in summer and high in winter due to the high temperature, which increases the photosynthesis process and thus the increased consumption of nitrate by phytoplankton growth. The results of this study were higher than those observed by Al-Amara., *et al*. (2008), in addition to and Fahmy, *et al*. (2016) found the range for NO2 was (0.0004 -0.01 mg/l) in red sea coastal Egypt.

3.3.3. Phosphate

The Phosphate (PO_4^{-3}) values ranged between (0.4– 1.78mg/l) during December of winter 2019 with an average value of (0.98 mg/l), and (0.2 – 1.9 mg/l) in June of summer in 2020 with an average value of (1.15 mg/l) as shown in figure [2] and annual mean (1.07 mg/l). Seasonally, the present study indicated that the high levels of phosphate in summer compared to winter, this increase due to the increase in household water discharges containing high concentrations of soap and detergents due to the high temperature in this season. The results of this study were higher than that reported by Al-Shwafi (2001) in Mangrove environment of Red sea coast of Yemen who registered PO_4 values ranged (0.003 – 0.0061 mg/L), Al-Shwafi and Mohsen (2009) who found PO_4 values ranging from (0.0103 – 0.0112 mg/L) in Hadhramout coast- Yemen, but it was less than that reported by Mohorjy and Hussein (2006) who found the range for PO_4 was (0.74-3.81 mg/L) in the Red Sea coast near Jeddah.

3.3.4. Silicate

The Silicate ((SiO_4^{-4}) content ranged between (0.11– 0.43 mg/l) during December of winter 2019 with an average value of (0.28 mg/l), and (0.1 – 0.48 mg/l) in June of summer in 2020 with an average value of (0.39 mg/l) as shown in figure 2 and annual mean (0.34 mg/l). Seasonally, the present study indicated that the high levels of Silicate in summer compared to winter, due to increased untreated sewage discharge, the effect of run-off from land and sandstorms in this season. The results of this study were lower than that reported by Al-Mur [28] in Jeddah Coast, Saudi Arabia were SiO_4 values ranged (0.29 – 0.633 mg/L) and Salah and Al- Halmi (2021) found the range for SiO_4 were (0.468 -0.998 mg/l) in surface seawater from the Aden coasts/Gulf of Aden.

