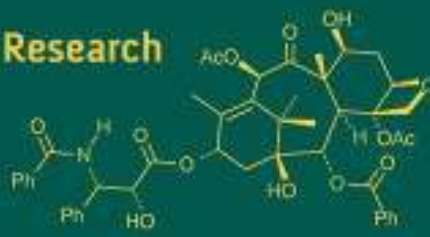
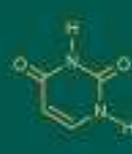


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Assessment of monthly variations in physico-chemical parameters at New Mangrol Fishing Port, Gujarat

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Abstract

Harbour environments are dynamic coastal systems that are highly prone to pollution due to intensive fishing operations, increased vessel movement and land-derived human activities. Therefore, systematic monitoring of harbour water quality is crucial for evaluating the effects of anthropogenic pressures. Accordingly, the present study evaluated the physico-chemical parameters of harbour water at Mangrol Harbour (New Mangrol Fishing Port), Gujarat, over an eight-month period from August 2024 to March 2025 across four sampling stations (Stations 1 to 4). Sixteen physico-chemical were analyzed to assess water quality. Water temperature ranged from 24.68 ± 0.064 °C to 30.37 ± 0.034 °C, salinity from 30.44 ± 0.017 ppt to 36.41 ± 0.062 ppt, and pH remained moderately alkaline, varying between 7.65 ± 0.034 to 8.36 ± 0.026 . Conductivity values ranged from 43.17 ± 0.077 mS/cm to 50.70 ± 0.069 mS/cm, while turbidity varied between 34.82 ± 0.090 NTU to 38.46 ± 0.144 NTU. Dissolved oxygen concentrations ranged from 3.60 ± 0.036 mg/L to 3.99 ± 0.039 mg/L, with biochemical oxygen demand values between 0.36 ± 0.029 mg/L to 0.78 ± 0.034 mg/L. Chloride content ranged from 16853.95 ± 8.570 mg/L to 20199.16 ± 35.091 mg/L, total hardness from 2470.19 ± 12.431 mg/L to 2969.68 ± 12.933 mg/L, and alkalinity from 122.42 ± 2.648 mg/L to 166.79 ± 1.882 mg/L. Total suspended solids ranged from 73.26 ± 0.355 mg/L to 80.47 ± 0.442 mg/L, total dissolved solids from 39.59 ± 0.044 g/L to 44.22 ± 0.261 g/L, and total solids from 39.67 ± 0.044 g/L to 44.29 ± 0.0265 g/L. Nutrient concentrations showed nitrate levels between 0.528 ± 0.093 mg/L to 1.234 ± 0.096 mg/L, phosphate from 0.067 ± 0.003 mg/L to 0.196 ± 0.003 mg/L, and ammonia from 0.240 ± 0.015 mg/L to 0.437 ± 0.020 mg/L. Seasonal variations indicated higher values of temperature, salinity, conductivity, dissolved solids, chloride, hardness and alkalinity during March, while turbidity, nutrients, suspended solids and microbial loads peaked in September. Overall, the water quality at New Mangrol Fishing Port remained within acceptable limits, though seasonal fluctuations reflect the influence of harbour activities and environmental conditions.

Keywords: Harbour water, New Mangrol Fishing Port, Physico-chemical Characteristics, Water Quality

Introduction

Water is a pure, flavourless, odourless and nearly colourless chemical substance that is essential for all known life forms. Although the oceans contain approximately 97% of the Earth's water, freshwater accounts for only about 3%, or nearly 36 million cubic kilometres [16]. Coastal waters, despite representing a relatively small proportion of the marine environment, support exceptionally high biological diversity and productivity. These ecosystems underpin global fisheries, including aquaculture, which are critical for food security by providing nutrition, income and livelihoods to millions of people worldwide [11]. Fishing activities stimulate the growth of fish processing industries and markets, transforming harbour areas into dynamic economic hubs that connect coastal and inland regions through efficient transportation networks. However, increasing anthropogenic pressures, particularly contamination and nutrient enrichment associated with intensified coastal activities, are disrupting ecological balance and threatening the sustainability of coastal ecosystems and fisheries [8, 19].

Harbours are typically semi-enclosed coastal systems with restricted water exchange, making them particularly vulnerable to the accumulation of pollutants [20]. Fishing harbours function as complex socio-ecological systems that support fish production and trade but

simultaneously generate significant quantities of waste from vessel operations, fish processing, market activities and improper waste disposal practices [15, 27]. While effective management and infrastructure can promote waste minimization and quality control, inadequate facilities and poor governance often result in deteriorating water quality, posing risks to marine ecosystems, public health and the long-term viability of fisheries [30].

