International Journal of Advanced Biochemistry Research 2025; 9(11): 185-194

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(11): 185-194
www.biochemjournal.com
Received: 12-08-2025
Accepted: 17-09-2025

Milan B Ram
Department of Aquatic Environment Management, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Dipakkumar T Vaghela
Department of Aquatic Environment Management, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Vivek R Tandel
Department of Aquatic Environment Management, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Mayur R Bhadarka
Department of Aquatic Environment Management, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Ritika A Tandel
Department of Fish Processing Technology, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Siddharth B Patel
Department of Aquaculture, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Corresponding Author:
Milan B Ram
Department of Aquatic Environment Management, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Assessment of water pollution index using Physico-chemical characteristics along the Chhara coastal waters, Gujarat

Milan B Ram, Dipakkumar T Vaghela, Vivek R Tandel, Mayur R Bhadarka, Ritika A Tandel and Siddharth B Patel

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i12c.6471

Abstract
The current study was performed on the "Assessment of Water Pollution Index Using Physico-Chemical Characteristics Along the Chhara Coastal Waters, Gujarat". Coastal water samples were taken every month from five different locations along the Chhara coast. The research was conducted between August 2024 and January 2025. A total of 14 physical and chemical parameters were examined. This included pH, salinity, temperature, electric conductivity (EC), turbidity, total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrite (NO_2), phosphate (PO_4), nitrate (NO_3), and hydrogen sulfide (H_2S). The findings of the physico-chemical parameter study were compared with seawater quality criteria. The pollution index for physicochemical parameters in Chhara was determined for the following: pH (0.983), temperature (0.939), turbidity (1.1083), salinity (0.994), EC (1.003), DO (1.203), BOD (1.64), TSS (2.6205), TDS (0.842), TS (0.844), phosphate (1.046), NO_3 (3.0583), NO_2 (2.6033), and H_2S (0.223). The water pollution index was determined to be 1.365 near the Chhara coast. Based on the Water Pollution Index categories, the Chhara coastline was found in lightly polluted Category. This study provided baseline data for water quality parameters and future research.

Keywords: Coastal water quality, Water Pollution Index (WPI), Physico-chemical parameters, Chhara coast, Gujarat

1. Introduction

Oceans are play important role for sustainable development, offering a range of economic, social, and environmental benefits. It is also important for our planet because it helps control the weather, provides homes for lots of different plants and animals, and keeps life going strong. However, since the Industrial Revolution, these marine environments have encountered numerous challenges due to human activities, including overfishing, habitat destruction, and pollution. Additionally, climate change manifested through rising sea temperatures and ocean acidification is disrupting marine ecosystems. Most of the earth is covered by water, about more than 70 percent. Most of the earth's water is around 96 percent ocean water. The remaining 4 percent is freshwater mostly frozen in ice caps, glaciers, and snow, making up about 1.74 percent of the total. Around 1.69 percent of freshwater is groundwater, with the rest being in, lakes, and rivers, like other surface water sources (Kumar *et al*., 2021) [9]. India boasts a coastline exceeding 11,098 kilometers. Approximately 25% of the nation's population resides in coastal regions, relying heavily on marine resources and activities for their livelihoods (CPCB, 1996).

Marine pollution is the direct or indirect introduction of substances or energy into the marine environment by humans, leading to harmful effects such as damage to living resources, threats to human health, obstacles to marine activities like fishing, reduced recreational value, and degradation of seawater quality. Nearly all human activities in coastal waters can cause environmental changes or damage, whether minor or major, short-term or long-term, if not properly planned and monitored (Varkey, 1999) [20]. Water pollution results from human actions such as urban growth, industrial processes, and agricultural practices. The overuse of pesticides and fertilizers, along with the improper disposal of sewage from residential and industrial regions, eventually contaminates aquatic environments. Aquatic pollution is a significant type of contamination with severe health consequences and the potential for causing death. Thus, it is crucial to regularly monitor and regulate the discharge of pollutants into nearby water bodies to lessen the effects of water pollution (Bashir *et al*., 2020) [1].

Mega-cities, with their large populations and industries, produce millions of tons of domestic and other wastes annually, posing a significant disposal challenge. In the 1960s and 1970s, many coastal seas became so polluted that some were rendered lifeless (Varkey, 1999) [20]. Water quality is dependent on environmental conditions and is determined by the physico-chemical parameters of the waters (Hamuna *et al*., 2018) [6].

1.1 Source of Water Pollution
Water pollution can result from natural processes in some instances, but the majority of pollution is caused by human activities (Zhang *et al*., 2020) [21]. Runoff comprises a combination of non-point and point sources of pollutant. Studies conducted in densely populated urban and industrial areas reveal that infectious and toxic pollutants are consistently discharged into runoff waters (Bay *et al*., 1996 [2]; Gold *et al*., 1991 [5]; Field *et al*., 1993) [4]. Point source Water Pollution described as a discharge into surface waters from a specific point through pipelines, outfalls, or waste disposal. While Non-Point source of water pollution, formerly known as "diffuse" pollution, results from a range of human activities where contaminants enter water bodies from widespread sources without a distinct, identifiable point of entry.

1.2 Status of Coastal Water Pollution
Approximately 80% of the unclean water from cities worldwide ends up in rivers, lakes, or the ocean without first being treated (Mateo-Sagasta *et al*., 2017) [11]. In 2009, India's more than 3600 operational wells produced over 880,000 barrels of oil per day. India has the second-largest proven natural gas and oil reserves in the Asia-Pacific area, after China, with about 38 trillion cubic feet and 5.6 billion barrels, respectively, according to the Oil and Gas Journal (Petzet 2010 [15], Sukhdhane *et al*., 2013) [18]. Every year, over 1.56 x 1012 m^3 of runoff from India's coastal rivers enters the ocean, carrying a variety of pollutants from the land. Additionally, the amount of pesticides consumed exploded, rising from 5000 t in 1950 to approximately 84,000 t in 1998-99. Together with China, India currently produces more than 10% of the world's basic pesticide chemicals, making it the second-largest producer in South Asia and Africa after Japan (Zingde 2005) [22].

1.3 Water Pollution Index
The water pollution index (WPI) is a metric used to evaluate and quantify the level of pollution in coastal waters. Managing many variables to define and monitor water quality is often difficult. The water pollution index is a comprehensive and flexible tool that can assess the physical, chemical, or biological quality of water based on current water quality standards. The water pollution index provides a basic understanding of the water's quality for any intended use (Hossain & Patra, 2020) [7].