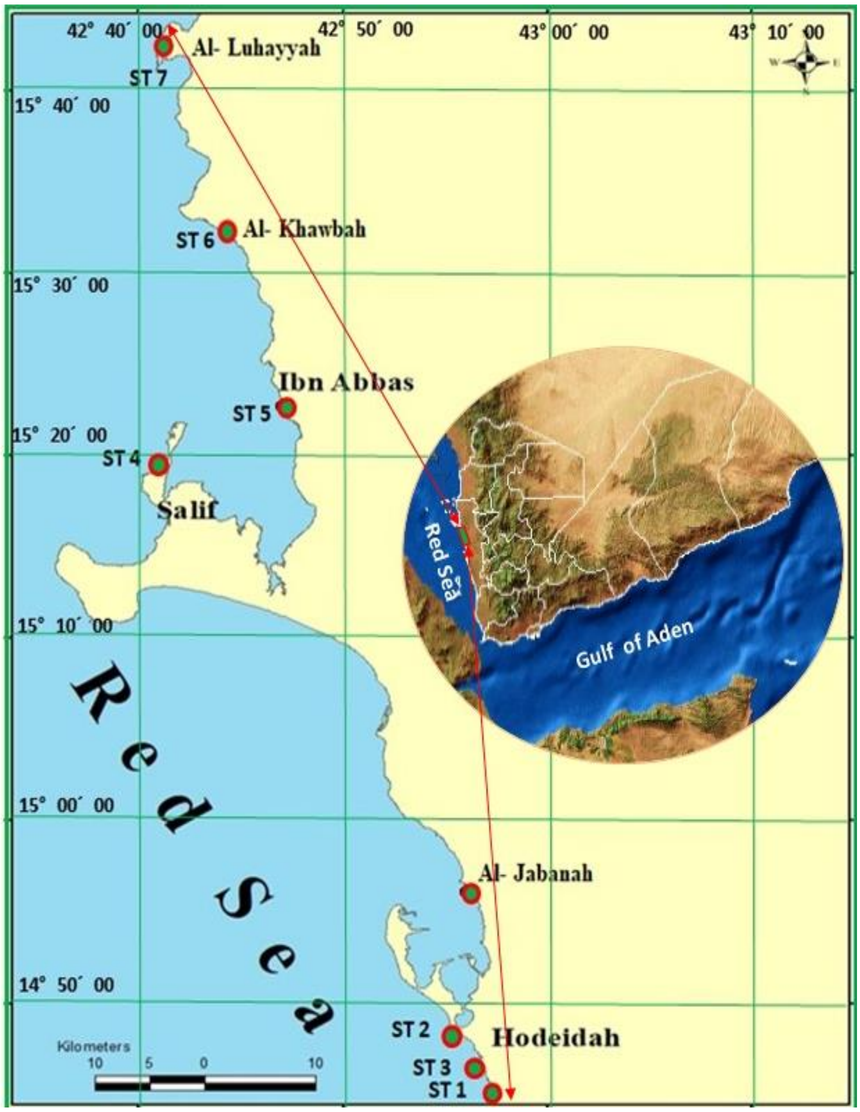

Fig-1: Sampling locations in the study area

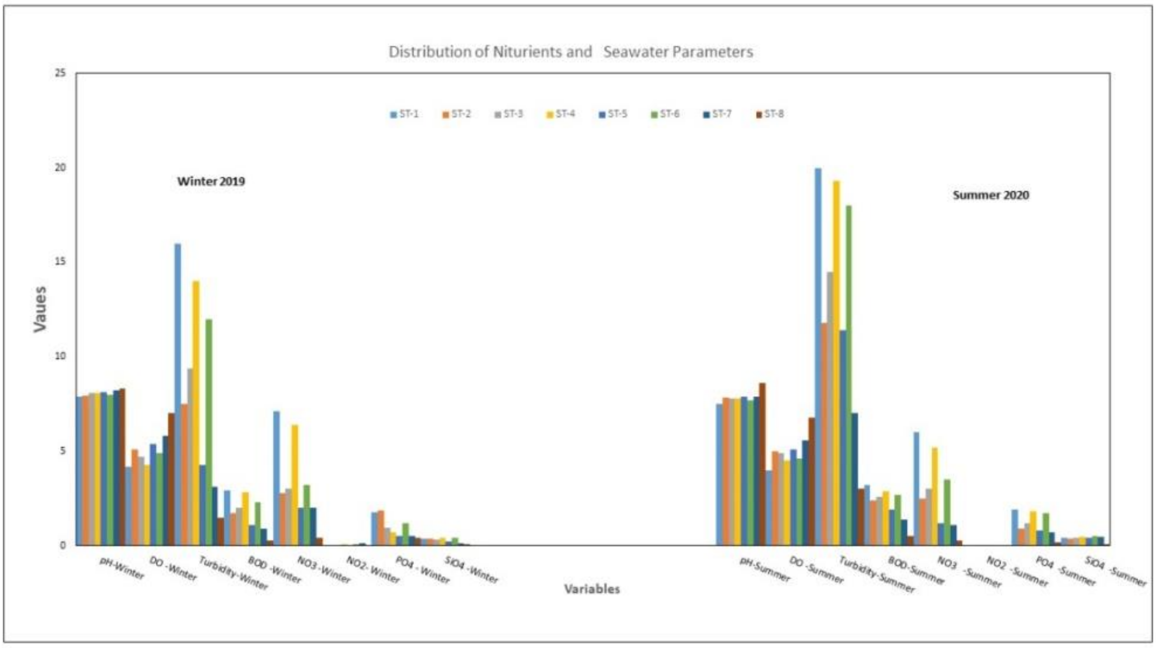

Fig-2: Distribution the results in the study area

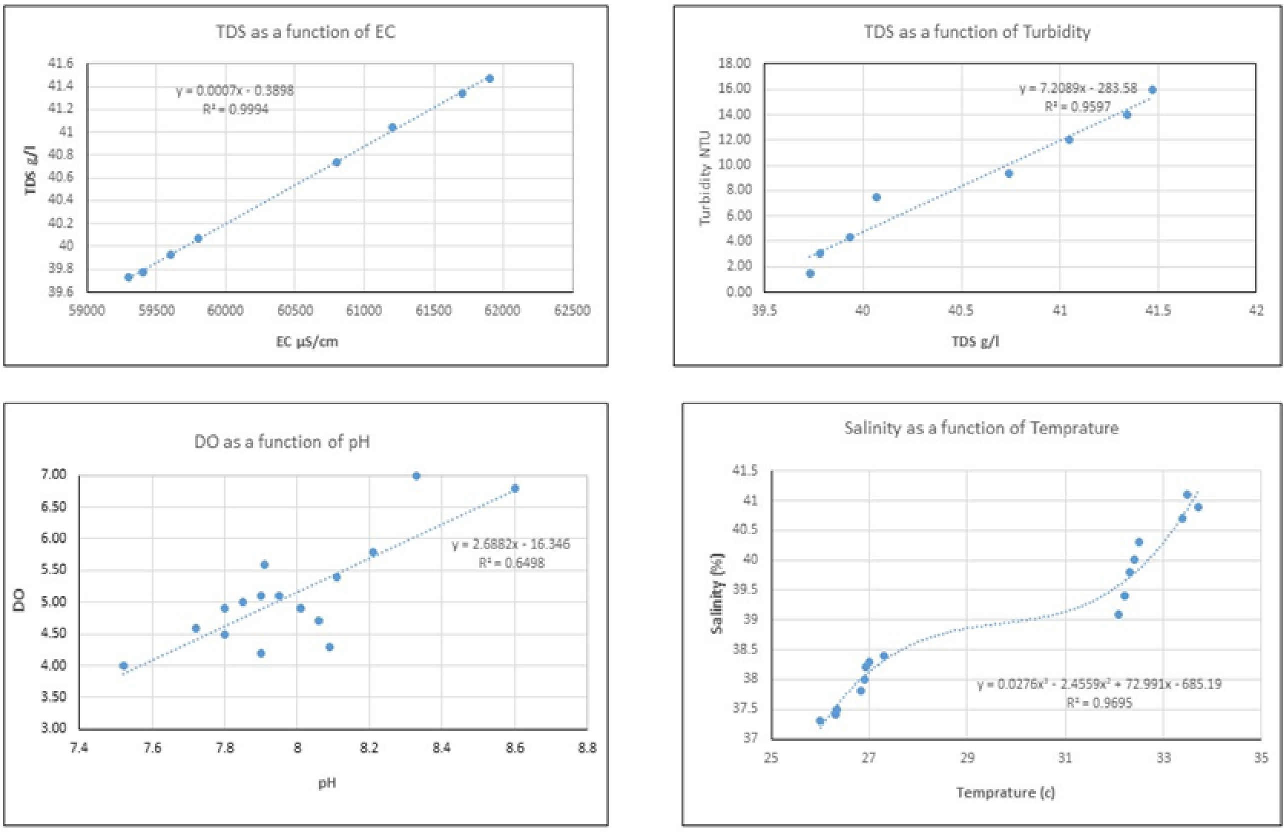

Fig-3: The relationships between the results of physicochemical characteristics

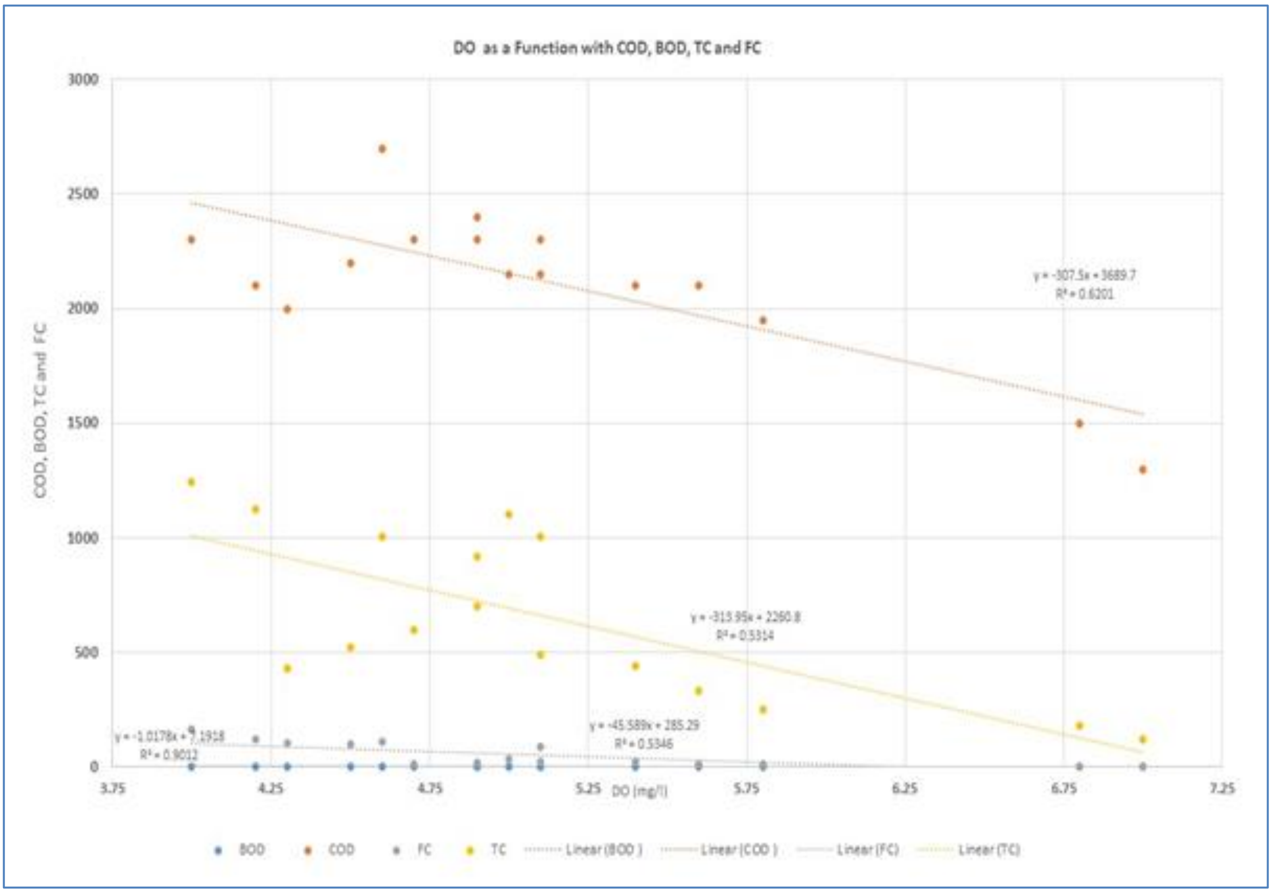

Fig-4: DO as a Function with COD, BOD, TC and FC

Table-1: Descriptive Statistics of the Results in the Study Area

Variable	Values of Parameters														
	T °C	S %	pH	DO mg/l	EC Us/cm	TDS g/l	Tur NTU	BOD mg/l	COD mg/l	NO_3 mg/l	NO_2 mg/l	PO_4 mg/l	SiO_4 mg/l	FC MPN/100ml	TC MPN/100ml
Minimum	26.00	37.30	7.52	4.00	59300.00	39.73	1.50	0.30	1300.00	0.30	0.00	0.20	0.09	0.0	120