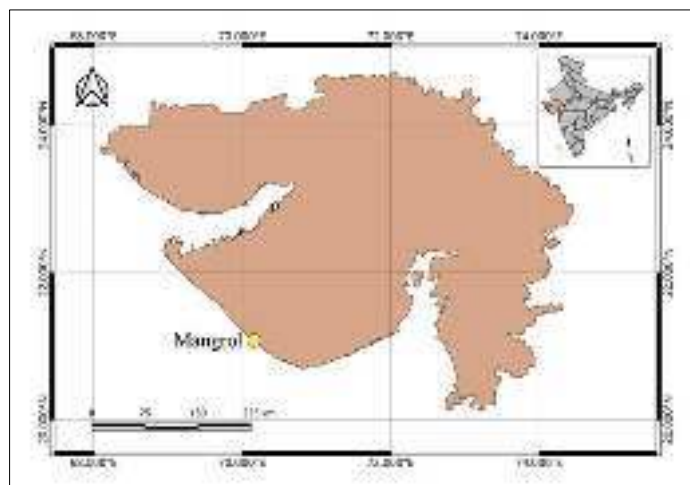
Gujarat possesses a well-developed fisheries infrastructure comprising eight major fishing harbours includes Jafrabad, Veraval, Mangrol, Vanakbara, Kotada, Okha, Porbandar and Chorwad along with numerous fish landing centres that enhance fishing efficiency through secure berthing and streamlined handling of catches [31]. However, the rapid intensification of fishing activities has increased pollution pressures within these harbour environments. Water pollution arising from sewage discharge, industrial effluents, agricultural runoff and oil spills represents a serious global concern, with nearly 2 million tons of waste entering water bodies daily [44]. Despite the apparent abundance of water resources, only about 1% is suitable for human consumption, and waterborne diseases continue to cause millions of deaths annually, highlighting the urgent need for effective water quality management in coastal and harbour ecosystems [1, 46]. In this context, the assessment of physico-chemical parameters is fundamental for evaluating harbour water quality and overall ecosystem health. Physical parameters such as sea surface temperature, salinity, chlorinity, turbidity (total suspended solids), total dissolved solids, electrical conductivity and water hardness regulate primary productivity, species distribution and water clarity, while also serving as indicators of contamination [3, 17, 18, 47].

Chemical parameters, including dissolved oxygen, pH, total alkalinity, biochemical oxygen demand and nutrients such as nitrate, phosphate and ammonia, further characterize ecological conditions by reflecting organic pollution, buffering capacity and eutrophication potential [32, 40, 49]. Regular monitoring of these parameters is therefore essential for understanding pollution dynamics, protecting marine ecosystems and public health, and ensuring the long-term sustainability of fishing harbours.

Material and Methods

Description of Study area

Mangrol is a coastal town in Junagadh district, Gujarat, located at 21°07'12.00" N latitude and 70°07'12.00" E longitude. Mangrol Harbour is a major fishing centre along the Gujarat coast, surrounded by boat-building yards and fish processing units. It consists of two fish landing centres: the old harbour (Mangrol Godi) and the newly developed Mangrol Fishing Port. The harbour primarily supports trawl fishing, with catches from single and multi-day trawlers brought directly for sorting, grading, weighing and cleaning. However, untreated wastewater generated from these activities is frequently discharged into the harbour, leading to deterioration of water quality. The New Mangrol Fishing Port is a modern, well-planned facility designed for large-scale fishing operations. It features two large curved breakwaters that protect the harbour and maintain calm waters. The port has wide landing areas, a deep and spacious basin that ensures good water circulation, and modern infrastructure including efficient roads, buildings and transport facilities, making it significantly more advanced than the older harbour.



A. Mangrol, a coastal town in Gujarat



B. Satellite image of different stations of New Mangrol Fishing Port (right)

Fig 1: Location of The Study Area

Table 3.1: Location of sampling stations along New Mangrol Fishing Port at Mangrol harbour.

