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Assessment of pollution index based on physico chemical parameters of coastal waters along veraval coast, Gujarat

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Abstract

The present study was conducted on the assessment of pollution index based on physico-chemical parameters of coastal waters along Veraval, Gujarat. Coastal water samples from three distinct stations along from the Veraval coast were collected on monthly basis. The study was carried out from October-2023 to March-2024. Total fourteen physico-chemical parameters were assessed. The findings indicate that the physico-chemical parameters such as temperature, pH salinity, electric conductivity (EC) and dissolved oxygen (DO) were meeting the coastal water standards. However, parameters such as turbidity, biochemical oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), nitrate (NO₃), nitrite (NO₂), phosphorus and hydrogen sulphide (H₂S) were exceeding their coastal water quality standard. The results of the physico-chemical parameter analysis were compared with the standards of sea water quality for marine biota. In Veraval, pollution index was generally higher for temperature (1.0028), pH (1.1049), salinity (1.0539), turbidity (1.184), EC (0.8529), DO (1.0989), BOD (1.654), TSS (1.9924), TDS (1.141), TS (1.1425), NO₃ (2.4350), NO₂ (1.4265), phosphorus (3.791), and H₂S (4.7274). The pollution index for each parameter were calculate and based on that the result of Overall index of pollution (OIP) was found 1.7577 at Veraval coast. Veraval coast was found to be in acceptable limit (Class C₂) based on the Overall Pollution Index categories. This benchmark will evaluate the intensity of pollution, guiding decisions on implementing stricter regulations.

Keywords: Coastal waters, pollution index, physico-chemical parameters, overall index of pollution (OIP), standard of sea water quality

1. Introduction

Ocean plays a crucial role in shaping the planet's climate, supporting diverse ecosystems, and sustaining life. More than 70% of the Earth's surface is covered by water. Out of this vast water resource, approximately 96% is saline water found in the oceans. The remaining 4% comprises freshwater, which is predominantly in the form of ice caps, glaciers, and permanent snow, accounting for about 1.74% of the total. Groundwater makes up approximately 1.69% of the freshwater, while the remaining portion exists in the form of rivers, lakes, and other surface water sources (Kumar *et al.*, 2021) ^[11]. Water pollution, resulting from urbanization, industrialization, and agriculture, involves contaminants like pesticides, fertilizers, and sewage entering aquatic environments. This degrades water quality and can spread diseases such as dysentery, diarrhea, and jaundice. The natural self-purification of water is often insufficient against uncontrolled contamination. Therefore, regular monitoring and control of pollutants are essential to mitigate water pollution's harmful effects (Bashir *et al.*, 2020) ^[5].

Annually, more than 4.54×10⁹ m³ (1.2 trillion gallons) of untreated sewage, storm water, and industrial waste flow into United States rivers because of overburdened treatment systems. Annually, almost 102×10⁶ m³ (27 billion gallons) of untreated sewage flow into New York Harbor alone. Agriculture, responsible for 70% of global water abstractions, significantly contributes to water pollution (Mateo Sagasta *et al.*, 2017) ^[12]. Approximately 300 million individuals residing in India's coastal region are estimated to produce an annual sewage volume of 1.11 x 10¹⁰ cubic meters.

Industries produce an estimated 1.35 million cubic meters of liquid effluent and about 34,500 tonnes of solid waste daily. The West coast of India, particularly Maharashtra and Gujarat, is more industrialized than the East coast. Meanwhile, aquaculture farms in Andhra Pradesh and Tamil Nadu generate around 2.37 million cubic meters of effluent per day (Panda *et al.*, 2017) ^[15].

To monitor coastal water quality, it's essential to measure various physical, chemical, and biological factors. Physical parameters include temperature, turbidity, and flow rate, which help understand the water's physical condition. Chemical parameters, such as pH level, dissolved oxygen content, and nutrient concentrations, indicate the water's chemical balance. Biological parameters involve studying aquatic organisms like algae, bacteria, and invertebrates to

assess ecological health and biodiversity. These measurements provide a comprehensive understanding of coastal water quality, aiding in informed decision-making to protect aquatic ecosystems (Tanjung *et al.*, 2019) ^[24]. The aim of this study is to assess the quality of the coastal waters in Veraval by analyzing the concentrations of physical and chemical parameters in relation to the water quality standards for marine biota. The findings from this research are intended to serve as foundational information, particularly regarding the quality of marine waters, and to offer recommendations for the management of coastal and marine areas in Veraval.

2. Materials and Methods

2.1 Study Area



Fig 1: Location of sampling stations at veraval coast

Veraval, the administrative centre of Gir Somnath district in Gujarat, is known for its boat-building heritage and fast-expanding fish industry. The city hosts numerous fish processing plants under the Gujarat Industrial Development Corporation (GIDC), along with major companies like Grasim Industries Limited, resulting in significant effluent production. The area is also home to various chemical, thread, and cement industries. Consequently, the coastal waters of Veraval are increasingly polluted due to the rise in industrial activities and commercial fishing. Three stations were selected: S1 referred to the coastal waters near Jaleshwar Temple, S2 to the coastal waters from the Chowpatty area, and S3 to the coastal waters near the Kharakuva area.

2.2 Methodology

Coastal water samples were collected monthly from three different stations along Veraval coast between October 2023 and March 2024. Samples were taken at a distance of 2 to 5 meters from the highest tideline using 2-liter pre-sterilized plastic bottles. After collection, the samples were stored in an icebox and transported to the laboratory for physico-chemical analysis. Parameters such as temperature and salinity were measured during sampling using a centigrade thermometer and refractometer, respectively. Coastal water samples for BOD (Biochemical Oxygen Demand) and DO

(Dissolved Oxygen) analysis were collected in 125 ml glass-stoppered bottles to prevent air bubbles. Dissolved oxygen samples were fixed using Winkler's reagents, and pH was measured with a digital pH meter. DO, BOD, nitrate (NO₃), nitrite (NO₂), hydrogen sulphide (H₂S), and phosphorus (P) were analyzed according to Strickland and Parsons (1972). Other water quality parameters like salinity, turbidity, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), and electrical conductivity (EC) were measured following methods outlined by Sankpal and Naikwade (2012) ^[21]. All physico-chemical parameters were analyzed on a monthly basis.

2.3 Pollution Index

The pollution index serves as a valuable tool for providing information about the quality of water. The water pollution index offers a comprehensive assessment score for environmental parameters, which can be analyzed to interpret the water quality. The calculation of the pollution index follows a formula outlined in the Decree of the Minister of Environment No. 51 in 2004. This formula was originally developed by Nemerow and Sumitomo in 1970. It serves as a standardized method to quantify and assess the extent of pollution in water bodies. By using this formula, level of pollution can be measured and environmental conditions can be monitored.