Maximum	33.70	41.10	8.60	7.00	62000.00	41.54	20.00	3.20	2700.00	7.10	0.15	1.90	0.50	165	1244
Range	7.70	3.80	1.08	3.00	2700.00	1.81	18.50	2.90	1400.00	6.80	0.15	1.70	0.41	165	1224
Mean	29.73	39.01	7.99	5.12	60987.50	40.86	10.80	1.98	2115.63	3.11	0.04	1.07	0.34	51.94	653.814
Standard Deviation	3.18	1.32	0.25	0.85	944.37	0.63	5.99	0.91	332.02	2.09	0.04	0.58	0.14	53.01	366.18
Standard Error	0.79	0.33	0.06	0.21	236.09	0.16	1.50	0.23	83.01	0.52	0.01	0.14	0.03	51.94	653.81
Variance	10.09	1.74	0.07	0.72	891833.30	0.40	35.91	0.83	110239.60	4.37	0.00	0.33	0.02	2810.59	134086.8
Lower 95% CL Mean	28.04	38.31	7.85	4.67	60484.28	40.52	7.61	1.50	1938.70	1.99	0.02	0.76	0.27	23.69	458.69
Upper 95% CL Mean	31.42	39.72	8.12	5.57	61490.72	41.19	13.99	2.47	2292.55	4.22	0.06	1.38	0.41	80.19	848.94