New Mangrol Fishing Port	S1	21°06'42"N 70°05'35"E
	S2	21°06'36"N 70°05'36"E
	S3	21°06'34"N 70°05'29"E
	S4	21°06'45"N 70°05'22"E

Methodology

The study was conducted over an eight-month period from August 2024 to March 2025, during which harbour water samples were collected monthly from eight stations, with

three replicates at each station to ensure the reliability and accuracy of the results. Harbour water samples were collected from the surface layer (0.5-1.0 m) at each station within the harbour using clean 2-liter plastic bottles and were immediately transported to the Aquatic Environment Management Laboratory, College of Fisheries Science, Veraval, for further analysis. Water temperature was measured using a thermometer (Sita Petroleum Research Company), salinity using an Atago® refractometer, and pH using an Igene Labserve® pH meter (Model IG-10pH) following Trivedy and Goel [41]. Conductivity was

determined using a Delux conductivity meter (Model 602), turbidity by the nephelometric method, dissolved oxygen by Winkler's method, biochemical oxygen demand (BOD) by incubation and titration, and total hardness by the EDTA titrimetric method. Chloride was analyzed by Mohr's titration method, alkalinity by titration, total suspended solids and total dissolved solids by filtration and evaporation methods, total solids by evaporation, nitrate by UV spectrophotometric screening, phosphate by the ascorbic acid spectrophotometric method, and ammonia by the phenate spectrophotometric method. The analysis of conductivity, turbidity, dissolved oxygen, BOD, total hardness, chloride, alkalinity, total suspended solids, total dissolved solids, total solids, nitrate, phosphate and ammonia was carried out following the standard methods prescribed by APHA [5].

Statistical Analysis

The collected data were subjected to standard statistical analyses to evaluate variations in physico-chemical. Descriptive statistics, including mean, standard deviation, and the determination of minimum and maximum values, were calculated for all variables. Differences among parameters and sampling periods were assessed for statistical significance using Duncan's post-hoc test. All statistical analyses were performed using Microsoft Excel (2021) and IBM SPSS Statistics version 27.0, following the statistical procedures outlined by Snedecor and Cochran [35].

Results and Discussion

All results are expressed as mean values with their corresponding standard deviation (Mean $\pm$ SD). Differences among treatments were evaluated using Duncan's multiple range post hoc test. Means bearing identical superscript letters indicate no significant variation, whereas different letters denote statistically significant differences between groups.

Water Temperature (°C)

Temperature strongly influences chemical processes in aquatic systems and the metabolic activity of aquatic organisms. In fish, increasing temperatures elevate metabolic rates up to an optimal level, beyond which physiological efficiency declines due to mitochondrial impairment [50]. During the present study, the mean water temperature at New Mangrol Fishing Port exhibited noticeable monthly variation, ranging from 24.68 $\pm$ 0.064 °C in December to 30.37 $\pm$ 0.034 °C in March. Duncan's post hoc test revealed significant differences among months, with each month forming a distinct group. Comparable temperature fluctuations have been reported in earlier studies, including Nithya *et al.* [28], who recorded values between 23.2 °C and 33.5 °C at Kasimedu and Ennore harbours, and Varma *et al.* [45], who observed temperatures ranging from 25.14 °C to 31.56 °C along the Veraval Coast, Gujarat.

Salinity (PPT)

Salinity is a key factor influencing the distribution and survival of aquatic organisms, particularly in estuarine environments where freshwater mixes with seawater. Variations in salinity can act as environmental stressors, and climate-driven fluctuations may adversely affect species adapted to specific salinity ranges, underscoring the

importance of regular monitoring [45]. During the present study, salinity at New Mangrol Fishing Port showed considerable monthly variation, ranging from 30.44 $\pm$ 0.017 ppt in September to 36.41 $\pm$ 0.062 ppt in March. Duncan's multiple range post hoc test revealed statistically significant differences among months, with each month forming a distinct group. Comparable salinity fluctuations have been reported in earlier studies, including Varma *et al.* [45], who observed values between 25.10 and 38.62 ppt along the harbour waters of the Veraval Coast, Gujarat, and Bamaniya *et al.* [7], who recorded salinity ranging from 32.65 to 33.43 ppt in Veraval harbour waters.

pH

pH is a key indicator of water quality, influencing the survival of aquatic organisms, the availability and toxicity of chemicals, and overall ecosystem health. Even minor fluctuations in pH can stress aquatic life, and changes may indicate pollution or affect water treatment processes [13, 43]. During the study period, pH at New Mangrol Fishing Port showed noticeable variation, ranging from 7.65 $\pm$ 0.034 to 8.36 $\pm$ 0.026, with the lowest values observed in September and the highest in December. Duncan's post hoc test revealed statistically significant monthly differences, with each month forming a distinct group. Similar patterns have been reported elsewhere: Prem Sudha *et al.* [37] recorded pH levels of 7.46-8.10 in the coastal waters of Nagapattinam Port, Tamil Nadu, while the Central Pollution Control Board (CPCB) [12], under the National Water Monitoring Programme (NWMP), reported ranges of 7.4-8.1 at Nizampattanam, 7.2-7.7 at Kakinada, and 7.0-7.9 at Gangoli Harbour.