2. Materials and Methods
2.1 Description of Study Locations
The study was conducted at Chhara coast, which is located in the Gujarat state, Gir-Somnath district of Kodinar Taluka and this area remains largely untouched by major pollutants. Chhara village has also a fish landing center associated with small-scale coastal fisheries and fishing is performed by using a gill net and other artisanal gear. According to the Census 2011, Chhara had a total population of 6310 people and the literacy rate is 56.89%. The total geographical area of the village is 1627.23 hectares. Kodinar is the nearest town to Chhara village for all major economic activities, which is approximately 6 km away.

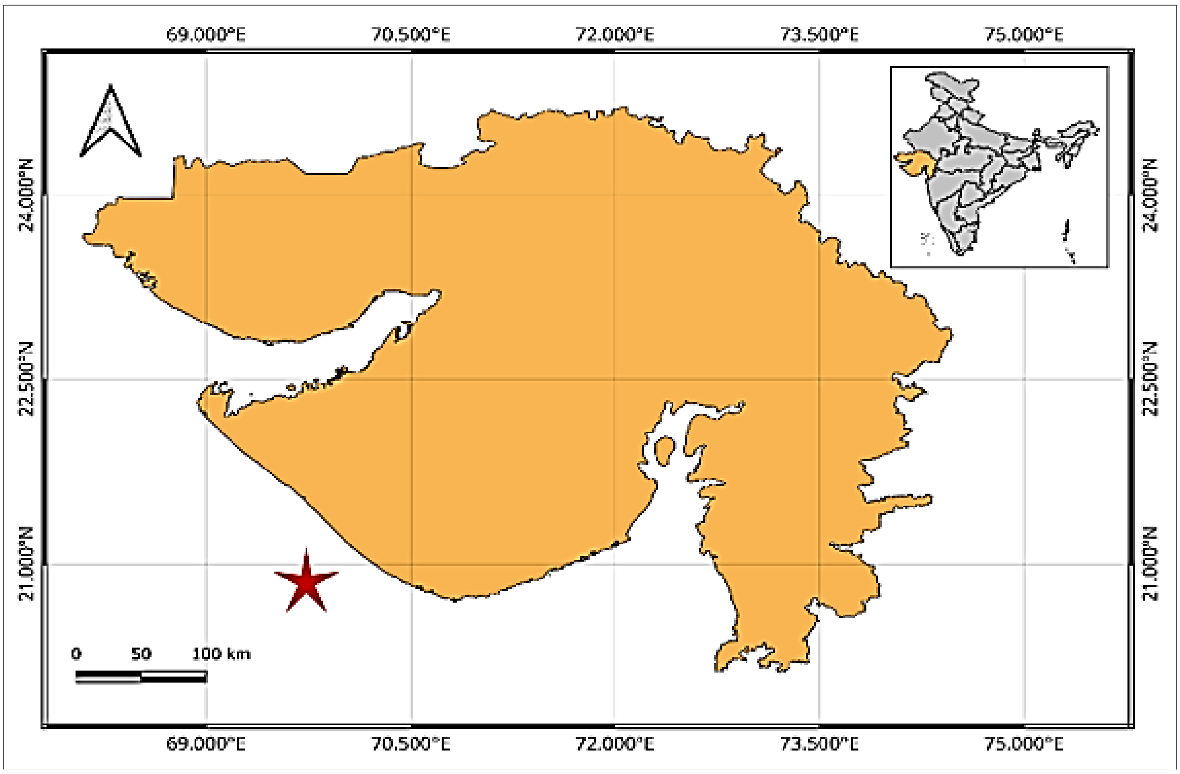

Fig 2.1: Satellite image of Chhara coast, Kodinar, Gujarat

The five difference stations were fixed with help of GPS for precise location for water sample collection at chhara coast.

Table 1 Sample stations at Chhara Coast, Kodinar

Station	Latitude	Longitude
S1	20°44'25"N	70°42'01"E
S2	20°44'21"N	70°42'07"E
S3	20°44'18"N	70°42'13"E
S4	20°44'18"N	70°42'19"E
S5	20°44'17"N	70°42'25"E

2.2 Analysis of Physico-Chemical Parameters

Surface water samples were collected from five stations along the coast each month from August 2024 to January 2025. Samples were taken in three sets from each station to sure and accurate results using standard methods.

Temperature were measured at site using a centigrade thermometer and salinity measured by refractometer. pH and turbidity were measured by pH meter and turbidity meter respectivelt. Water samples were collected in 125 ml and 300 ml glass stopper bottles without entangling air bubbles for measurement of Dissolve oxygen and Biochemical oxygen demand, respectively. Dissolve oxygen and initial DO for Biochemical Oxygen Demand samples were fixed with Winkler's reagents and brought to laboratory for further analysis. BOD sample bottle were also brought in laboratory and kept in incubation and analysed after 5 days. For further analysis of physico-chemical parameters water samples were obtained using clean 1-liter plastic bottles and immediately placed in a box to ensure their integrity during transportation to the laboratory. The methodologies outlined by APHA (2017) Trivedi and Goel (1986), were used to assess Total solids (TS) total suspended solids (TSS), total dissolved solids (TDS), electric conductivity (EC), nitrate (NO_3), nitrite (NO_2), hydrogen sulfide (H_2S), and phosphate. Additional water quality parameters, including Dissolve oxygen (DO), Biochrmical oxygen demans (BOD) was analyzed by Winkler method. All physicochemical parameters were analyzed on a monthly basis.

2.3 Calculation of Water Pollution Index

Based on the results of the study, the pollution index will be evaluated by using the formula given by Hossain & Patra (2020) [7].

$$\boldsymbol{PLi} = 1 + \left[\frac{ci - si}{Si} \right]$$

Where, PLi = Individual parameter pollution index
Ci = Ci indicates observed concentration of parameter.
Si = Si is the standard limit for the respective parameter
To determine overall water pollution along the site using the Water Pollution Index, sum up the pollution levels of all its factors and divide by the total number of factors. However, if any factor has a concentration of 0, exclude it when counting the total number of factors for that sample (Hossain & Patra, 2020) [7].

$$\textbf{WPI} = \frac{1}{n} \sum_{i=1}^{n} PLi$$

WPI = Overall water pollution index, PLi = Pollution index for ith parameter
n = Number of parameters.

3. Results

The analysis of physicochemical parameter along Chhara coast analyzed by standard methods. Results and similar study of each parameter are given given below. Results are compare with Minister of Environment Decree No. 51 year 2004 about Seawater Quality Standards for Marine Biota, Indonesia (Tanjung and Hamuna 2019) [19].