Median	29.70	38.75	7.93	4.95	61300.00	41.10	11.60	2.15	2150.00	2.90	0.04	0.92	0.38	23	650
Mean from Median	3.03	1.15	0.19	0.61	725.00	0.48	4.90	0.75	215.63	1.57	0.03	0.48	0.10	40.94	308.81
Coefficient of Variation	0.11	0.03	0.03	0.17	0.02	0.02	0.55	0.46	0.16	0.67	0.91	0.54	0.40	1.02	0.56
Coefficient of Dispersion	0.10	0.03	0.02	0.12	0.01	0.01	0.42	0.35	0.10	0.54	0.74	0.52	0.27	1.78	0.55

Table-2: Pearson Correlations Matrix

Parameters	Temperature °C	Salinity %	pH	DO mg/l	Turbidity NTU	BOD mg/l	NO3 mg/l	NO2 mg/l	PO4 mg/l	SiO4 mg/l	EC µs/cm	TDS g/l	COD mg/l	FC MPN/100ml	TC MPN/100ml
Temperature															
Salinity	0.957														
pH	-0.500	-0.664													
DO	-0.209	-0.436	0.806												
Turbidity	0.538	0.747	-0.827	-0.873											
BOD	0.384	0.610	-0.823	-0.949	0.965										
NO3	0.023	0.265	-0.558	-0.855	0.788	0.850									
NO2	-0.346	-0.225	0.003	-0.284	0.110	0.177	0.393								
PO4	0.287	0.483	-0.787	-0.747	0.793	0.775	0.687	0.037							
SiO4	0.515	0.663	-0.837	-0.781	0.822	0.823	0.515	-0.052	0.675						
EC	0.666	0.785	-0.626	-0.705	0.875	0.842	0.619	-0.058	0.514	0.773					
TDS	0.654	0.771	-0.622	-0.704	0.867	0.839	0.611	-0.066	0.506	0.772	0.999				
COD	0.375	0.518	-0.804	-0.787	0.705	0.732	0.408	0.153	0.632	0.809	0.550	0.554			
FC	0.256	0.433	-0.648	-0.731	0.766	0.744	0.835	0.151	0.800	0.524	0.538	0.529	0.402		
TC	0.233	0.388	-0.743	-0.729	0.690	0.750	0.591	-0.067	0.808	0.583	0.520	0.533	0.644	0.657	1.000