Electrical Conductivity

Electrical conductivity (EC) serves as a key indicator of the health of aquatic ecosystems and the environment. High EC levels can negatively impact biological condition scores and modify community composition in streams, making it a valuable overall metric for ecological evaluation [39]. During the monitoring period, EC at New Mangrol Fishing Port exhibited noticeable fluctuations, values ranged from 43.17 $\pm$ 0.077 mS/cm in September to 50.70 $\pm$ 0.069 mS/cm in March. Duncan's post hoc test revealed statistically significant monthly differences, with each month forming a distinct group. Comparable trends have been reported elsewhere: the Central Pollution Control Board (CPCB) [12] recorded conductivity ranging from 25, 500 to 51, 700 μ mho/cm at Kakinada Harbour and from 41, 000 to 53, 400 μ mho/cm at Nizampattanam Harbour, while Tandel *et al.* [38] observed EC along the Veraval Coast, Gujarat, ranging from 42.61 $\pm$ 0.080 mS/cm to 44.10 $\pm$ 0.033 mS/cm.

Turbidity (NTU)

Turbidity, caused by suspended particles that scatter and absorb light, is an important indicator of coastal water quality. It influences light penetration, which affects photosynthesis and the health of seagrass, benthic communities, and coral reefs, making its monitoring essential for managing dredging and port operations [10, 29]. In the present study, turbidity at New Mangrol Fishing Port ranged from 34.82 $\pm$ 0.090 NTU in December to 38.46 $\pm$ 0.144 NTU in September. Duncan's post hoc test revealed statistically significant monthly differences, with each month forming a distinct group. Similar trends have been

reported in other studies: Varma *et al.* [45] recorded turbidity levels of 52.39-66.54 NTU along the Veraval Coast, Gujarat, while Bamaniya *et al.* [7] observed values ranging from 77.12 ± 5.87 NTU to 80.20 ± 7.91 NTU in Veraval Fishing Harbour, Gujarat.

Dissolved Oxygen (mg/L)

Dissolved oxygen (DO) is a crucial parameter for marine organisms, reflecting the oxygen available for respiration. Low DO levels, often resulting from organic pollution and the decomposition of organic matter, can lead to hypoxic conditions, while estuarine DO is also influenced by freshwater inflow, water mixing, and nutrient-driven algal blooms [33]. In the present study, DO at New Mangrol Fishing Port showed distinct temporal and spatial variations. At New Mangrol Fishing Port, values ranged from 3.60 ± 0.036 mg/L in March to 3.99 ± 0.039 mg/L in December. Duncan's post hoc test confirmed statistically significant monthly differences, with each month forming a separate group. Similar trends have been observed in other studies: under the National Water Monitoring Programme, the Central Pollution Control Board (CPCB) [12] reported DO levels of 6.0-7.4 mg/L at Kakinada Fishing Harbour, 5.9-6.7 mg/L at Nizampatnam Fishing Harbour, and approximately 7.0 mg/L at Gangoli Harbour. Bamaniya *et al.* [7] recorded DO fluctuations between 1.08 and 2.19 mg/L in Veraval Fishing Harbour.

Biochemical oxygen demand (mg/L)

Biochemical Oxygen Demand (BOD) measures the oxygen consumed by microorganisms during the breakdown of organic matter and the metabolism of cellular components in sewage, reflecting the amount of oxidizable organic material in water [26]. In the present study, BOD levels at New Mangrol Fishing Port showed clear seasonal and spatial variations. At New Mangrol Fishing Port, values ranged from 0.36 ± 0.029 mg/L in December to 0.78 ± 0.034 mg/L in September, with Duncan's post hoc test confirming statistically significant monthly differences. Similar trends have been reported in other Indian fishing harbours. The Central Pollution Control Board (CPCB) [12], under the National Water Monitoring Programme (NWMP), recorded BOD levels of 2.5-2.9 mg/L at Nizampatnam Fishing Harbour, 1.8-2.2 mg/L at Kakinada Fishing Harbour, and approximately 2.0 mg/L at Gangoli Harbour, Kundapura. Bamaniya *et al.* [7] observed BOD fluctuations between 0.74 and 2.73 mg/L in Veraval Fishing Harbour.

Chloride (mg/L)

Chloride concentrations are useful indicators of saltwater intrusion and contamination from sewage or industrial effluents. Elevated chloride levels, commonly observed in areas influenced by seawater, can be toxic to aquatic organisms, impacting both plants and animals [36]. In the present study, chloride levels at New Mangrol Fishing Port exhibited distinct seasonal and spatial variations, ranging from 16853.95 ± 8.570 mg/L in September to 20199.16 ± 35.091 mg/L in March. Duncan's post hoc test confirmed statistically significant differences among months, with each month forming a separate group. Similar patterns have been reported in other Indian harbours. Meiaraj and Jeyapriya [22] recorded chloride concentrations of 16, 254-18, 970 mg/L in the coastal waters of Tuticorin Harbour, while Bamaniya *et al.* [7] observed values between

17, 992 ± 1 , 264.4 mg/L and 18, 388 ± 1 , 242.8 mg/L in Veraval Fishing Harbour, Gujarat.