3.1 pH

The mean pH at the Chhara coast was ranged from 7.21±0.013 to 8.05±0.027. The lowest pH values were observed in December, while the highest pH levels were recorded in October (Fig. 3.1). This may have been because of October had warm temperatures, and water can hold less CO_2 at higher temperatures. Additionally, plants absorbed more CO_2 from the water during the warmer temperatures compared to colder ones. Similar work by Salvi *et al*. (2014) [17] analyzed coastal water quality parameters in specific regions of Okha, Sikka, and Khijadiya in Gujarat, focused on seasonal variations across different metrics. They found that the pH fluctuated between 7.24 and 8.52.

3.2 Temperature

The monthly mean temperature (°C) at several locations along Chhara coast ranged from 27.40±0.046 °C to 29.22±0.102 °C. The lowest mean temperatures were recorded in December, owing to the winter season (Fig. 3.2). While the greatest mean temperatures were recorded in October might be due to the transitional period between monsoon and winter. Jeyageetha and Sugirtha (2015) [8] examined the physicochemical parameters of saltwater in the Tuticorin coastal region. They observed temperatures ranged from 27.4 to 34 °C.

3.3 Turbidity

The mean turbidity at the Chhara coast fluctuated monthly, ranged from 5.20±0.011 NTU to 6.02±0.012 NTU (Fig. 3.3). In December recorded the lowest mean turbidity, while August had the highest. The elevated turbidity might be caused by river runoff carrying sediment and shoreline erosion, particularly during the rainy season in August 2024. Additionally, wave action during the monsoon also increase turbidity. Similar work conducted by Salvi *et al*. (2014) [17] conducted an extensive examination of coastal water quality parameters in specific regions of Okha, Sikka, and Khijadiya coast. And found turbidity level 3.9 to 46.40 NTU.

3.4 Salinity

The mean salinity along the Chhara coast varied from 34.62±0.042 ppt to 35.05±0.084 ppt. The lowest mean salinity was reported in December, while the highest levels were detected in October (Fig. 3.4). The October month was transitional period between monsoon and winter, when temperatures were slightly higher. Warm temperatures produced high evaporation rates, contributing to increased salinity. Additionally, areas with low river discharge showed minimal fluctuations of salinity during monsoon. According to Kumari *et al*. (2023) [10] studied physico-chemical parameters of the Kanyakumari Coastal Waters, from July 2018 to May 2019, and observed the salinity ranged from 29.7ppt to 38.1ppt.

3.5 Electric Conductivity (EC)

The average electric conductivity (EC) along the Chhara coast ranged between 50.24±0.056 mS/cm and 51.64±0.031 mS/cm. August had the highest average EC values, while December had the lowest levels (Fig. 3.5). EC variations were attribute to changes in total dissolved solids (TDS). Similar investigate done by Mehta and Mehta (2021) [12] assessed the quality of coastal water along the Hathab shore in Bhavnagar district, Gujarat, India. They measured electric conductivity, which ranged between 45.1 mS/cm to 48.3 mS/cm.

3.6 Dissolved Oxygen (DO)

The mean dissolved oxygen (DO) levels throughout the Chhara coast fluctuated between 5.64±0.032 mg/l to 6.1527±0.017 mg/l. Chhara coasts had the lowest mean DO values in October, while the greatest levels were seen in December (Fig. 3.6). The solubility of oxygen in liquids reduces with increasing temperature. As a result, colder winter water contains more dissolved oxygen than warmer summer water. Similar work conducted by Bhadja and Kundu (2012) [3] studied the changes in seawater quality along the Saurashtra coastline in India, noting that Do levels at the Veraval coast ranged from 5.64±0.04 mg/ to 6.38±0.04 mg/l.

3.7 Biochemical Oxygen Demand (BOD)

The mean Biochemical oxygen demand (BOD) at the Chhara coast were ranged from 2.14±0.028 mg/l to 2.93±0.019 mg/l. The lowest mean BOD values were observed in December, while the highest mean BOD value were recorded in October (Fig. 3.7). It might be due to lower temperatures slowed down the decomposition rate of bacteria. Olawusi-Peters *et al*. (2023) [13] had conducted a simila study to assess the consequences of water pollution on four coastal communities in Ilaje Local Government, Ondo State, Nigeria, with BOD levels ranged from 1.95 mg/l to 2.08 mg/l.

3.8 Total Suspended Solids (TSS)

The average TSS in the Chhara coast varied from 50.57±0.108 mg/l to 53.98±0.019 mg/l. The Chhara coast's mean TSS was lowest in January and highest in August (Fig. 3.8). Weather variables may have impacted the dynamic variations in TSS levels. During the rainy season in August, it is possible that land erosion and coastline erosion might be the primary factors influencing the TSS levels. According to Pandit and Fulekar (2017) [14] conducted research to analyze the physicochemical properties of water in several coastal regions of Gujarat, India, and found that TSS ranged from 15 to 37.7 mg/l of TSS.

3.9 Total Dissolved Solids (TDS)

The mean Total dissolved solids (TDS) at the Chhara coast ranged from 27.19±0.065 g/l to 31.57±0.117 g/l. The lowest mean TDS were observed in December, while the highest mean TDS were recorded in August (Fig. 3.9). It may have been because of sedimentary discharge and other dissolved minerals from river and runoff sedimentation in the ocean. Bhadja and Kundu (2012) [3] performed similar work and analysis on changes in saltwater quality from India's South Saurashtra coastline. They measured TDS in ranged from 39.03 to 44.82 g/l.

3.10 Total Solids

The mean TS of Chhara coast varied between 27.24±0.065 to 31.62±0.117 g/l. The minimum mean TS along the Chhara coast was recorded in December, and the highest in August (Fig. 3.10). It could be attributed to high levels of suspended and dissolved solids in August and the lowest mean TS recorded in December. Similar work conducted by Bhadja and Kundu (2012) [3] studied seawater quality along the South Saurashtra coastline in India and found that the average total solids value ranged from 39.56 to 45.68 g/l.

3.11 Phosphate

In the Chhara coast, monthly variations in mean phosphate, ranged from 0.051±0.00080 to 0.074± 0.00144 mg/l (Fig. 3.11). In september, the phosphate level was high because it may have been possible that phosphate from agricultural fertilizers, rain, or irrigation washed this excess phosphate into nearby water bodies, which eventually flowed into the ocean through rivers and streams. Kumari *et al*. (2023) [10] studied physicochemical properties of Kanyakumari Coastal Waters on India's Southwest Coast. They observed Phosphate values was ranged from 0.05 to 1.04 mg/l.

