Seasonal Variations in the Physico-chemical Characteristics of Coastal Waters in Aden City-Southern Yemen

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Abstract

The seasonal and spatial distributions of physicochemical parameters that determine water quality was studied in Aden coastal. Eight Stations were selected for study in December 2019 (winter season) and June 2020 (summer season), and selected one stations as reference station for compared due its far from pollutants sources. The Physiochemical water quality parameters showed seasonal and spatial variation. Where the sea surface temperature ranged from 26.30 to 33.00 C°. pH was between 7.85 and 8.25. Salinity ranged from 36.50 to 38.40 ppt. Turbidity ranged between 2.15 and 20.10 NTU. Variation in Dissolved Oxygen (DO) content was from 3.74 to 5.40 mg/L. Biochemical oxygen demand (BOD_5) ranged from 0.45 to 3.14 mg/L. The nutrient concentrations showed seasonally and spatially variations, where nitrite and nitrate concentrations were higher in winter and lower in summer, while phosphate and silicate concentrations were higher in summer and lower in winter. Stations 5 and 7 recorded the highest concentrations of nutrients while station 8 (Reference station) recorded the lowest concentrations of nutrients.

Keywords: seawater, Nutrients, physicochemical characteristics, Gulf of Aden, Aden City.

1 Introduction

Water is the most important natural resource and essential for life, as it provides habitat for diverse types of aquatic life in rivers, lakes and oceans, and it covered about 70% of the earth surface. it is known the water constitutes about 70% of the human body. Availability of water resources in countries is a principal factor for the development. Therefore, it is necessary to protect it from the pollution problems and manage it uses **[1,2]**.

Marine systems control the global climate, contribute to the water cycle, preserve biodiversity, offer food and energy resources, and generate opportunities for recreation and tourism **[3]**. Pollution of seawater is one of the serious environmental impacts that threaten human health and marine organisms where this pollution arises in many different forms such as: toxic chemicals (e.g., organic compounds, pharmaceuticals, pesticides, and metals), solid waste pollutants (e.g., plastic bags or bottles), increased nutrients (e.g., nitrates silicates and phosphates) and sediment inputs due to human activities such as

industry, agriculture, deforestation, wastewater discharge, aquaculture, radioactivity, oil spillages, and superfluous fishing nets **[4,5]**.

Scientific researches has confirmed that the effect of pollutants on the marine environment and its living resources varies according to many factors, including: the degree of pollution, the type of contaminated metal, the degree of toxicity of the metal, the type of living organisms exposed to pollution, the period of survival and continuation of pollution, the area in which the pollution occurs, and the prevailing environmental conditions, especially weather conditions, marine currents, waves, temperatures **[6]**.

Physico-chemical parameters are responsible for the spatio-temporal variations of all aquatic organisms. The investigations on meteorological and hydrographical features are necessary for assessing the fertility and productivity of any ecosystem **[7]**. There are many studies that dealt with the physical and chemical properties of sea water in the Gulf of Aden and the Red Sea such as: **[8-16]**.

Aden City is one cities that were not safe from the damages of marine pollution by industrial waste and wastewater, where many hotels, chalets and houses have built on or near the sea coast, population and visitors dispose of some consumer products in the sea shores, as well as untreated sewage is discharged directly into the sea. This study will try to contribute in knowledge through showing of the impact of pollutants especially untreated wastewater on the physical and chemical characteristics of coastal waters in Aden city using several analysis instruments to quantify these pollutants and propose solutions to this problem.