The pollution index can be calculated by the following formula

$$PI_j = \sqrt{\frac{(C_i / L_{ij})^2_M + (C_i / L_{ij})^2_R}{2}}$$

PI_j-The pollution index for a specified coastal water quality parameter

C_i-Measured coastal water quality parameters

L_{ij}-Standard coastal water quality parameter for each parameter at specified coastal water quality purpose

(C_i / L_{ij})_M-Maximum value of C_i / L_{ij}

(C_i / L_{ij})_R-Average value of C_i / L_{ij}

The total pollution level along Veraval coast was calculated as the average of all parameter's pollution index.

2.4 Overall Index of Pollution (OIP)

The Overall Index of Pollution (OIP) represents the overall quality of water at a particular station. It is calculated as an average of all the pollution indices (Pi) for the individual water quality parameters considered in the study. The formula for calculating OIP can be expressed mathematically as (Sargaonkar & Deshpande, 2003) [22].

$$OIP = \frac{\sum Pi}{n}$$

Where,

Pi = pollution index for ith parameter. i = 1, 2,.....n

N = number of parameters.

The Overall Index of Pollution is represented by numerical estimates that correspond to specific categories or classes.

0-1: Excellent (Class C1) 1-2: Acceptable (Class C2)

2-4: Slightly polluted (Class C3) 4-8: Polluted (Class C4)

8-16: Heavily polluted (Class C5).

3. Results

The quality of water is called polluted if it exceeds the maximum level. The results of the physico-chemical parameter analysis done at Veraval coast was presented in following charts. According to Decree of the Minister of Environment of the Republic of Indonesia No. 51 year 2004 about sea water quality standards, Temperature, Salinity and Turbidity were within the limits of the standards.

3.1 Temperature

Temperature is one of the factors that greatly influencing the life of aquatic organisms. Temperature of Veraval coast ranging from 29.87±0.011 °C to 30.11±0.011 °C (Figure 2). The lowest mean temperatures for Veraval coast were documented in January due to winter season, with the highest mean temperatures recorded during March because of summer season. Studied seasonal variations in physico-chemical characteristics of Kanyakumari Coastal Waters, India and noted temperatures between 23.5 °C to 33.9 °C. Adnina *et al.* (2023) [1] examined water quality in Bojonegara coastal waters, Indonesia, during different periods, finding temperatures from 28.4 °C to 37.5 °C. These findings align with observations in Gujarat, India, indicating consistency in temperature ranges across these coastal regions.

3.2 Salinity

In coastal waters, salinity indicates how salty the water is where rivers and streams flow into the sea. Tides, river flow, and the sun's heat all play a part in these shifts. The Salinity of the water in Veraval coast was between 36.63±0.019 to 36.98±0.011 (Figure 3). Minimum difference in salinity may be due to the little rain and runoff of water by nearby river. According to Salvi *et al.* (2014) [20] Okha, Sikka, and Khijadiya, of Gujarat seasonal variations in pH range between 7.24 to 8.52.

3.3 Dissolved oxygen (DO)

The ocean's dissolved oxygen is mostly derived from the surrounding plants and air. Understanding marine habitats and chemistry requires an understanding of this dissolved oxygen (DO). It is important for aquaculture, marine research, and water quality assessment (Dong *et al.*, 2024) [8]. Dissolved oxygen (DO) at Veraval Coast Ranges between 5.271±0.0185-5.601±0.0128 (Figure 4). The uniformity in DO might be due to no rainfall during this period. Minimum mean DO levels for the Veraval coast was in March and maximum was recorded in January month. In their 2023 study, Anitha *et al.* investigated the seasonal variations in physico-chemical characteristics of Kanyakumari Coastal Waters on the South West Coast of India. They reported DO content ranging from 3.67 to 5.63 mg/L.

3.4 Biochemical oxygen demand (BOD)

Biochemical Oxygen Demand (BOD) is an important tool for evaluating water quality, especially given the influence of both human actions and natural occurrences on marine environments. BOD indicates the quantity of dissolved oxygen needed by tiny organisms to break down organic materials found in the water. The Veraval coast exhibited monthly variations in mean biochemical oxygen demand (BOD), ranging from 2.29±0.012 mg/L to 2.58±0.010 mg/L (Figure 5). Raghunathan *et al.* in 2003 found BOD levels ranging from 0.91 to 1.12 mg/L at temperatures between 26.5 °C and 26.8 °C in their study on the impact of turbidity on intertidal macro fauna at Gopnath, Mahuva, and Veraval coasts.

3.5 pH

The pH level in marine water is a fundamental factor that signifies the degree of acidity or alkalinity present within the ocean. The monthly variations in mean pH along the Veraval coast ranged from 8.17±0.003 to 8.33±0.013 (Figure 6). The minimum mean pH for Veraval coast occurred in March, with the maximum mean pH recorded in January. Jeyageetha and Kumar (2015) [9] conducted study on the physico-chemical parameters of seawater in the Tuticorin coastal area, evaluating their quality in Tamil Nadu. They observed pH range between 7.42 and 8.69 from July 2014 to December 2014.

3.6 Turbidity

Turbidity in coastal waters refers to how murky or cloudy the water appears due to suspended particles like silt, clay, organic matter, and plankton. This haziness can arise from various factors, including human actions such as farming, construction, and wastewater discharge, as well as natural processes like erosion, river flow, and tidal movements. Monthly variations of mean turbidity of Veraval coast range

from 5.687 ± 0.025 NTU to 5.991 ± 0.028 NTU (Figure 7). The lowest mean turbidity for Veraval coast were recorded in January, with the highest mean turbidity recorded in October month. The increased turbidity levels could be attributed to warmer temperatures prompting greater biological activity and sediment transportation by rivers such as Hiran, Sarasvati, and Kapila into the ocean. Bhadja and Kundu (2012) ^[6] conducted a comprehensive investigation into the spatial and temporal variations of seawater quality along the South Saurashtra coastline in India and recorded the turbidity between 4.20 NTU to 5.37 NTU at Veraval coast.