3.12 Nitrate (NO_3)

The monthly variations in mean nitrate along the Chhara coast ranged from 0.0067±0.00072 to 0.0363± 0.00061 mg/l. In August, a High level of nitrate was found, while the nitrate level was low in December (Fig. 3.12). It may have been possible that nitrate from agricultural fertilizer runoff, rain, or irrigation washed this excess nitrate into nearby water bodies, which eventually flowed into the ocean through rivers. Similar work conducted by Jeyageetha and

Sugirtha (2015) [8] evaluated the quality of seawater in the Tuticorin coastal area of Tamil Nadu by analyzing its physicochemical parameters. Nitrate levels ranged from 2.14±0.04 to 3.48±0.02 mg/l between July 2014 and December 2014.

3.13 Nitrite (NO_2): The monthly mean variations of nitrite along the Chhara coast ranged from 0.0099±0.00027 to 0.0167± 0.00044 mg/l. In September, a high level of nitrite was found, while it was low in December (Fig. 3.13). It may have been possible that nitrite from waste from rural areas, environmental deposition and agricultural fertilizer runoff had led to an excess of nitrites entering nearby water bodies, which eventually flowed into the ocean through rivers. Raghunathan *et al*. (2004) [16] assessed the water from Saurashtra coast of Gujarat, Arabian Sea. They showed the average nitrite content, ranged between 0.0074 and 0.0395 mg/l.

3.14 Hydeogen Sulphide (H_2S)

The monthly variations in mean H_2S along the Chhara coast ranged from 0.0194±0.0074 to 0.0266±0.0063 mg/l. In December, a low level of H_2S was found, while the H_2S level was high in September (Fig. 3.14). It might be during the month of September that heavy runoff from coastal areas, carrying both human and animal waste, along with H_2S produced during the bacterial breakdown of waste, occurred. This also included runoff from agricultural fertilizers. According to Pandit and Fulekar (2012) [14] determined seasonal fluctuations in water physicochemical characteristics in Gujarat, India's coastal districts. They estimated hydrogen sulphide ranged from 0.37 to 1.03 mg/l.

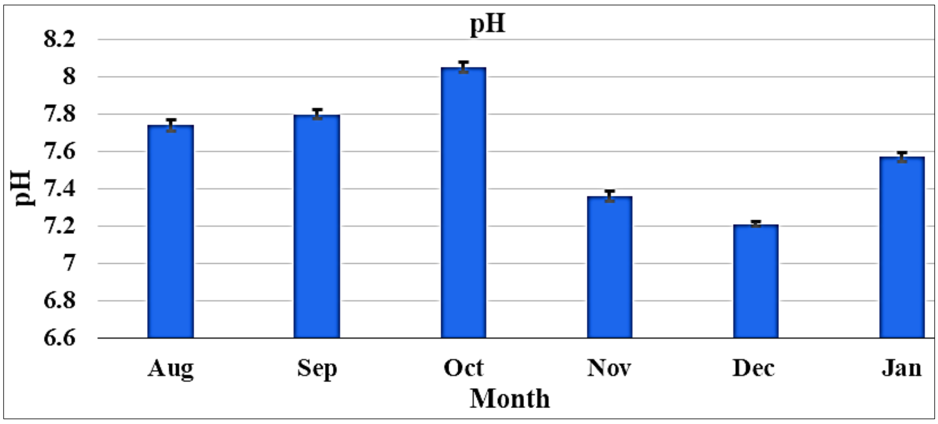

Fig 3.1: Monthly mean pH variation along chhara coast

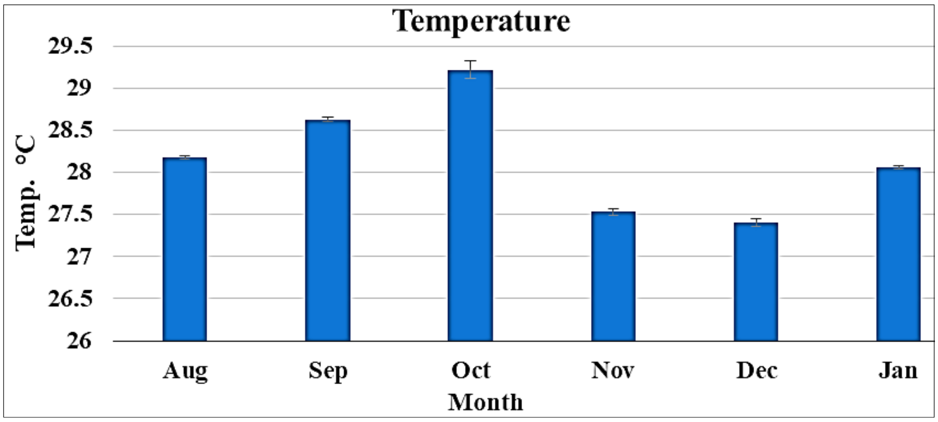

Fig 3.2: Monthly mean Temperature variation along chhara coast.