Total Hardness

Total hardness is a key water quality parameter, reflecting the concentrations of calcium and magnesium. High levels, especially in waters with significant alkalinity, can cause scale formation when heated or when pH increases, leading to clogged pipes and deposits in boilers and heat exchangers [9]. In the present study, total hardness values ranged from 2, 470.19 ± 12.43 mg/L in September to 2, 969.68 ± 12.93 mg/L in March at New Mangrol Fishing Port. Duncan's post hoc test confirmed that these variations were statistically significant, with each month forming a separate group. Similar seasonal trends have been reported in other coastal areas of Gujarat. Gosai and Mankodi [14] recorded total hardness in surface waters along the western coast of Bhavnagar, Gulf of Khambhat, ranging from 6, 697.3 ± 353.9 mg/L during the pre-monsoon to 4, 231.0 ± 261.5 mg/L in the monsoon and 5, 851.8 ± 857.4 mg/L in the post-monsoon period. Likewise, Bamaniya *et al.* [7] observed fluctuations between 2, 525.33 ± 178.24 mg/L and 2, 644.37 ± 123.67 mg/L in Veraval Fishing Harbour, Gujarat.

Alkalinity (mg/L)

Alkalinity plays a vital role in maintaining the stability of aquatic ecosystems by regulating pH variations and protecting aquatic organisms. Fluctuations in alkalinity levels often reflect anthropogenic impacts, particularly from industrial and domestic effluent discharges, which alter the ionic composition and buffering capacity of harbour waters [23]. The results of the present study revealed noticeable seasonal variations in alkalinity at New Mangrol Fishing Port, with values ranging from 122.42 ± 2.65 mg/L to 166.79 ± 1.88 mg/L. The lowest alkalinity levels were recorded in September, while the highest were observed in March. These variations were statistically significant, as confirmed by Duncan's post-hoc test, which categorized the months into distinct groups. Comparable seasonal patterns have been reported from other coastal regions of India. Singh *et al.* [34] documented alkalinity values ranging from 62.20 to 138.00 mg/L along the Bhavnagar coast, Dahej coast (Bharuch), Dumas Beach (Surat), and the Purna estuaries in Navsari. Similarly, Bamaniya *et al.* [7] reported alkalinity fluctuations between 143.20 ± 16.65 mg/L and 180.08 ± 37.28 mg/L in Veraval Fishing Harbour, Gujarat.

Total Suspended Solids (mg/L)

Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Total Solids (TS) are important indicators of water quality, reflecting the presence of both natural and anthropogenic organic and inorganic materials. TDS represents dissolved salts and minerals, while TSS indicates suspended particles that affect water clarity, light penetration, and overall aquatic ecosystem health, often transporting pollutants such as heavy metals and organic contaminants [4]. At New Mangrol Fishing Port, TSS values ranged from 73.26 ± 0.36 mg/L in December to 80.47 ± 0.44 mg/L in September. Duncan's post hoc test confirmed that these variations were statistically significant, with each month forming a distinct group. Similar trends have been reported in other coastal areas of Gujarat. Zala [48] recorded TSS values ranging from 71.33 to 84.63 mg/L while assessing heavy metal concentrations and physico-chemical

parameters along the Veraval Coast. Likewise, Malamadi ^[21] observed TSS fluctuations between 70.63 and 84.63 mg/L in harbour waters and sediments along the same coast.

Total Dissolved Solids (g/L)

During the study period, total dissolved solids (TDS) at New Mangrol Fishing Port showed marked seasonal variations. TDS values ranged from 39.59±0.04 g/L in September to 44.22±0.26 g/L in March. Duncan's post hoc test confirmed that these differences were statistically significant, with each month forming a distinct group. Similar seasonal patterns have been observed in other coastal regions. Prem Sudha *et al.* ^[37] reported TDS concentrations of 3.49-70.31 mg/L in the coastal and marine waters of Nagapattinam Port, Tamil Nadu, India. Likewise, Tandel *et al.* ^[38] recorded TDS values between 37.96±0.056 g/L and 40.44±0.04 g/L along the Veraval Coast, Gujarat.