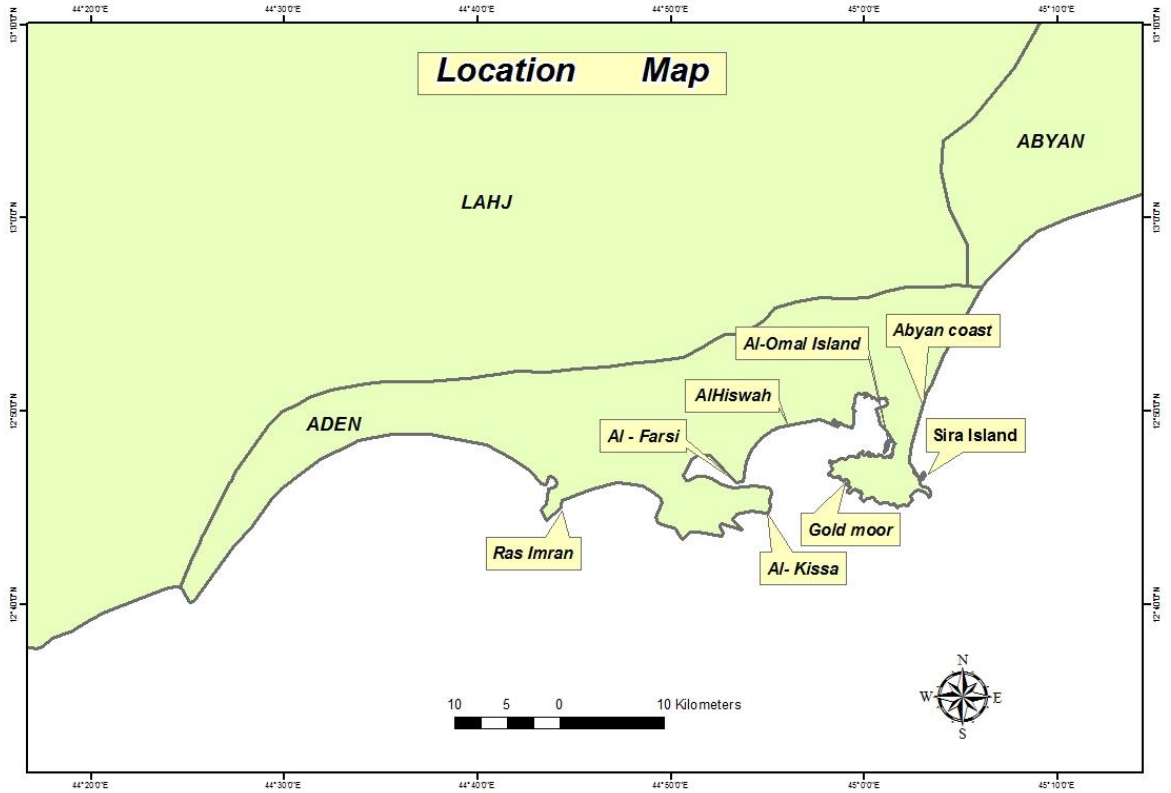


Figure (1): A map showing the locations of the studied samples

2 Materials and Methods

Surface water samples were collected in December, 2019 and June 2020 from eight sampling stations along the coastal area of Aden (Figure 1 and Table 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. The BOD was determined using the relation, BOD = DO before incubation - DO after incubation.

The water samples for NO_2, NO_3, PO_4 and SiO_4 determination were analyzed according to the recommended methods by **[17]**, using UV-Spectrophotometer DR 3900 HACH.

Table (1): Sampling Stations

Name of Station	Station No.	Latitude	Longitude
Sira Island	Station 1	12°46'35"N	45°02'48"E
AL-Omal Island	Station 2	12°48'36"N	45°01'06"E
Abyan Coast	Station 3	12°50'02"N	45°2'04"E
Gold moor	Station 4	12°46'28.4"N	44°59'04"E
AL-Hiswah	Station 5	12°49'27" N	44°55'59"E
AL-Farsi	Station 6	12°46'19.2"N	44°53'16.8"E
AL-Khissa	Station 7	12°44'45" N	44°54'26"E
Ras Imran	Station 8	12°45'52" N	44°44'52"E

3 Results and Discussion

3.1 Physico-chemical characteristics

3.1.1 Water Temperature (C°)

The results obtained for Water Temperature values in the studied sites are presented in (Fig. 2). Seasonal variation of surface water temperature showed higher values in summer (31.20-33.00 C°) compared to winter (26.30-27.10 C°) in all stations, this was associated with the duration of the sun's brightness and high air temperature in this season. The results also showed a spatial variation in surface water temperature values, the highest values were observed in stations 5, 2 and 7 as shown in (Fig. 2), these stations recorded high pollution rates by untreated sewage. Where the rates of chemical and biological reactions increase with increasing temperature, this indicate the effect of sea water pollution with untreated sewage on the water temperature **[18]**. While the lowest value recorded at the reference station.

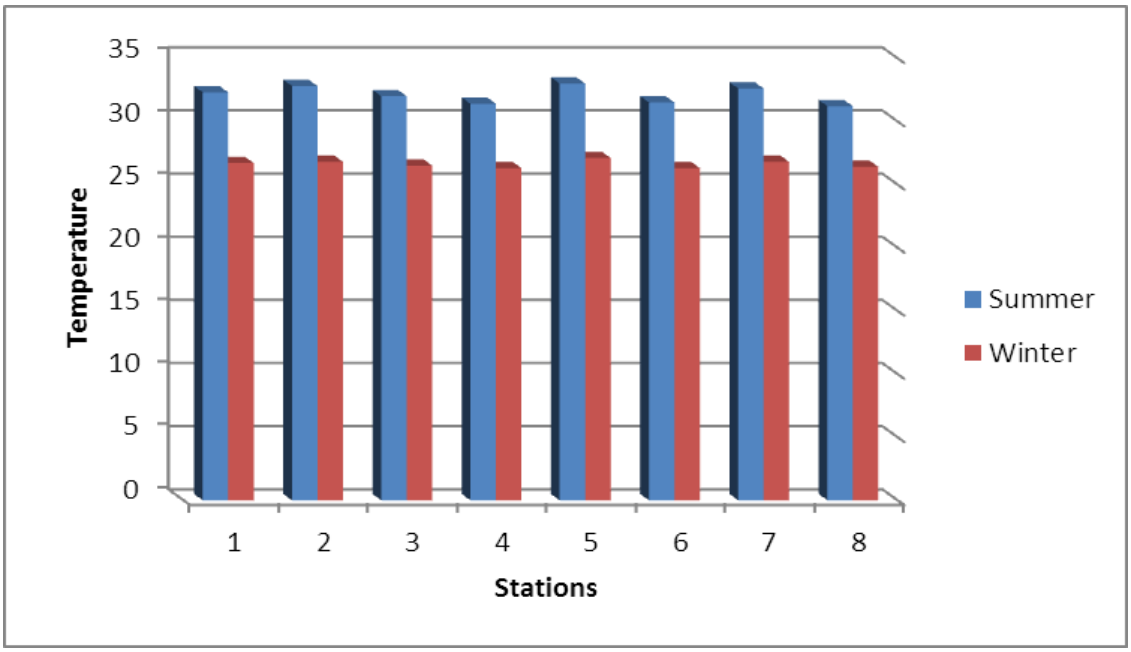


Figure (2): Seasonal variation of Water Temperature (C°) in Aden coasts during study period.