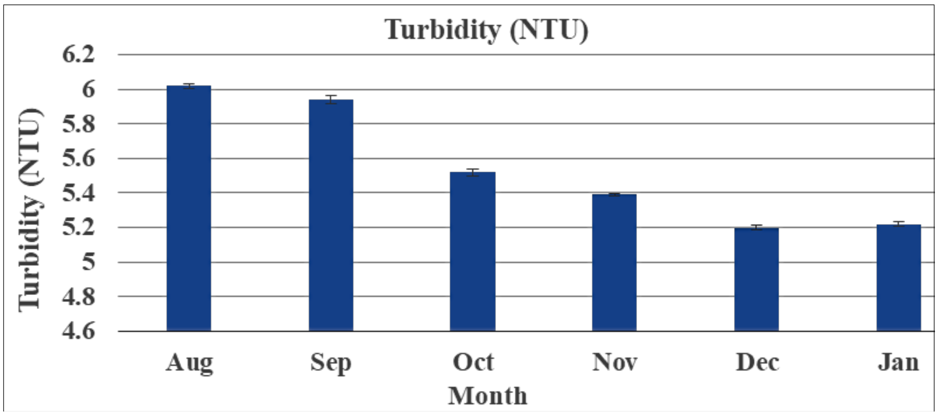

Fig 3.3: Monthly mean Turbidity variation along chhara coast

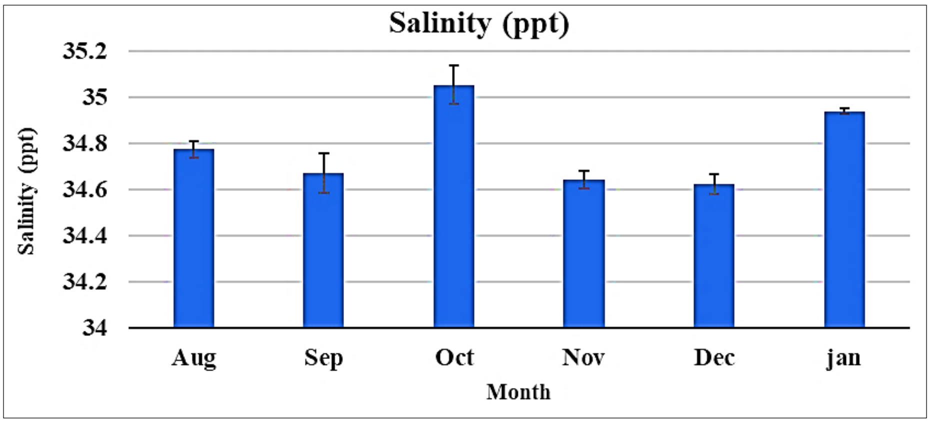

Fig 3.4: Monthly mean Salinity variation along chhara coast

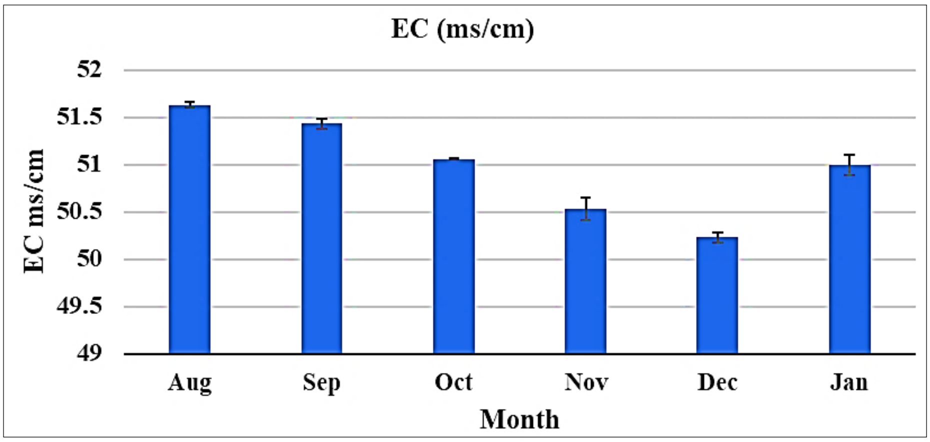

Fig 3.5: Monthly mean EC variation along chhara coast

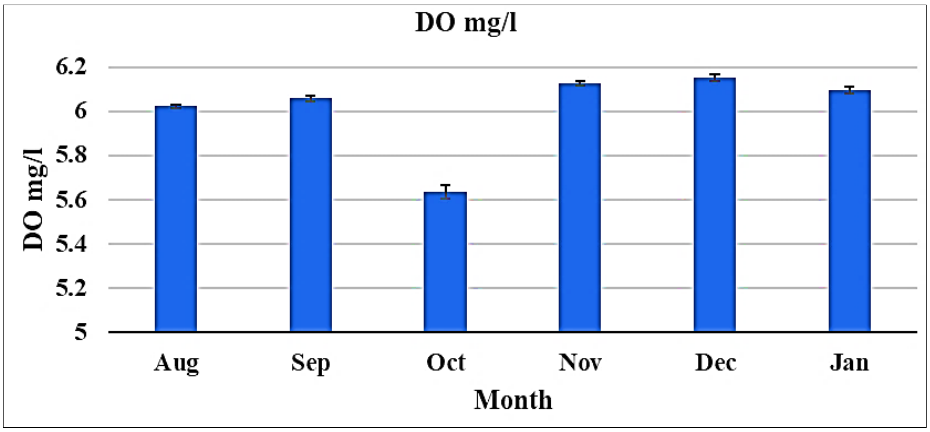

Fig 3.6: Monthly mean DO variation along chhara coast

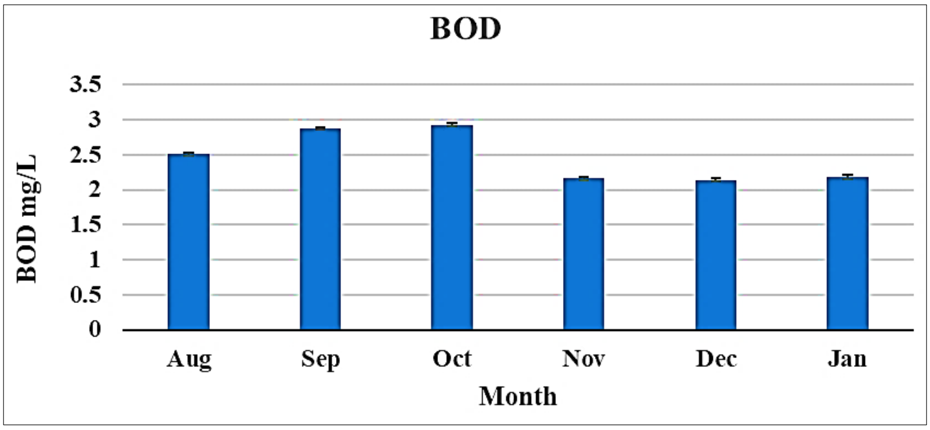

Fig 3.7: Monthly mean BOD variation along chhara coast

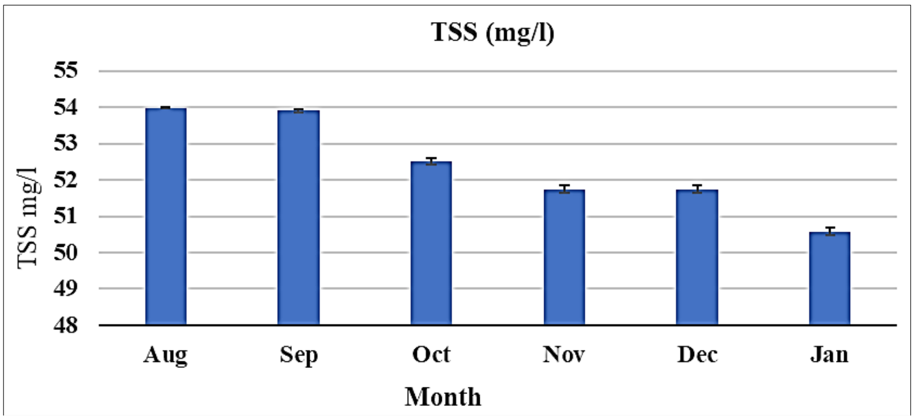

Fig 3.8: Monthly mean TSS variation along chhara coast

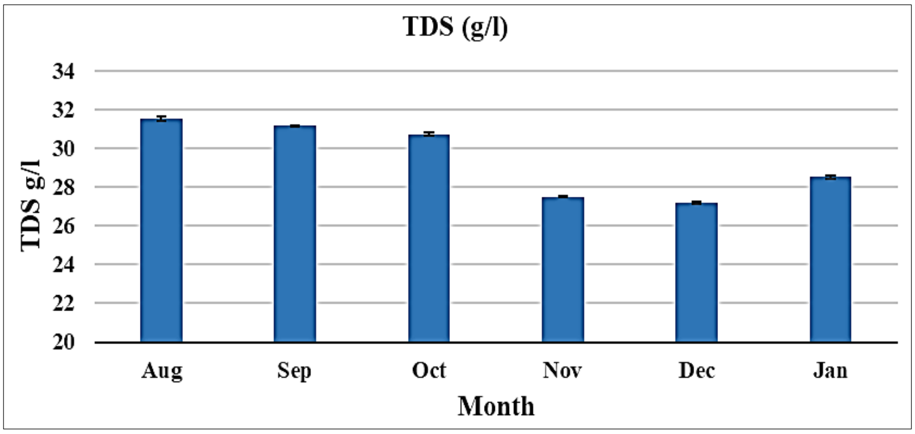

Fig 3.9: Monthly mean TDS variation along chhara coast

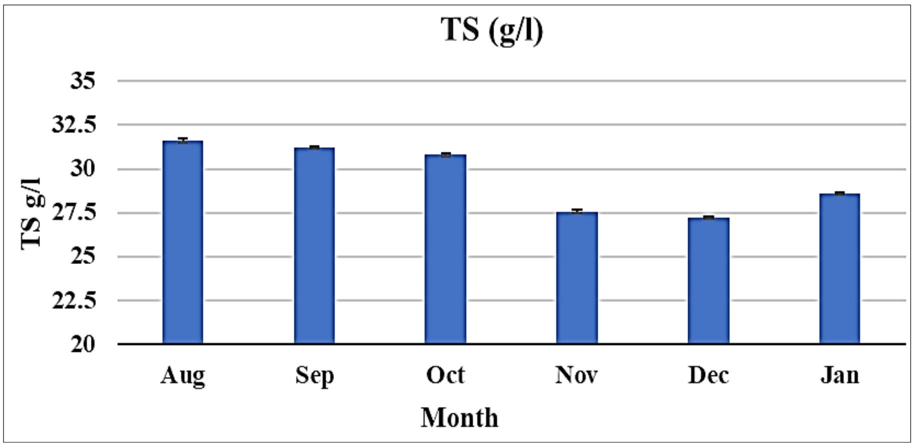

Fig 3.10: Monthly mean TS variation along chhara coast

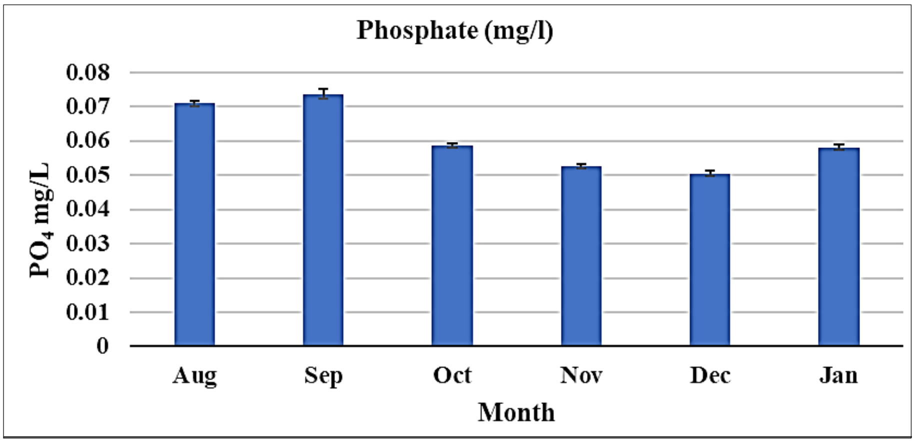

Fig 3.11: Monthly mean phosphate variation along chhara coast

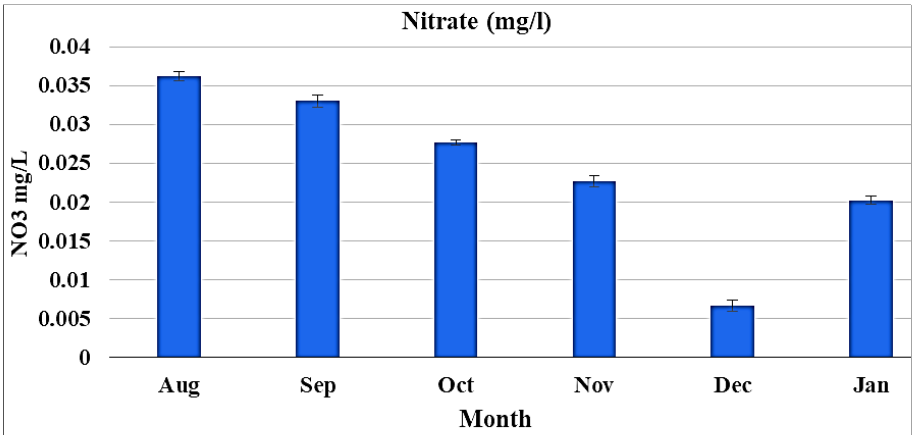