3.7 Electric Conductivity (EC)

Coastal waters' electric conductivity, which is determined by the presence of dissolved ions such salts, is the water's capacity to conduct an electric current. In coastal areas, the conductivity of the water is a crucial measure of salinity and water quality. The monthly variations in mean electrical conductivity (EC) along the Veraval coast ranged from 42.61 ± 0.080 mS/cm to 44.10 ± 0.033 mS/cm (Figure 8). March saw the highest mean EC level in Veraval. The rise in electrical conductivity could be the heightened mobility of ions resulting from increased temperatures. In their 2012 study, Pandit and Fulekar investigated the physicochemical parameters of water across various coastal regions of Gujarat, India. They observed electric conductivity ranging from 3.53 to 62.9 mS/cm, with the Dwarka region exhibiting the highest electric conductivity of 62.9 mS/cm.

3.8 Total suspended solids (TSS)

Total Suspended Solids is a critical factor in assessing the quality of estuarine and coastal waters, as it directly impacts how much light can penetrate the water, which in turn affects the ability of plankton to carry out photosynthesis, thereby influencing ocean primary production (May *et al.*, 2003) ^[13]. Monthly variations of mean TSS of Veraval coast range from 47.97 ± 0.019 mg/L to 50.34 ± 0.495 mg/L (Figure 9). Minimum mean TSS in Veraval coast was recorded in January month, and maximum mean TSS was recorded in October month, this might be due to sediment runoff from rivers near the Veraval coast. Balakrishnan *et al.* (2017) ^[4] studies the Seasonal variations in physico-chemical characteristics of Tuticorin coastal waters, southeast coast of India over a 12-month period and observed the TSS ranged between 24mg/L to 97 mg/L. Raghunathan *et al.* (2004) ^[17] conducted a study on the record of live corals along the Saurashtra coast of Gujarat, Arabian Sea. They reported an average concentration of TSS ranging from 48 mg/L at low tide and 51.3mg/L during high tide.

3.9 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) in coastal waters include all the different stuff dissolved in the water, like minerals and other substances from nature and human activities. The Veraval coast exhibited monthly variations in mean total dissolved solids (TDS), ranging from 37.96 ± 0.056 g/L to 40.44 ± 0.040 g/L (Figure 10). The minimum mean TDS for the Veraval coast occurred in January, with the maximum recorded in March, this also might be due to the sedimental runoff from rivers in Veraval coast. Bhadja and Kundu (2012) ^[6] conducted a comprehensive investigation into the spatial and temporal variations of seawater quality along the South Saurashtra coastline in India. They reported TDS

ranges of 39.31 g/L to 44.82 g/L in the Veraval coast. Salvi *et al.* (2014) ^[20] conducted a thorough study on Coastal Water Quality Parameters in selected areas including Okha, Sikka, and Khijadiya. They observed TDS ranges between 33 g/L to 37 g/L.

3.10 Total Solids (TS)

Total Solids in coastal waters encompass all the materials, both dissolved and suspended, present in the water. Total Solids can originate from various sources, including natural processes such as erosion, weathering of rocks, and biological activity, as well as human activities like urban runoff, industrial discharges, and agricultural practices. Monthly variations of mean TS of Veraval coast range from 38.004 ± 0.056 to 40.495 ± 0.040 (Figure 11). Minimum mean TS in Veraval coast was recorded in January month. This might be due to high level of Total suspended solids and total dissolved solids were present in October (post monsoon) month, and maximum mean TS was recorded in October month. Bhadja and Kundu (2012) ^[6] conducted an extensive investigation into the spatial and temporal variations of seawater quality along the South Saurashtra coastline in India and determined that the total solids average value in Veraval coast was 39.75 g/L during winter and 45.68 g/L in monsoon season due to high amount of sediment load was transported by rivers into ocean.

3.11 Nitrate (NO₃)

Nitrates found in coastal waters come from different places like runoff from farms, sewage, and even the air. When there's too much nitrate, it can cause a problem called eutrophication, where extra nutrients make algae grow too much. This can use up the oxygen in the water and create harmful algal blooms. The Veraval coast displayed monthly variations in mean nitrate levels, ranging from 0.243 ± 0.0007 mg/L to 0.280 ± 0.0015 mg/L (Figure 12). The minimum mean nitrate for Veraval coast was recorded in January, with the maximum observed in October month. Higher level of nitrate in Veraval might be due to the agricultural runoff by rivers into Veraval coast. Conducted a study on the physicochemical parameters of water across various coastal regions of Gujarat, India. Their investigation revealed seasonal variations in different parameters, including nitrate levels ranging from 0.18 mg/L to 3.8 mg/L, which aligns with the observed trends in this study.

3.12 Nitrite (NO₂)

Nitrite is usually formed in coastal waters through a mix of biological and chemical activities. One main way is when nitrifying bacteria turn ammonia into nitrite and then nitrate. This process, called nitrification, is important for the nitrogen cycle and happens mainly where there's plenty of oxygen. The Veraval coast exhibited monthly variations in mean nitrite levels, ranging from 0.062 ± 0.0024 mg/L to 0.084 ± 0.0011 mg/L (Figure 13). The minimum mean nitrite for the Veraval coast was recorded in January, with the maximum observed in October. Conducted a study on the Physicochemical Parameters and Water Quality Index in the Coastal waters of Vamsadhara Estuary, Srikakulam District Andhra Pradesh, and India. They found nitrite levels ranging between 0.012-0.086 mg/L. Similarly, Raghunathan *et al.* (2004) ^[17] conducted a study on the record of live corals along the Saurashtra coast of Gujarat, Arabian Sea. They reported an average concentration of nitrite ranging from 0.0074 to 0.0395 mg/L.

3.13 Phosphorus (P)

Phosphorus stands out as a major contributor to the worldwide nutrient dilemma and the urgent loss of biodiversity in both freshwater and marine environments. Its effects range from harmful algal blooms to large-scale fish die-offs, along with the release of greenhouse gases (Johnes *et al.*, 2022) ^[10]. The Veraval coast exhibited monthly variations in mean phosphorus levels, ranging from 0.046 ± 0.0009 to 0.061 ± 0.0019 (Figure 14). The lowest mean Phosphorus for Veraval coast was recorded in January, with the highest mean phosphorous recorded in October month. Salvi *et al.* (2014) ^[20] conducted a comprehensive study on Coastal Water Quality Parameters in selected areas including Okha, Sikka, and Khijadiya. They observed phosphate levels ranging between 0.01-0.24 mg/L from January to April. Anitha Kumari *et al.* (2023) ^[2] conducted a study on the Seasonal Variations in Physico-Chemical Characteristics of Kanyakumari Coastal Waters, situated on the South West Coast of India. They found phosphorus levels ranging between 0.05-1.04 mg/L.