3.1.2 *Hydrogen Ion Concentration (pH)*

The results obtained for pH values in the studied sites are presented in (Fig. 3.). The values obtained for pH at all the locations reflected little influence of season with slightly higher values during summer (7.95-8.29) compared to winter (7.85-8.23), this may be due to the abundance of phytoplankton during summer season where the activity of photosynthesis processes increases causing more consumption of carbon dioxide and pH increased. Generally, in this study the pH values in all stations were slightly alkaline and consistent with the results reported by **[15]** who found the range for pH was 7.87-8.01 in seawater of Aden coastal, **[10]** who found pH values ranged between 7.80 - 8.03 , and the mean value was 7.97 in the Gulf of Aden, and **[13]** in Hadramout coast-Yemen who found the pH range was 7.83-8.01. When comparing the results obtained in this study with the reference station (station 8), the pH values for all stations were lower than the reference station.

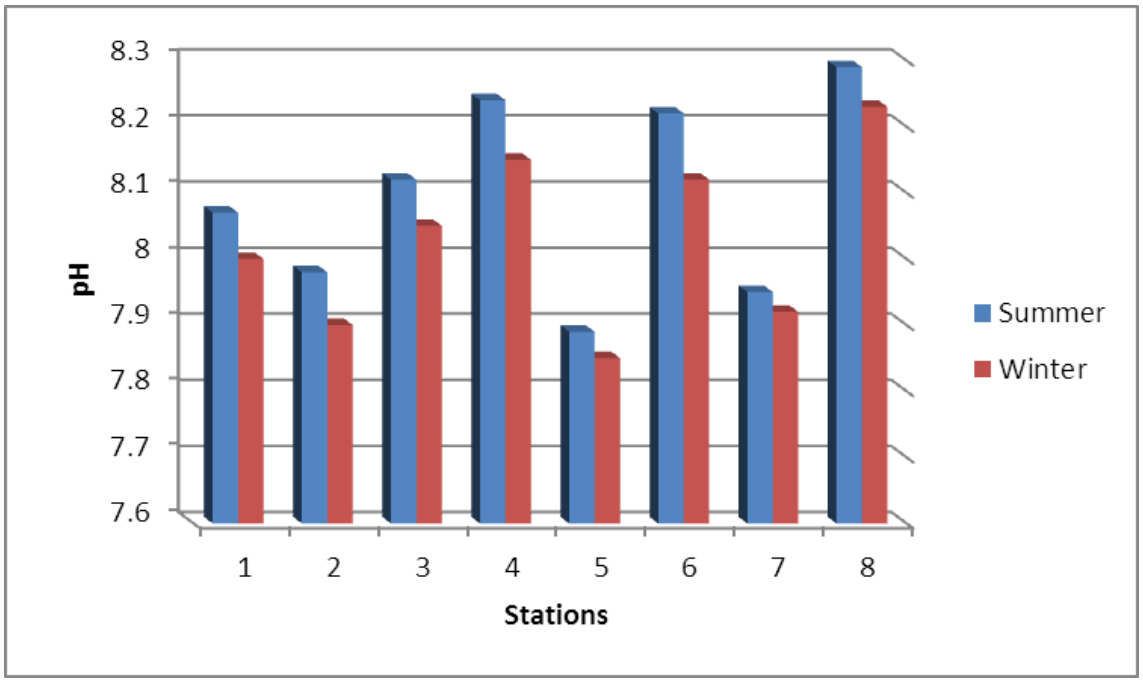


Figure (3): Seasonal variation of Hydrogen Ion concentration (pH) in Aden coasts during study period.

3.1.3 Salinity (S‰= ppt)

The results obtained for Salinity values in the studied sites are presented in (Fig. 4). Salinity of the different locations of the study area varied according to season and distance from wastewater discharge points, the highest salinity values were found in summer (37.00-38.40 ppt) compared to winter (36.50-37.90 ppt), this could be associated with higher temperature that leads to increasing evaporation rate of seawater in summer. Station 2 (AL-Omal Island) and station1 (Sira) exhibited the higher values of salinity, this may be due to that these sites, are more semi-closed coasts, whereas stations 7 (Al-Khissa) and station 5 (Al-Hiswah) recorder slightly low in salinity values, this may be due to increase sewage discharge at these sites.

Compared with the reference station (station 8), the salinity values of all stations were lower than the value of the reference station except for station 2 and 1, which were higher. The results of this study were similar with the results that reported by **[15]** who found salinity values ranging from 37.3 to 38.3 ppt in sea water coasts of Aden city-Yemen, but it was higher than that reported by **[13]** who found salinity values ranging 36.09-36.40 ppt in Hadramout coasts-Yemen. The statistical analysis showed significant differences between summer and winter seasons in salinity at ($P \leq 0.05$), and significant differences between stations.