Fig 3.12: Monthly mean Nitrate variation along chhara coast

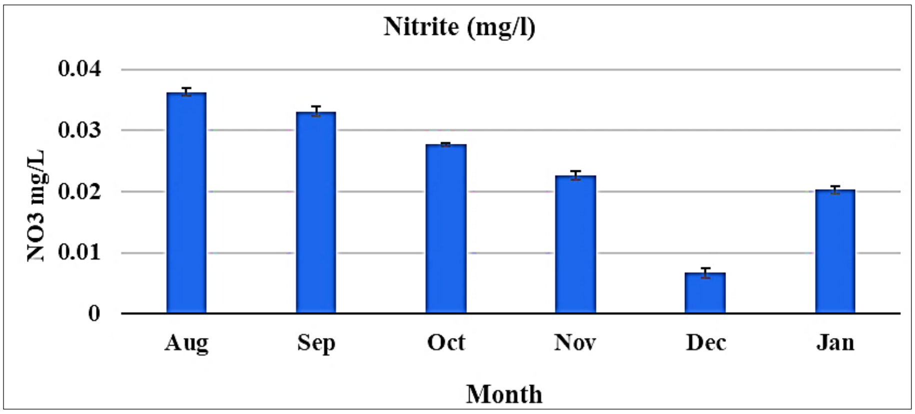

Fig 3.13: Monthly mean Nitrite variation along chhara coast

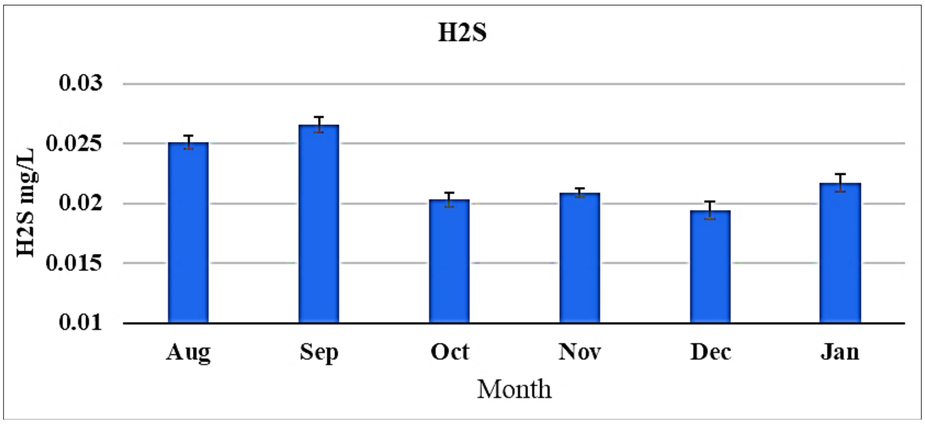

Fig 3.14: Monthly mean H_2S variation along chhara coast

3.15 Water Pollution Index

Table 3.1 Monthly variation of water pollution index along Chhara coast

Month	Pollution Index
August	1.516
September	1.539
October	1.413
November	1.326
December	1.130
January	1.261

The pollution index also helps us measure how much pollution there is and understand how healthy the coastal water ecosystem is (Tanjung *et al*., 2019) [19] The monthly pollution index along the Chhara coast ranged from 1.130 to 1.539. The highest pollution index was recorded in September, while the lowest was observed in December. It might be due to in September month most parameter pollution index was high which contribute to higher monthly pollution index. The Chhara coastal waters were classified under the lightly polluted category during the study month.