3.14 Hydrogen Sulphide (H₂S)

Hydrogen sulphide (H₂S), also known as sulphide, naturally exists within marine sediment. However, excessive sulphide production due to coastal water eutrophication can present a serious danger to sea grasses. This increase in sulphide levels can adversely affect the health and survival of sea grass ecosystems (Rubiano *et al.*, 2022) ^[19]. The Veraval coast exhibited monthly variations in mean hydrogen sulphide (H₂S) levels, ranging from 0.39 ± 0.011 to 0.51 ± 0.010 (Figure 15). The minimum mean H₂S for the Veraval coast was recorded in January, with the maximum observed in October. The reason for highest level of hydrogen sulphide in October at Veraval coast might be because of agricultural runoff with excess nutrient and industrial discharge due to post monsoon season. Conducted a study on the physicochemical parameters of water in various coastal regions of Gujarat, India, which revealed seasonal variations in different parameters. They found hydrogen sulphide levels ranging from 0.37 to 1.03 mg/L, consistent with the observed trends in this study.

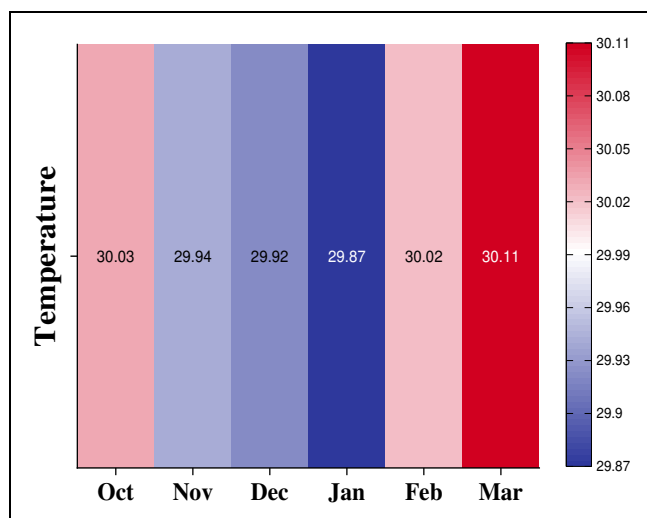


Fig 2: Monthly variation in temperature

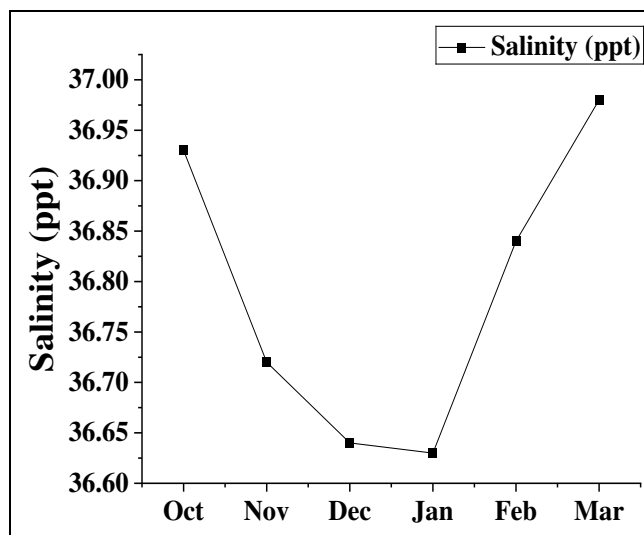


Fig 3: Monthly variation in salinity

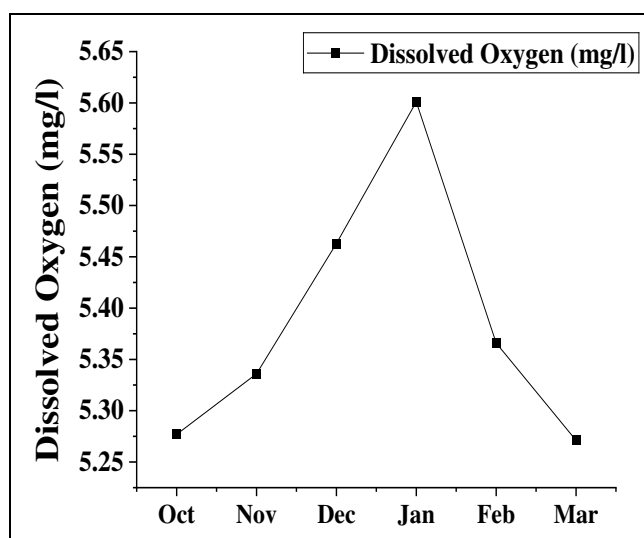


Fig 4: Monthly variation in dissolved oxygen

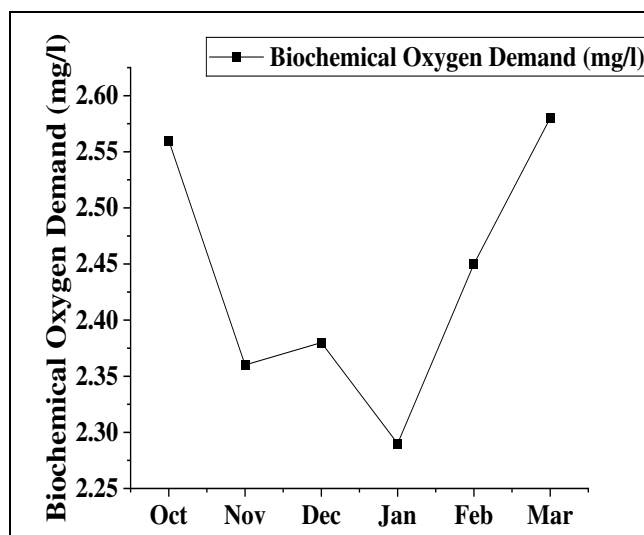


Fig 5: Monthly variation in BOD

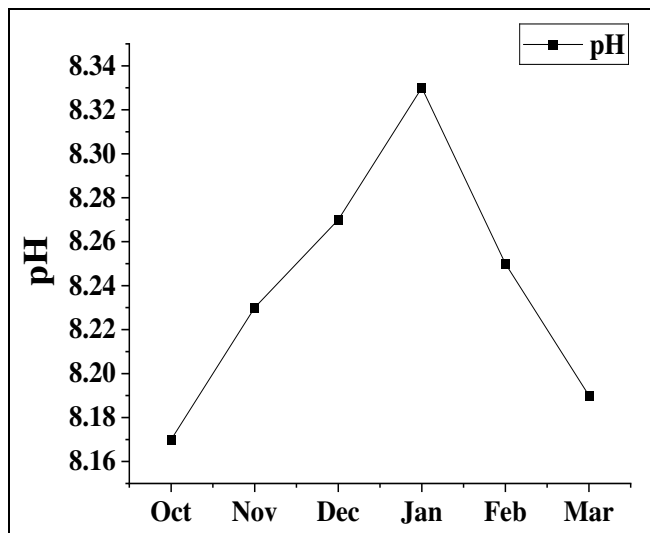


Fig 6: Monthly variation in pH

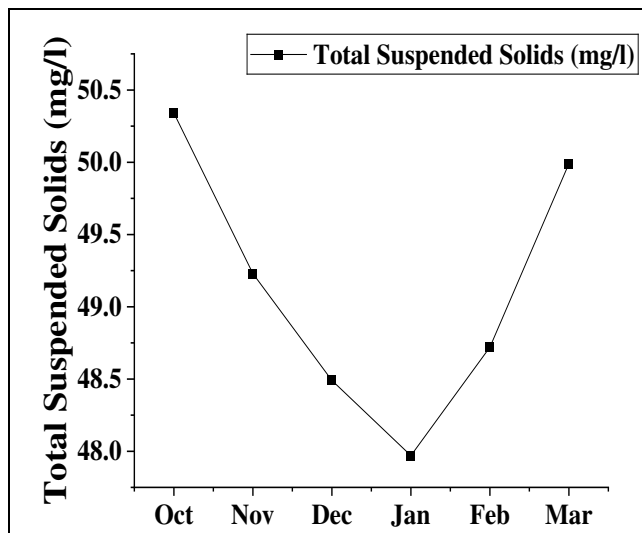


Fig 9: Monthly variation in TSS

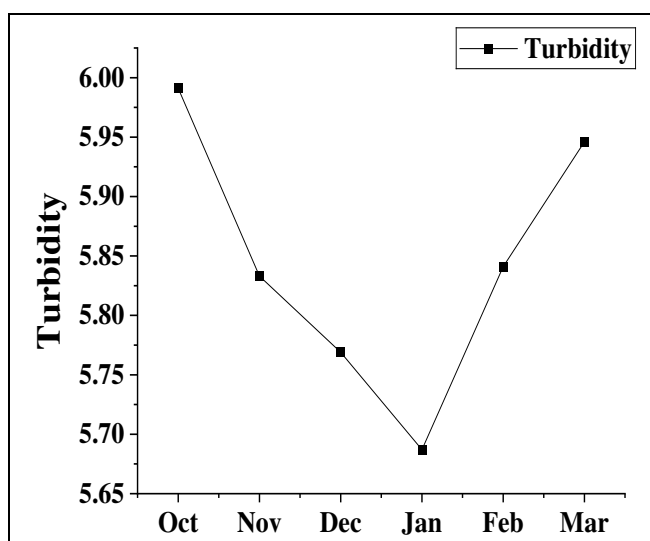


Fig 7: Monthly variation in turbidity

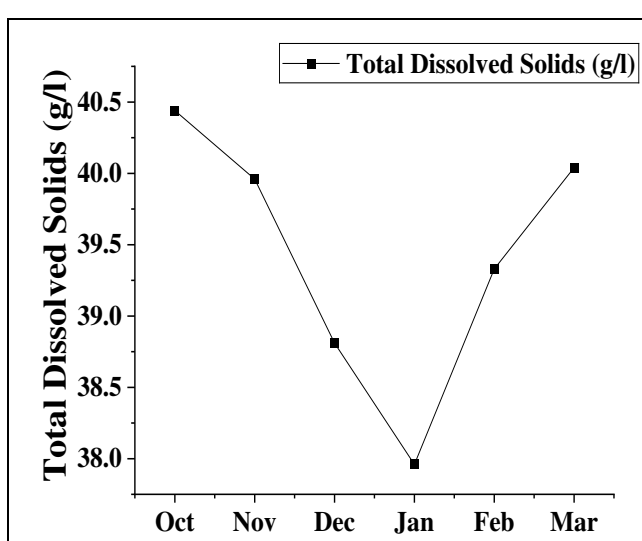