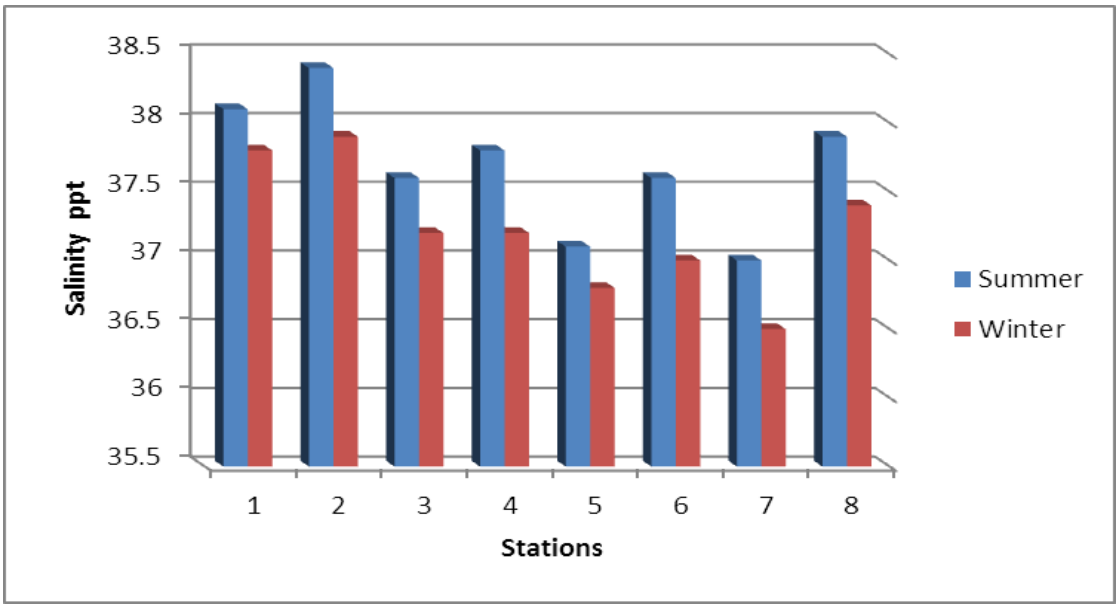


Figure (4): Seasonal variation of Salinity (ppt) in Aden coasts during study period.

3.1.4 Turbidity

As shown (Fig. 5), seasonal variations showed that the turbidity values were higher during summer (2.42-20.10 NTU) compared to winter (2.15-14.40 NTU), where the statistical analysis revealed significant differences ($P \leq 0.05$) in pH between seasons (25.64%), may be due to the abundance of phytoplankton, massive contribution of suspended solids from sewage and the influx of rainwater carrying suspended soil particles and other substances to sea in summer.

The highest values of turbidity during winter and summer were found in stations 5 and 7 (14.40, 20.10 NTU) and (11.55, 16.80 NTU) respectively, the increase in station 5, may be due to increase sewage discharge to Al-Hiswah Reserve and its runoff with plant debris, animal waste and soil particles into sea water, also the increase in station 7, may be due to the drainage of sewage from the village of Al-Khissa directly to the coast, as well as it is an area where fishing boats are anchored. Whereas the reference station (station 8) recorded the lowest value (2.15 NTU) in winter and (2.42 NTU) in summer. The results of this study were higher than that that reported by **[9]** in Hadhramout coast-Yemen (0.1-4.02 NTU). Compared with the reference station (station 8) the turbidity values of all stations were higher than the reference station.

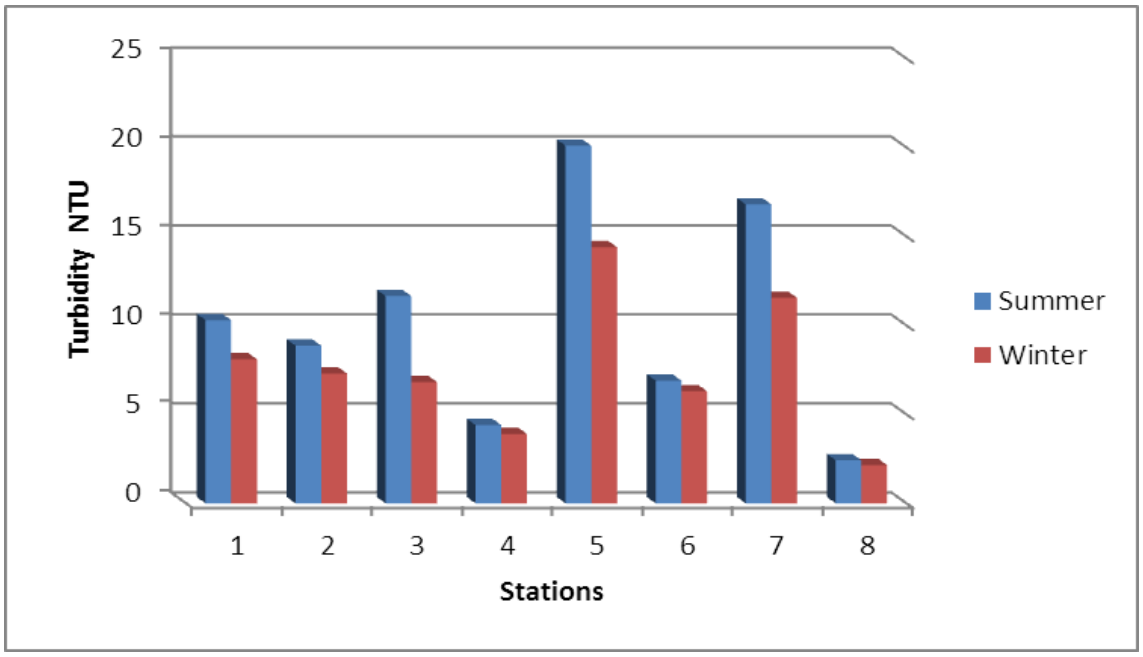


Figure (5): Seasonal variation of Turbidity (NTU) in Aden coasts during study period.