Total Solids (g/L)

Total solids (TS) concentrations at New Mangrol Fishing Port showed clear seasonal variations across both monitoring sites. TS values ranged from 39.67±0.04 g/L in September to 44.29±0.03 g/L in March. Duncan's post hoc test confirmed that these variations were statistically significant, with each month forming a distinct group. Similar trends have been reported in other coastal regions. Bamanaya *et al.* ^[7] observed TS concentrations ranging from 67, 173.29±3, 296.29 mg/L to 70, 699.37±3, 532.65 mg/L in Veraval Fishing Harbour, while Tandel *et al.* ^[38] documented monthly TS fluctuations along the Veraval Coast, ranging from 38.004±0.056 g/L to 40.495±0.040 g/L.

Nitrate (mg/L)

The nitrate ion plays a significant role in human health and environmental quality, with excessive concentrations posing risks to ecosystems and disrupting natural balance ^[2]. During the study period in New Mangrol Fishing Port, concentrations ranged from 0.528±0.093 mg/L in December to 1.234±0.096 mg/L in September. Duncan's post hoc test confirmed that these differences were statistically significant, with each month forming a distinct group. Similar seasonal trends have been reported in other Indian

coastal harbours. The Central Pollution Control Board (CPCB) ^[12] recorded nitrate concentrations of 0.9-1.3 mg/L at Nizampatnam Fishing Harbour and 0.6-1.4 mg/L at Kakinada Fishing Harbour. Likewise, Tandel *et al.* ^[38] observed nitrate levels along the Veraval Coast ranging from 0.243±0.0007 mg/L to 0.280±0.0015 mg/L.

Phosphate (mg/L)

Phosphorus, the second most important nutrient after nitrogen, is essential for plant and animal growth but can act as a pollutant at elevated concentrations. Excessive phosphorus input is a key driver of eutrophication in lakes and other water bodies worldwide ^[6]. At New Mangrol Fishing Port, phosphate concentrations showed clear seasonal variations. At New Mangrol Fishing Port, values ranged from 0.067±0.003 mg/L in March to 0.196±0.003 mg/L in September, with Duncan's post hoc test confirming statistically significant differences and grouping each month into distinct categories. Similar seasonal patterns have been observed in other coastal regions. Prem Sudha *et al.* ^[37] reported phosphate concentrations of 0.44-1.55 mg/L in marine waters of Nagapattinam Port, Tamil Nadu, while Bamanaya *et al.* ^[7] recorded levels of 0.98-1.31 mg/L in Veraval Fishing Harbour.

Ammonia

Ammonia exposure in marine organisms, particularly shrimp, can lead to hemolymph accumulation, acid-base and ionoregulatory disturbances, oxidative and ER stress, and impaired energy metabolism, ultimately resulting in gill dysfunction, reduced oxygen uptake, and mortality ^[24, 25]. In the present study, ammonia concentrations at New Mangrol Fishing Port, values ranged from 0.240±0.015 mg/L in December to 0.437±0.020 mg/L in September, with Duncan's post hoc test confirming statistically significant differences among months. Comparable observations have been reported in other Indian coastal harbours. Prem Sudha *et al.* ^[36] recorded ammonia levels of 0.75-3.70 mg/L in the marine waters of Nagapattinam Port, Tamil Nadu, while Nithya *et al.* ^[28] reported concentrations between 0.040 and 0.158 mg/L in harbour waters of Kasimedu and Ennore, Chennai, influenced by port activities.

Table 2: Mean Monthly Physico-chemical parameter variations at New Mangrol Fishing Port (Mean±Standard Deviation, N=4)