Table-3: Comparing the results of the study with other studies around the world

Location	NO_3	NO_2	PO_4	SiO_4	BOD	COD	Salinity	EC	TDS	Turbidity	References
Red Sea Yemen	3.11	0.045	1.07	0.34	1.98	2116	39.01	60987	40.861	10.80	Present study
Red Sea Jeddah	0.876	0.046	0.009	0.407	-	-	40.60	-	-	-	Al-Mur, 2020
Red Sea Yemen	0.002	0.001	0.005	0.019	-	-	-	-	-	-	Al-Shwafi, 2011
Red Sea Mokha Yemen	1.34	0.023	0.061	0.22	-	-	-	-	-	-	Al-Amara, *et al.* 2008
Andaman Sea, Malaysia	0.045	0.011	2.98	-	-	-	35.27	-	-	0.51	Idrus, *et al*. 2017
Arabian Sea ,India	15.25	-	0.16	-	0.63	-	-	-	48.66	6.62	Sankpal, *et al.* 2014
Gulf of Aden, Yemen	4.29	0.041	0.599	0.943	2.39	-	-	-	-	8.87	Salah and Halimi 2021
Hadramout Coast ,Yemen	0.019	0.012	0.011	0.03	-	-	-	-	-	-	Al-Shwafi and Mohsen,2009
Mimka Coastal, Indonesia	0.18	-	0.44	-	0.63	-	33.15	-	-	0.74	Tanjung *et al*., 2019
Arabian Sea, India	-	-	0.07	-	0.7	-	34.11	8.21	42.06	5.15	Bhadja and Kundu, 2012
Red Sea , Jeddah	16.76	-	2.28	-	-	1091	-	-	-	-	Mohorjy and Khan , 2006
Red Sea, Egypt	0.05	0.005	0.023	-	-	-	-	-	-	-	Fahmay *et al*., 2016

Table-4: Factors analysis after Varimax Rotation

Variables	Factor1	Factor2	Factor3	Communality
Temperature	0.012064	0.775341	0.116362	0.903767
Salinity	0.092586	0.79486	0.031311	0.918758
pH	0.688657	0.177428	0.000827	0.866912
DO	0.631427	0.115799	0.187583	0.934808
Turbidity	0.475318	0.41019	0.083816	0.969324
BOD	0.555886	0.276972	0.138265	0.971123
NO3	0.394007	0.052249	0.461925	0.908181
NO2	0.000011	0.03437	0.691373	0.725754
PO4	0.814879	0.036641	0.00505	0.85657
SiO4	0.446406	0.346163	0.000912	0.793481
EC	0.15089	0.73746	0.050234	0.938585
TDS	0.153825	0.722007	0.047043	0.922875
COD	0.529275	0.121199	0.000946	0.65142
FC	0.516174	0.059417	0.116166	0.691756
TC	0.804169	0.020366	0.00069	0.825225
Total	6.265574	4.680462	1.932503	12.878539
%	48.65128	36.34311	15.00561	100

4. STATISTICAL & FACTOR ANALYSIS

The results of this study were distributed in different PCA factors communalities after Varimax Rotation. According to the results of the PCA, the original variables could be reduced to three components. Eigenvalues less than 1, which accounted for 11.499 of the total variances (Table 4). Factor 1 (F1) accounting for 6.266 and represents 48.651 % of total variance. It includes with strong positive loadings: PO_4 (0.814879), TC (0.804169), in addition to high and good positive loadings for pH (0.688657), DO (0.631427), BOD (0.555886), COD (0.529275) and FC (0.516174). Factor 2 accounts 4.680 and represents 36.343 % of the total variance. It shows poor positive loadings in Salinity (0.79486), Temperature (0.775341), EC (0.73746) and TDS (0.722007). Factor 3 represents the mixed of F1 and F2 and accounts 1.933 and represents 15.933 % of the total variance. It controlled by NO_2 that has (0.691373) of total loading of factor 3 and NO_3 that shows good positive loading (0.461925).

As can be seen in correlation matrix displayed in the table (2), the relations between most of the characteristics and variables are high to moderate significance excepts DO and pH. DO and pH have negative relationships with all variables except for the positive strong relationship (0.806122) between DO between and pH. It is clear from the table (2), that the discharged water to the marine environment is characterized by a very high load of organic matter and coliform bacteria, and this is clear from the relationship between BOD and all the properties except for the relationship between BOD NO_2.

5. CONCLUSION

It is evident from the results of the study that some of the sites are polluted with sewage waste as a result of being discharged into the marine environment directly without treatment, in addition to use huge amount of soap by public. So, we recommend using the sewage treatment plant to treat the wastewater before discharges into marine environment.

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