3.1.5 Dissolved Oxygen (DO)

Dissolved oxygen (DO) levels were generally low but variable, between different study stations as shown in (Fig. 6), where the range was from 3.74 mg/L to 5.40 mg/L. Seasonally the results showed low values in summer (3.74-5.18 mg/L) compared to winter (3.88-5.40 mg/L). High temperature, increasing turbidity by rainfall and winds, increasing addition of sewage and other waste in summer might be responsible for low values of DO, this was consistent with reported by **[11]** in the coasts of Al-Hodeidah-Yemen, who found that the DO values were higher in summer compared to winter. The statistical analysis revealed significant differences ($P \leq 0.05$) in DO between seasons (4.25%), and significant differences between stations.

During the study period, the lowest values of DO observed at station 7 and 5, with mean 3.81and 3.88 mg/L respectively, this decrease may be mainly attributed to the microbial activity and consumption of DO in the oxidation of organic matter due d untreated sewage that discharge into these stations, in addition to the presence of energy production plant in the same place impact to change the nature of the marine environment based on study **[19]** who found that the Al-Hiswah Plant effects on seawater quality. While the highest value recorded at station 8 (the reference station).

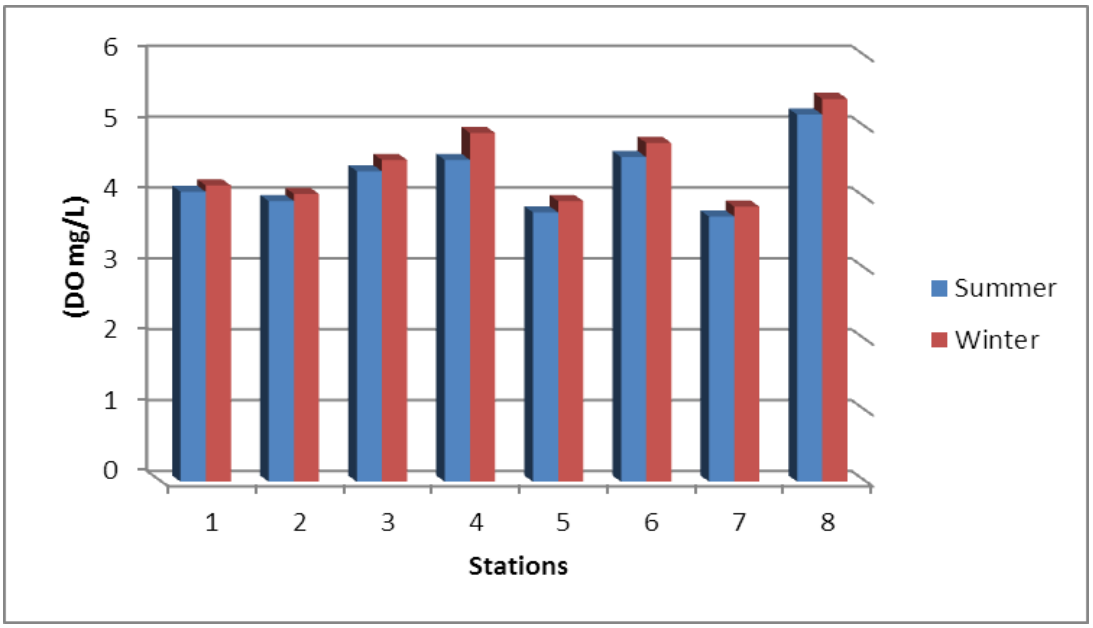


Figure (6): Seasonal variation of Dissolved Oxygen (DO mg/L) in Aden coasts during study period.

3.1.6 Biochemical Oxygen Demand (BOD_5)

BOD_5 values showed that organic matter contents in most the study stations were high, also it exhibited variation between the seasons in all the locations . The values of BOD_5 ranged from 0.45 mg/L at station 8 to 3.14 mg/L at station 7 as shown in (Fig. 7). BOD_5 values recorded the highest levels during summer (0.50-3.10 mg/L) and the lowest during winter (0.45-3.00 mg/L), this may be due to the high temperature, sunshine and their effect on the activity of living organisms in seawater. Compared with the reference station (station 8), the BOD_5 values of all stations were higher than the value of the reference station.

During the period study station 7 and 5 recorded the highest levels of BOD_5, where these stations have a higher pollution rate compared to other stations, this corresponds to the results of the study conducted by **[18]** in Libyan coast, they noticed a decrease in values of dissolved oxygen in some marine sites that have high pollution compared to the sites that have low pollution.