Physico-chemical Parameter	August	September	October	November	December	January	February	March
Water Temperature (°C)	28.15±0.048 ^d	28.39±0.033 ^c	29.48±0.047 ^b	26.27±0.070 ^f	24.68±0.064 ^b	24.94±0.051 ^s	27.66±0.050 ^c	30.37±0.034 ^a
Salinity (PPT)	31.22±0.033 ^s	30.44±0.017 ^h	32.85±0.040 ^c	32.23±0.021 ^f	34.00±0.026 ^d	34.47±0.022 ^c	35.71±0.034 ^b	36.41±0.062 ^a
pH	7.75±0.030 ^f	7.65±0.034 ^s	7.83±0.032 ^c	8.19±0.034 ^c	8.36±0.026 ^a	8.27±0.031 ^b	8.03±0.040 ^d	7.76±0.036 ^f
Electrical conductivity (mS/cm)	44.76±0.095 ^s	43.17±0.077 ^h	45.46±0.069 ^f	46.79±0.070 ^c	47.36±0.103 ^d	47.90±0.061 ^c	48.29±0.068 ^b	50.70±0.069 ^a
Turbidity (NTU)	35.71±0.084 ^c	38.46±0.114 ^a	37.77±0.103 ^b	36.70±0.146 ^c	34.82±0.090 ^s	35.15±0.088 ^f	35.77±0.068 ^c	36.44±0.071 ^d
Dissolved oxygen (mg/L)	3.88±0.038 ^{cd}	3.77±0.029 ^c	3.64±0.026 ^f	3.89±0.036 ^{bc}	3.99±0.039 ^a	3.94±0.024 ^{ab}	3.83±0.049 ^d	3.60±0.036 ^f
Biochemical oxygen demand (mg/L)	0.53±0.039 ^c	0.78±0.034 ^a	0.62±0.039 ^b	0.47±0.043 ^d	0.36±0.029 ^c	0.45±0.035 ^d	0.44±0.024 ^d	0.53±0.039 ^c
Chloride (mg/L)	17264.89±35.54 ^{2s}	16853.95±8.570 ^h	18186.14±21.327 ^c	17837.98±9.090 ^f	18836.61±16.109 ^d	19044.91±13.759 ^c	19760.02±19.360 ^b	20199.16±35.091 ^a
Total Hardness (mg/L)	2575.86±11.682 ^f	2470.19±12.431 ^s	2578.12±11.224 ^f	2630.98±10.856 ^c	2651.34±6.960 ^d	2765.34±17.769 ^s	2828.36±12.092 ^b	2969.68±12.933 ^a
Alkalinity (mg/L)	127.07±1.499 ^s	122.42±2.648 ^h	133.48±3.324 ^f	142.86±2.696 ^c	148.72±1.068 ^d	152.50±2.717 ^c	158.92±2.092 ^b	166.79±1.882 ^a
Total Suspended Solids (mg/L)	77.30±0.446 ^c	80.47±0.442 ^a	78.20±0.393 ^b	75.59±0.558 ^d	73.26±0.355 ^f	73.55±0.228 ^f	74.51±0.437 ^c	75.27±0.637 ^d

Total Dissolved Solids (g/L)	39.98±0.033 ^{ef}	39.59±0.044 ^f	40.23±0.383 ^e	41.13±0.380 ^d	41.21±0.420 ^d	42.03±0.203 ^c	42.70±0.214 ^b	44.22±0.261 ^a
Total solids (g/L)	40.06±0.033 ^{ef}	39.67±0.044 ^f	40.31±0.383 ^e	41.20±0.383 ^d	41.28±0.420 ^d	42.10±0.203 ^c	42.77±0.214 ^b	44.29±0.265 ^a
Nitrate (mg/L)	0.958±0.065 ^b	1.234±0.096 ^a	0.954±0.113 ^b	0.780±0.085 ^c	0.528±0.093 ^c	0.646±0.043 ^{de}	0.745±0.072 ^{cd}	0.863±0.062 ^{bc}
Phosphate (mg/L)	0.155±0.002 ^c	0.196±0.003 ^a	0.174±0.003 ^b	0.145±0.004 ^d	0.122±0.002 ^c	0.104±0.001 ^f	0.085±0.002 ^g	0.067±0.003 ^h
Ammonia (mg/L)	0.371±0.021 ^b	0.437±0.020 ^a	0.334±0.024 ^c	0.297±0.019 ^{de}	0.240±0.015 ^e	0.266±0.009 ^{fg}	0.289±0.024 ^{ef}	0.320±0.023 ^{cd}