Fig 10: Monthly variation in TDS

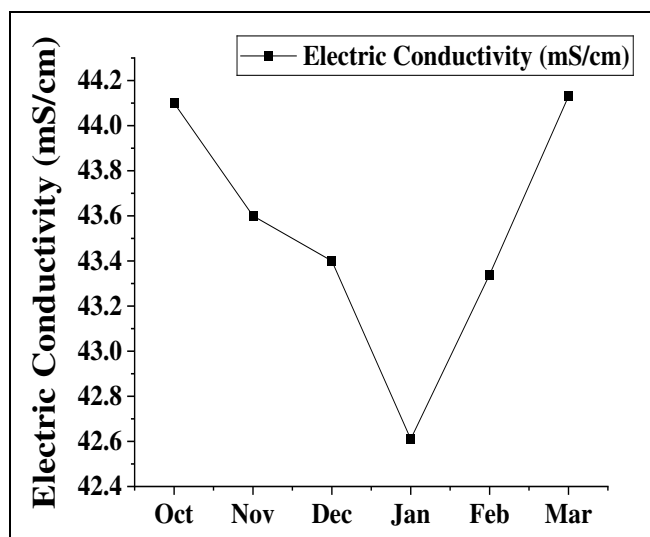


Fig 8: Monthly variation in EC

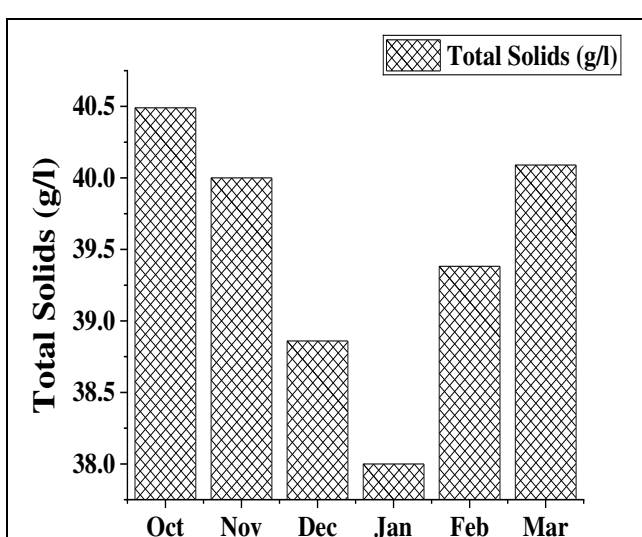


Fig 11: Monthly variation in TS

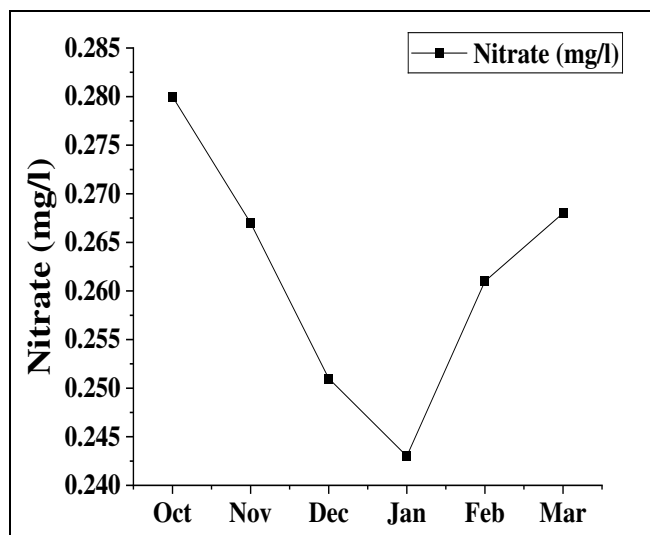


Fig 12: Monthly variation in TDS

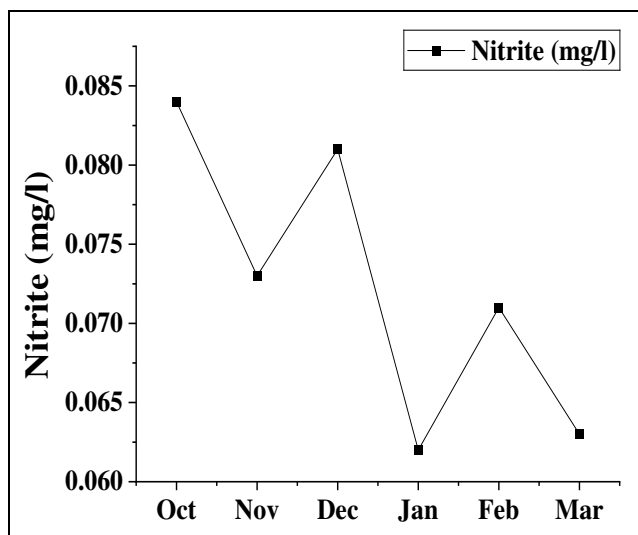


Fig 13: Monthly variation in TDS

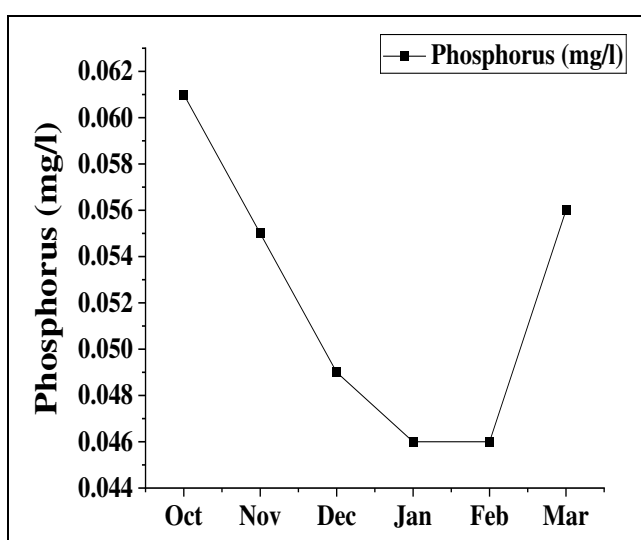


Fig 14: Monthly variation in TDS

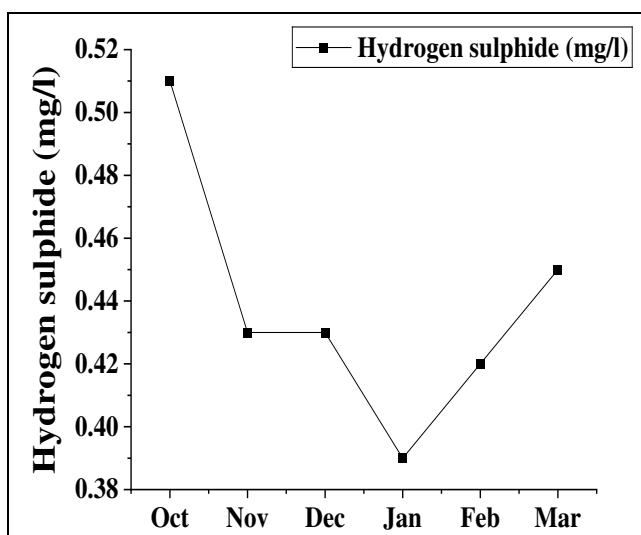


Fig 15: Monthly variation in TDS

3.15 Overall Index of Pollution (OIP)

Overall Index of Pollution for the Veraval coast was calculated based on the pollution index of all parameters as Overall index of pollution is the mean of all parameter's

pollution indices. Veraval observed the OIP of 1.7894. Veraval coastal sites were classified in acceptable (Class-2) category of Overall pollution index.