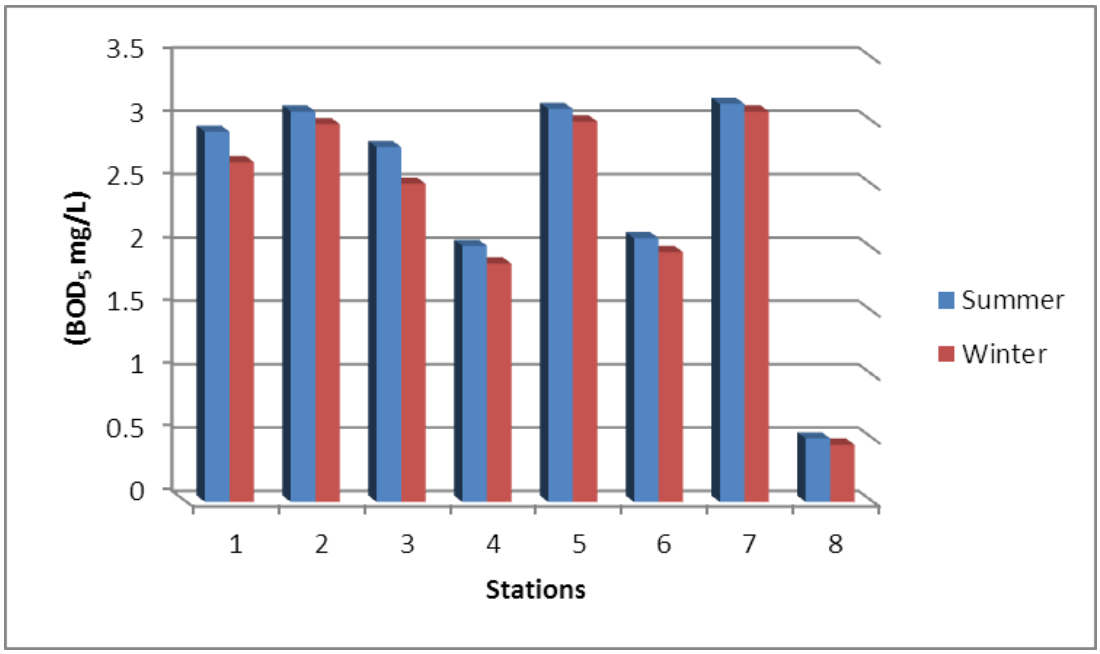


Figure (7): Seasonal variation of Biochemical Oxygen Demand (BOD_5 mg/L) in Aden coasts during study period.

3.1.7 Nutrient Salts

The Gulf of Aden is characterized by a low-salinity, nutrient-rich layer, ranging in depth between 120 and 420 m **[20].** The nutrients concentrations are generally high in the study area, especially in the stations near sewage outfalls, this indicates that the main source of nutrients in this study is untreated wastewater that is discharged directly to the sea, especially after the sewage treatment Plants stopped in 2015.

3.1.7.1 Nitrite and Nitrate

The content of nitrite and nitrate showed a distinct seasonal variation in this study as shown in (Fig. 8 and 9), where nitrite and nitrate levels were lower during summer (0.002-0.084 mg/L) and (0.750-7.400 mg/L) respectively, and higher during winter (0.006-0.122mg/L) and (0.780-11.500 mg/L) respectively, the decrease may be as a result of nutrients consumption by phytoplankton and aquatic plants which are more concentrated in summer season. Similarly, maximum value in winter season and minimum value in summer season was also recorded by **[21]** in the coastal waters of the Red Sea - Egypt.

During this study, stations 5, 7, 2, and 1 recorded the highest values of nitrate and nitrate, this increase may be due to the increasing amount of domestic discharges into these stations. Whereas stations 3, 6 and 4 recorded the lowest values, this indicates that the effect of untreated wastewater was low in these stations.

Compared with the reference station (station 8), the nitrite and nitrate concentrations of all stations were higher than the reference station. The results obtained in this study were higher than those found by **[14],** where the nitrite concentration ranged between 1.43-7.84 ug/L in the coastal waters of the Red Sea – Yemen.