The results of the pollution index analysis of coastal water bodies offer essential insights into the quality of coastal waters. The Water Pollution Index for the chhara coasts was determined by averaging the pollution index of all parameters, which analyzed during August 2024 to January 2025. Based on calculation, Chhara coast observed over all WPI value was 1.365, which is include in lightly polluted Category.

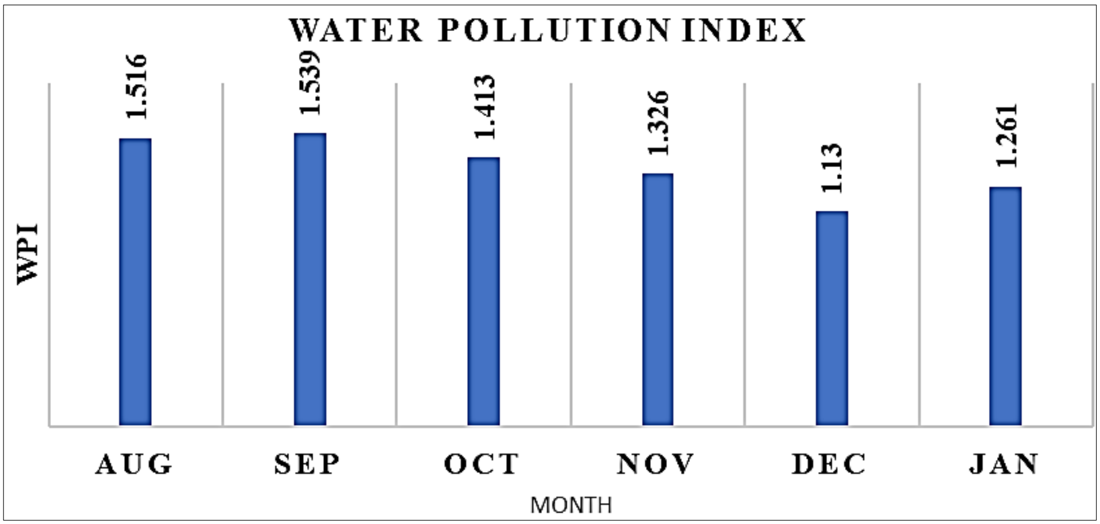

Fig 3.15: Monthly pollution index along Chhara coast

4. Conclusion

The study was carried out on "assessment of coastal water pollution index based on Physico-chemical parameters along Chhara, Kodinar, Gujarat". It ran for six months, from August 2024 to January 2025. Throughout this time, samples were collected monthly from 3 replication group from 5 locations. The Coastal Pollution Index was calculated using an examination of physicochemical factors.