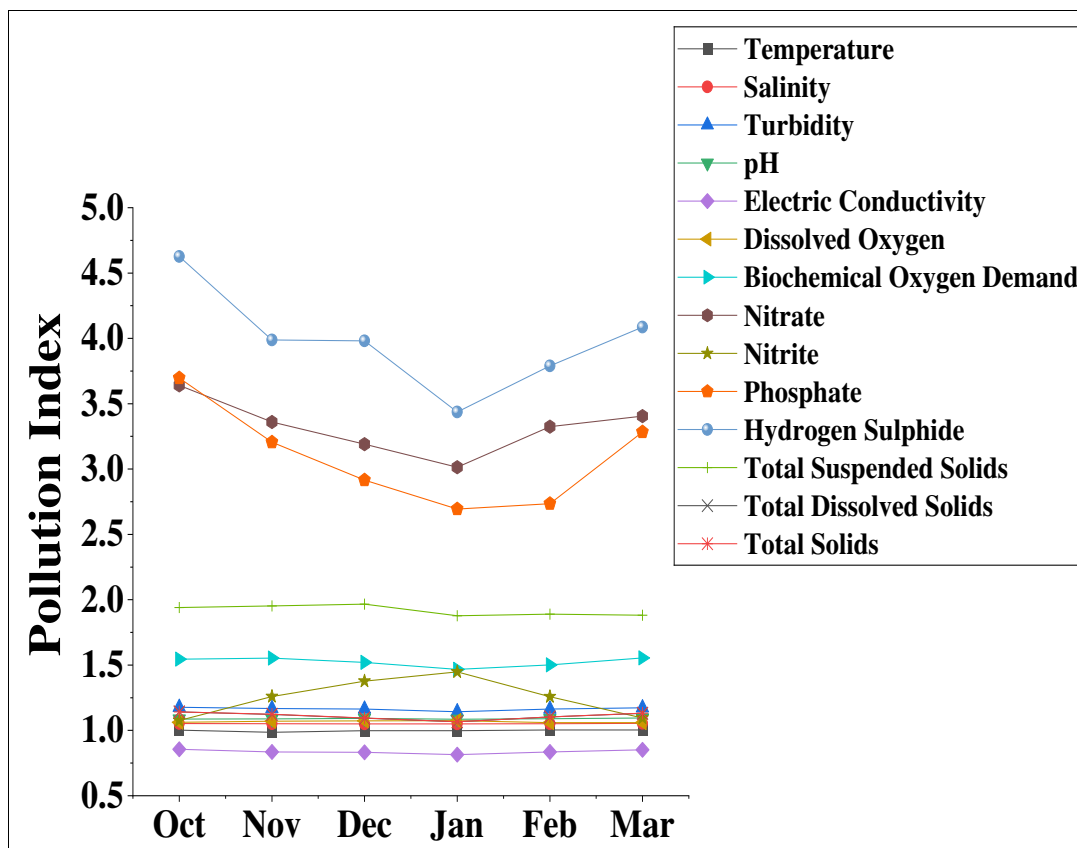


Fig 16: Monthly parameter wise pollution index

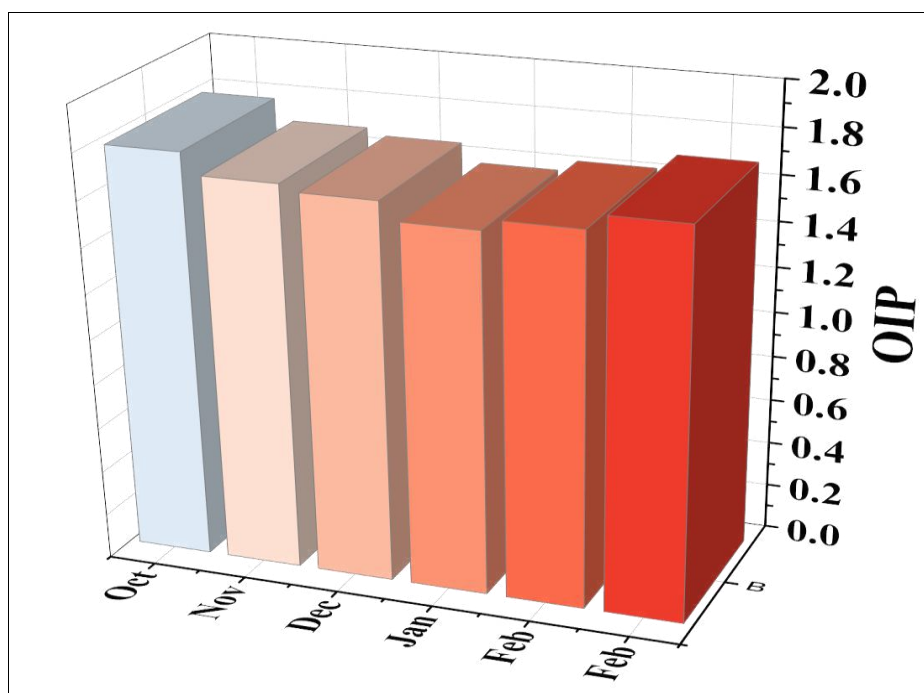


Fig 17: Monthly overall index of pollution

The higher Overall Index of Pollution (OIP) observed in Veraval coast could be attributed to a higher concentration of industrial waste, increased agricultural runoff from rivers, and more anthropogenic activities in Veraval. October month found with the highest OIP of 1.913. October month Veraval coast found to be highest polluted might be due the runoff from the rivers and land in post monsoon season, while January month observed with the lowest OIP value of

1.685 (Table 1, Figure 17). Tanjung *et al.*, (2019) ^[24] conducted a study on the coastal water quality and pollution index in the Mimika region of Indonesia. Their findings indicated that the pollution index assessment classified Mimika's coastal waters into two categories: lightly polluted (Keakwa and Pomako waters) and moderately polluted (Moga, Puriri, Inaoga, and Atuka waters), with pollution index values ranging from 3.51 to 6.95.

Table 1: Pollution index for different parameters

Parameters	Oct	Nov	Dec	Jan	Feb	Mar
Temperature (°C)	1.003	0.999	0.998	0.997	1.003	1.003
Salinity (ppt)	1.054	1.052	1.050	1.050	1.052	1.054
Turbidity	1.192	1.180	1.175	1.157	1.177	1.192
pH	1.086	1.088	1.092	1.095	1.090	1.086
Electric Conductivity (mS/cm)	0.859	0.846	0.845	0.829	0.845	0.859
Dissolved Oxygen (mg/l)	1.057	1.068	1.081	1.095	1.062	1.057
Biochemical Oxygen Demand (mg/l)	1.594	1.560	1.554	1.500	1.549	1.601
Nitrate (mg/l)	4.050	3.778	3.600	3.435	3.778	3.814
Nitrite (mg/l)	1.349	1.345	1.472	1.342	1.318	1.164
Phosphate (mg/l)	4.100	3.667	3.334	3.134	3.100	3.767
Hydrogen sulphide (mg/l)	5.100	4.401	4.504	3.900	4.250	4.550
Total Suspended Solids (mg/l)	2.017	1.997	1.983	1.890	1.896	1.927
Total Dissolved Solids (g/l)	1.159	1.144	1.113	1.084	1.123	1.149
Total Solids (g/l)	1.160	1.144	1.114	1.084	1.124	1.150
Overall Pollution Index	1.913	1.805	1.779	1.685	1.741	1.812

4. Conclusion

The present study on "Assessment of Pollution Index Based on physico-Chemical Parameters of Coastal Waters along Veraval, Gujarat" underscore the significant impact of pollution on coastal ecosystems. Over the course of six months, extensive analysis of various physicochemical parameters revealed distinct differences in pollution levels in different months along Veraval coastal areas.