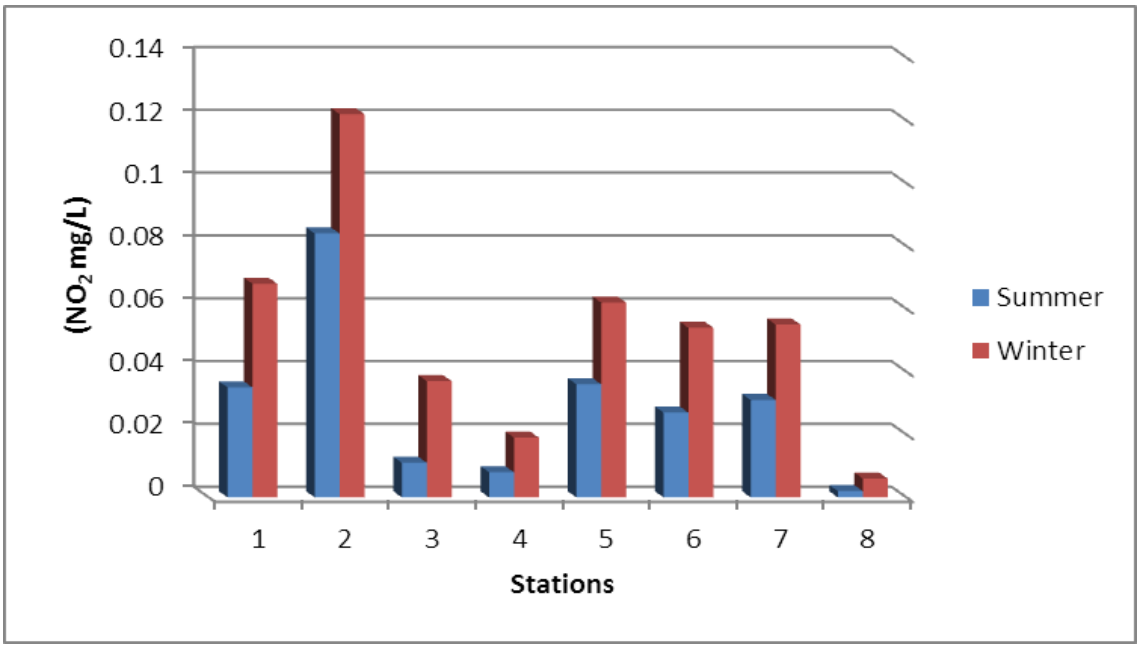


Figure (8): Seasonal variation of Nitrite (NO_2 mg/L) in Aden coasts during study period

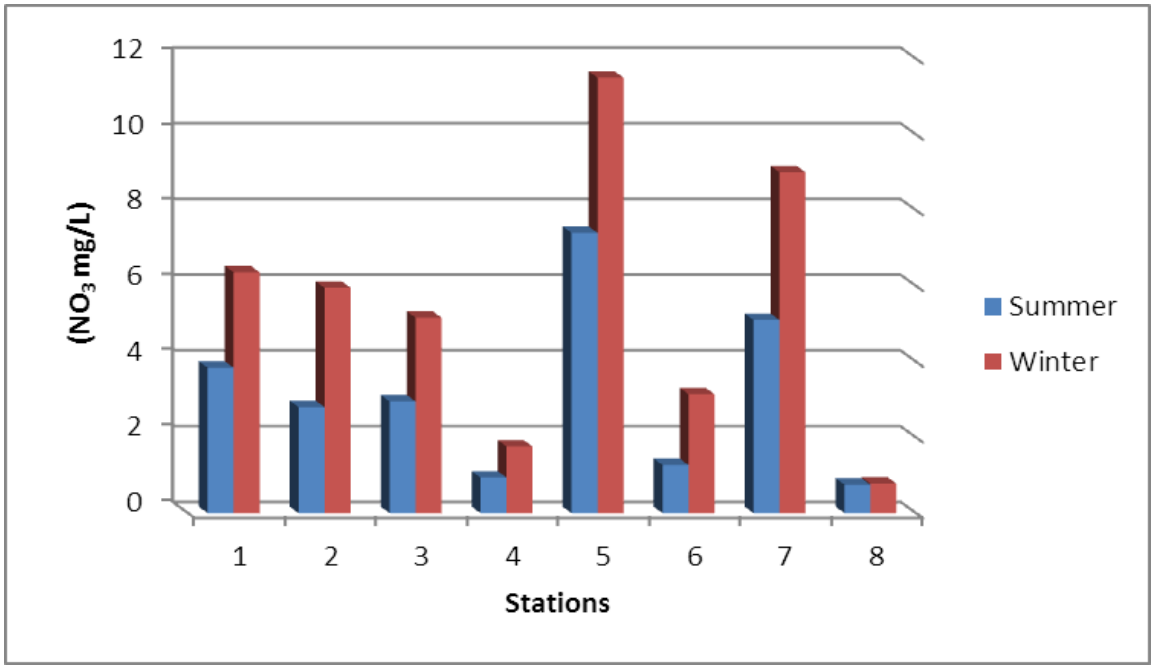


Figure (9): Seasonal variation of Nitrate (NO_3 mg/L) in Aden coasts during study period.

3.1.7.2 Phosphate (PO_4^{-3}) and Silicate (SiO_4^{-4})

As shown in (Fig. 10 and 11), the values of phosphate and silicate ranged (0.030 -1.250 mg/L) and (0.170-2.014 mg/L) respectively. Seasonally, the phosphate and silicate levels were higher during summer and lower during winter.

The statistical analysis revealed significant differences in PO_4 and SiO_4 between seasons (39.54%) and (12.25%) respectively. The high phosphate concentrations in summer may be due to the increase in household water discharges containing high concentrations of soap and detergents. Similarly maximum values in summer and minimum values in winter were also recorded by **[21]** in the Red sea coastal waters-Egyp. Whereas the increase in silicate concentration in summer may be due to increased untreated sewage discharge, the effect of run-off from land and sandstorms in this season.

The result of the analysis of phosphate and silicate in the surface water showed that the highest levels were at stations close to untreated sewage outlets (stations 5, 2, 7 and 1) as shown in (Fig. 10 and 11), this indicating that the sewage as a source of phosphate and silicate in this study. Phosphate and silicate concentrations in this study were higher than that reported by **[16]** in the Coastal Water of Jeddah, Red Sea-KSA, who found the phosphate and silicate values ranged from (ND to 58.31 ug/L) and (ND to 68.84 ug/L) respectively.

The results referred that phosphate concentration in all stations were higher than the reference station, the results also showed that silicate concentrations in most stations were higher than the reference station.