- In the Chhara coast, the lowest pH values were reported in December, at 7.21, while the highest pH levels were recorded in October, at 8.05. the ph measurement found a pollution index of 0.983 along the Chhara coast.
- The lowest temperature documented on the Chhara coast was 27.40 in December because of the season of winter, while the highest was 29.22 in October because of the transitional time between monsoon and winter. Temperature measurements revealed a pollution index of 0.939 along the Chhara coast.
- The minimum average turbidity values for the Chhara coast were observed in December (5.20 NTU), with the greatest mean turbidity reported in August (6.02 NTU). Turbidity measurements revealed a pollution index of 1.1083 along the Chhara shoreline.
- The mean salinity levels along the Chhara coast were lowest in December (34.62 ppt), and greatest in October (35.05 ppt). Based on salinity measurements, the pollution index was 0.994 along the Chhara coast.
- In Chhara coast electric conductivity was determined to be highest in August (51.64 mS/cm) and lowest in December (50.24 mS/cm). The EC measurements revealed a pollution index was1.003 along the Chhara shore.
- Dissolved oxygen concentrations were maximum in December at 6.1527 mg/l and minimum in October at 5.64 mg/l near the Chhara shoreline. The pollution index was 1.20 based on do measurements.
- The greatest Biochemical Oxygen Demand (BOD) value was recorded in October (2.93 mg/L), while the lowest BOD value was observed in December (2.14 mg/L). The BOD readings suggested a pollution index of 1.64.
- In January, lowest TSS value 50.57mg/l at the Chhara coast, and highest in August at 53.98 mg/l. The pollution index 2.6205 based on the TSS measurements.
- The Chhara coast's total dissolved solids (TDS) values were lowest in December (27.19 g/l) and highest in August (31.57 g/l), resulting in a pollution score of 0.841.
- The Chhara coast's lowest TS level was 27.24 g/L in December, while the highest was 31.62 in August. The TS measurements showed a pollution index was 0.844 at the Chhara coast.
- The lowest phosphate value on the Chhara coast was 0.0505 in December, while the highest was 0.0737 in september. Phosphate measurements revealed a pollution score of 1.046 along the Chhara shore.
- The Chhara coast’s lowest nitrite level was 0.0099 mg/l in December, while the highest was 0.0167 mg/l in September. The measurement showed a pollution index was 2.6033.
- Nitrate levels were found to be high in August was 0.0363 and low in December 0.0067. Nitrate measurements found a pollution score of 3.0583 along the Chhara coastline.

In December, the lowest H_2S level was 0.019 mg/l, while in September, the highest H2S level was 0.0266. H2S tests indicated a pollution score of 0.223 along the Chhara beach.

References

1. Bashir I, Lone FA, Bhat RA, Mir SA, Dar ZA, Dar SA, *et al*. Concerns and threats of contamination on aquatic ecosystems. In: Bioremediation and biotechnology: sustainable approaches to pollution degradation. 2020. p. 1-26.
2. Bay SM, Greenstein DJ, Lau SL, Stenstrom MK, Kelley CG, *et al*. Toxicity of dry weather flow from the Santa Monica Bay watershed. Bulletin Southern California Academy of Sciences. 1996;95(1):33-45.

3. Bhadja P, Kundu R, *et al*. Status of the seawater quality at few industrially important coasts of Gujarat (India) off Arabian Sea. Indian Journal of Geo-Marine Sciences. 2012;41(1):90-7.
4. Field R, O'Shea M, Brown MP, *et al*. The detection and disinfection of pathogens in storm-generated flows. Water Science and Technology. 1993;28(3-5):311-5.
5. Gold M, Bartlett M, Dorsey J, McGee C, *et al*. Storm drains as a source of surf zone bacterial indicators and human enteric viruses to Santa Monica Bay. Santa Monica Bay Restoration Project. 1991 Aug.
6. Hamuna B, Tanjung RH, Maury H, *et al*. Kajian kualitas air laut dan indeks pencemaran berdasarkan parameter fisika-kimia di perairan Distrik Depapre, Jayapura. Jurnal Ilmu Lingkungan. 2018;16(1):35-43.
7. Hossain M, Patra PK, *et al*. Water pollution index - a new integrated approach to rank water quality. Ecological Indicators. 2020;117:106668.
8. Jeyageetha JC, Sugirtha PK, *et al*. Study of physico-chemical parameters of sea water in Tuticorin Coastal area and assessing their quality, Tamil Nadu, India. Journal of Chemical and Pharmaceutical Research. 2015;7(5):1298-304.
9. Kumar N, Kumar A, Marwein BM, Verma DK, Jayabalan I, Kumar A, *et al*. Agricultural activities causing water pollution and its mitigation A review. International Journal of Modern Agriculture. 2021;10(1):590-609.
10. Kumari A, Christobel J, Lawrence B, *et al*. Seasonal variations in physico-chemical characteristics of Kanyakumari Coastal Waters, South West Coast of India. Journal of Survey in Fisheries Sciences. 2023;10(2S):3549-61.
11. Mateo-Sagasta J, Zadeh SM, Turral H, Burke J, *et al*. Water pollution from agriculture: a global review. Executive Summary. 2017.
12. Mehta N, Mehta S, *et al*. Quality analysis of coastal water at Hathab Coast, Gujarat, India. International Journal of Scientific Research and Engineering Development. 2021;4:1247-61.
13. Olawusi-Peters OO, Igejongbo F, Adegunloye D, Igbasan V, *et al*. Coastal water pollution: a case study of four coastal towns in Ondo State, Nigeria. Ethiopian Journal of Environmental Studies & Management. 2023;16(2):186-96.
14. Pandit PR, Fulekar MH, *et al*. Quality characterization of coastal water in Gujarat coast, India. IOSR Journal of Biotechnology and Biochemistry. 2017;3(4):8-15.
15. Petzet A, *et al*. World's frontier basins beckon exploration. Oil & Gas Journal. 2010;108(18):34-7.
16. Raghunathan C, Gupta RS, Wangikar U, Lakhmapurkar J, *et al*. A record of live corals along the Saurashtra coast of Gujarat, Arabian Sea. Current Science. 2004;87(8):1131-8.
17. Salvi H, Patel R, Thakur B, Shah K, Parmar D, *et al*. Assessment of coastal water quality parameters of selected areas of Marine National Park & Sanctuary (Okha, Sikka & Khijadiya). SSRN. 2014. Available from: SSRN 2456093.
18. Sukhdhane KS, Priya ER, Raut SM, Jayakumar T, *et al*. Status of oil pollution in Indian coastal waters. Fishing Chimes. 2013;33(5):53-4.
19. Tanjung RHR, Hamuna B, *et al*. Assessment of water quality and pollution index in coastal waters of Mimika, Indonesia. Journal of Ecological Engineering. 2019;20(2):87-94.
20. Varkey MJ, *et al*. Pollution of coastal seas. Resonance. 1999;4(1):36-44.
21. Zhang J, Wang C, Jiang X, Song Z, Xie Z, *et al*. Effects of human-induced eutrophication on macroinvertebrate spatiotemporal dynamics in Lake Dianchi, a large shallow plateau lake in China. Environmental Science and Pollution Research. 2020;27(12):13066-80.
22. Zingde MD, *et al*. Inputs into the oceans from land/rivers and pollution. In: *India: Universities Press*. 2005. p. 92-117.