Temperature fluctuations, though within standard values, exhibited slight differences, with March showing a marginally higher pollution index. Similarly, variations in pH and salinity showing higher pollution index in march while turbidity and electrical conductivity contributed to higher pollution indices along the Veraval coast in October month might be due to post monsoon season, highlighting the influence of industrial discharges and agricultural runoff on coastal water quality. Dissolved oxygen levels, crucial for marine life, displayed notable variations, with the march exhibiting slightly lower levels compared to the January month. Moreover, elevated levels of biochemical oxygen demand (BOD) were showing the highest value of pollution index in March. Total suspended solids (TSS), and total dissolved solids (TDS) and Total Solids (TS) in Veraval further emphasize the detrimental impact of pollution on water quality. Nitrate and nitrite levels, indicative of nutrient pollution, were notably showing higher level of pollution indexes, suggesting a heightened risk of eutrophication and algal blooms in the former. Additionally, phosphorus and hydrogen sulphate concentrations were significantly elevated in Veraval, pointing to severe pollution levels and potential ecological risks.

In this study in October month, Veraval coast found to be highest polluted might by the runoff activities during the post monsoon season and in January Veraval coast was at the lowest pollution level. Overall, the study's Assessment of pollution indices, encompassing a wide range of physicochemical parameters, provides valuable insights into the health of coastal ecosystems in Veraval.

Furthermore, the classification of Veraval coast was found to be within the acceptable pollution category (Class C2) based on the Overall Pollution Index categories. The importance of this study was to determine pollution of coastal waters of Veraval and to promote sustainable coastal management practices.

5. References

1. Adnina GSN. Water pollution index based on physical-chemical parameters in Bojonegara Coastal Waters of Banten Bay, Indonesia. IOP Conf Ser Earth Environ Sci. 2023 Oct;1251(1):012023.
2. Kumari AC, Christobel J, Lawrence B. Seasonal variations in physico-chemical characteristics of Kanyakumari Coastal Waters, South West Coast of India. J Surv Fish Sci. 2023;10(2S):3549-3561.
3. American Public Health Association. Standard methods of water and wastewater. 21st Ed. Washington, DC: American Public Health Association, 2005, p. 2-61.
4. Balakrishnan S, Chelladurai G, Mohanraj J, Poongodi J. Seasonal variations in physico-chemical characteristics of Tuticorin coastal waters, southeast coast of India. Appl Water Sci. 2017;7:1881-1886.
5. Bashir I, Lone FA, Bhat RA, Mir SA, Dar ZA, Dar SA. Concerns and threats of contamination on aquatic ecosystems. In: Bioremediation and biotechnology: sustainable approaches to pollution degradation, 2020, p. 1-26.
6. Bhadja P, Kundu R. Status of the seawater quality at few industrially important coasts of Gujarat (India) off Arabian Sea. Indian J Geo Mar Sci. 2012;41(1):90-97.
7. Bhargavi K, Priyanka PK, Shyamala PN, Nageswara RG. Physico-chemical parameters and water quality index in coastal waters of Vamsadhara Estuary, Srikakulam District, Andhra Pradesh, India. Int J Eng Technol Res. 2022;10(5):15-19.
8. Dong L, Wang D, Song L, Gong F, Chen S, Huang J, *et al.* Monitoring dissolved oxygen concentrations in the coastal waters of Zhejiang using Landsat-8/9 imagery. Remote Sens. 2024;16(11):1951.
9. Jeyageetha JC, Kumar SP. Study of physico-chemical parameters of sea water in Tuticorin coastal area and assessing their quality, Tamil Nadu, India. J Chem Pharm Res. 2015;7(5):1298-1304.
10. Johnes P, Heathwaite A, Spears B, Brownlie W, Elser J, Haygarth P, *et al.* Phosphorus and water quality. In: Chapter 5; c2022. Available from: <https://doi.org/10.13140/RG.2.2.14950.50246>
11. Kumar N, Kumar A, Marwein BM, Verma DK, Jayabalan I, Kumar A, *et al.* Agricultural activities

- causing water pollution and its mitigation – A review. *Int J Mod Agric*. 2021;10(1):1-21.
12. Sagasta MJ, Zadeh SM, Turrall H, Burke J. Water pollution from agriculture: a global review. Executive summary. Rome, Italy: FAO; Colombo, Sri Lanka: IWMI; 2017.
 13. May CL, Koseff JR, Lucas LV, Cloern JE, Schoellhamer DH. Effects of spatial and temporal variability of turbidity on phytoplankton blooms. *Mar Ecol Prog Ser*. 2003;254:111-128.
 14. Minister of Environment. Decree of the Minister of Environment No. 51 year 2004 about Water Quality Standard for Coastal water. Jakarta: Minister of Environment of the Republic of Indonesia; 2004.
 15. Panda A, Mohanty B, Jena A. Coastal pollution in India. *Aquastar Mag*, 2017, p. 6.
 16. Pandit PR, Fulekar MH. Quality characterization of coastal water in Gujarat coast, India. *IOSR J Biotech Biochem*. 2017;3(4):8-15.
 17. Raghunathan C, Gupta RS, Wangikar U, Lakhmapurkar J. A record of live corals along the Saurashtra coast of Gujarat, Arabian Sea. *Curr Sci*. 2004;1131-1138.
 18. Raghunathan C, Tewari A, Joshi HV, Kumar VS, Trivedi RH, Khambhaty Y. Impact of turbidity on intertidal macrofauna at Gopnath, Mahuva, and Veraval coasts (west coast of India). *Indian J Mar Sci*. 2003;32(3):214-221.
 19. Rubiano S, Larkin P. An assessment of hydrogen sulfide intrusion in the seagrass *Halodule wrightii*, 2022.
 20. Salvi H, Patel R, Thakur B, Shah K, Parmar D. Assessment of coastal water quality parameters of selected areas of Marine National Park & Sanctuary (Okha, Sikka & Khijadiya). Available from: SSRN 2456093, 2014.
 21. Sankpal ST, Naikwade PV. Physicochemical analysis of effluent discharge of fish processing industries in Ratnagiri, India. *Biosci Discov*. 2012;3(1):107-111.
 22. Sargaonkar A, Deshpande V. Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environ Monit Assess*. 2003;89(1):43-67.
 23. Strickland JDH, Parsons TR. A practical handbook of seawater analysis, 1972.
 24. Tanjung RH, Hamuna B, Alianto. Assessment of water quality and pollution index in coastal waters of Mimika, Indonesia. *J Ecol Eng*. 2019;20(2):87-94.
 25. Trivedy RK, Goel PK. Chemical and biological methods for water pollution studies. Environmental Publications; 1984.