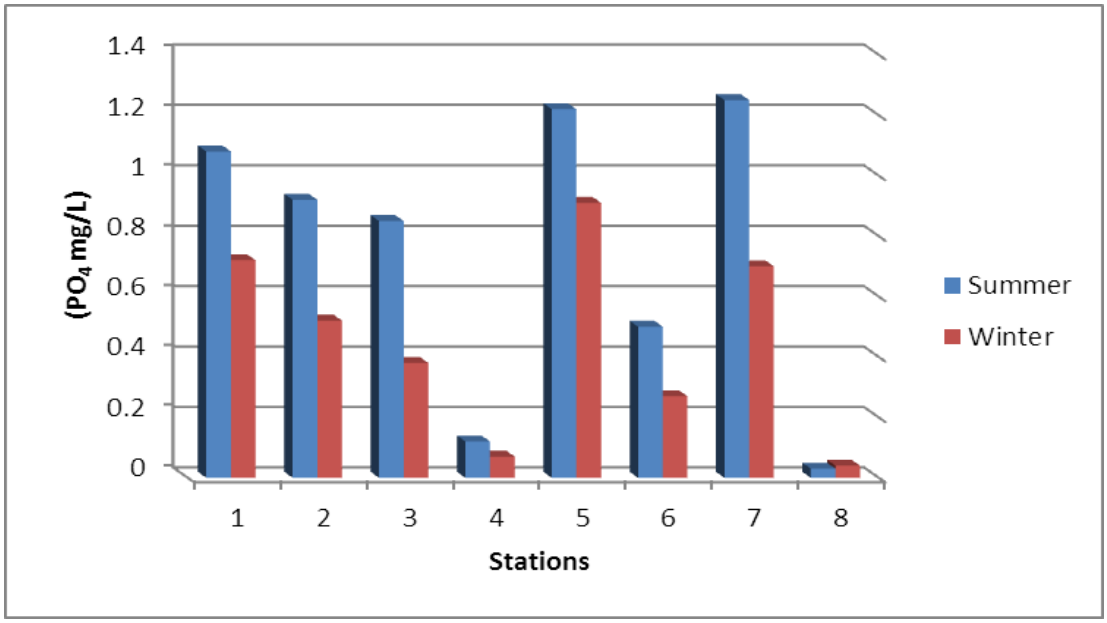


Figure (10): Seasonal variation of Phosphate (PO_4 mg/L) in Aden coasts during study period

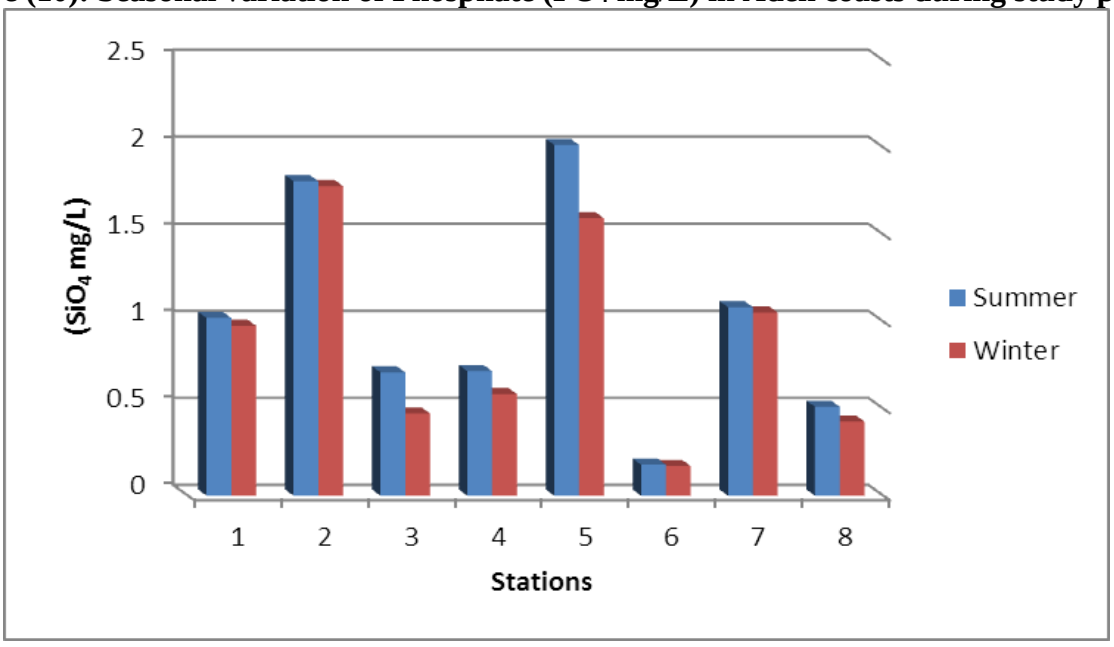


Figure (11): Seasonal variation of Silicate (SiO_4 mg/L) in Aden coasts during study period.

4 Recommendations

Maintaining and repairing the sewage network and reconnecting cities with Al-Arish station. The waste is not directly discharged to the sea until after it has been treated, provided it is safe. Connecting the

rest of the cities, such as Al-Khisa and Amran, to the sewage networks. Regular maintenance of sewage networks and treatment plants. The application of legislation and regulations related to the protection of the marine environment.

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