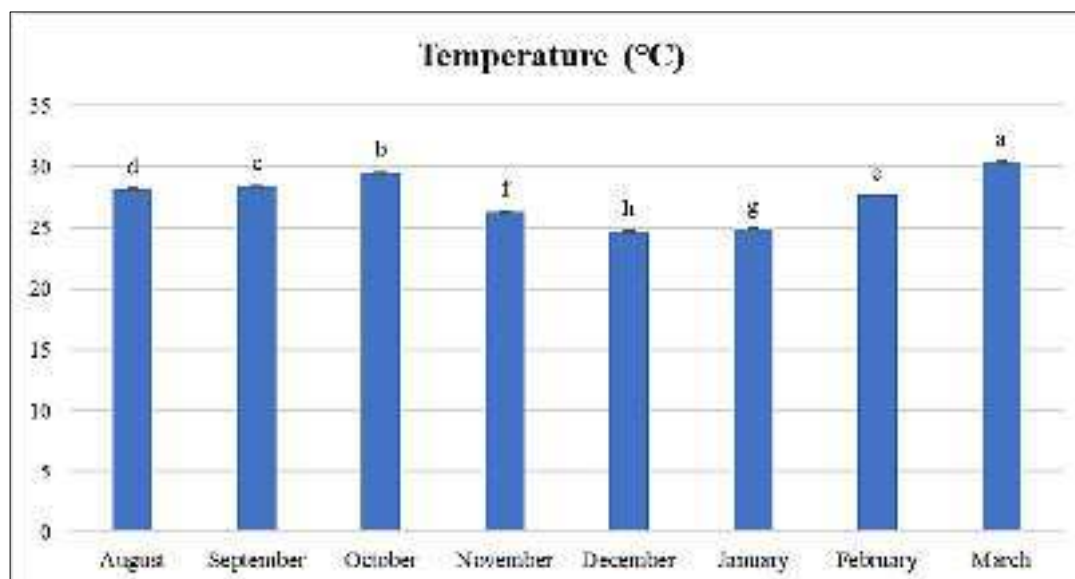


Fig 2: Monthly mean water temperature variations at New Mangrol Fishing Port

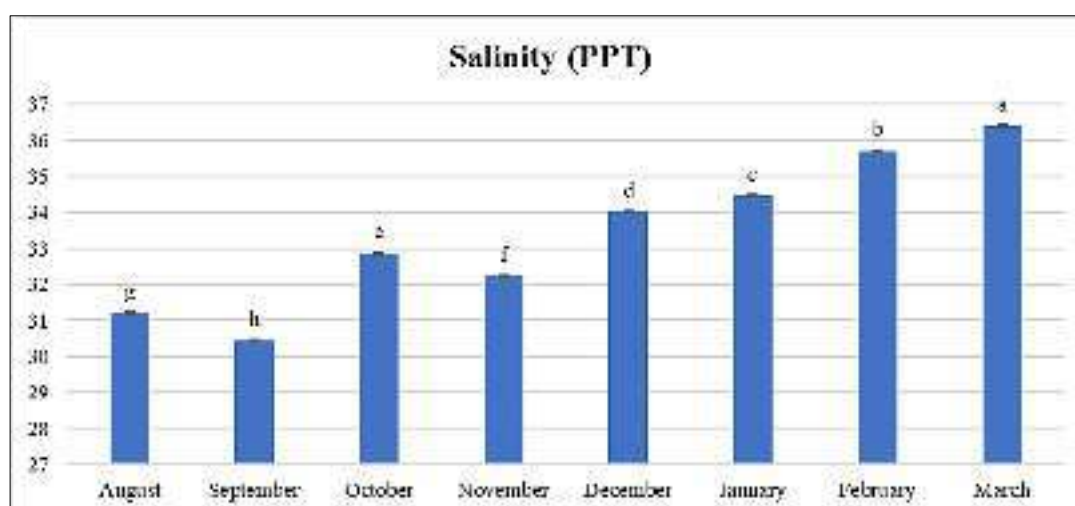


Fig 3: Monthly mean salinity variations at New Mangrol Fishing Port

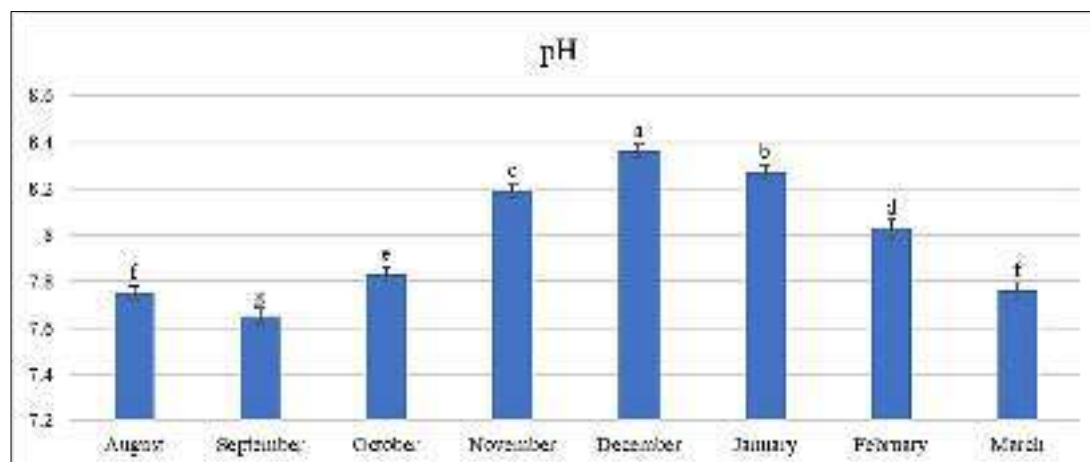


Fig 4: Monthly mean pH variations at New Mangrol Fishing Port

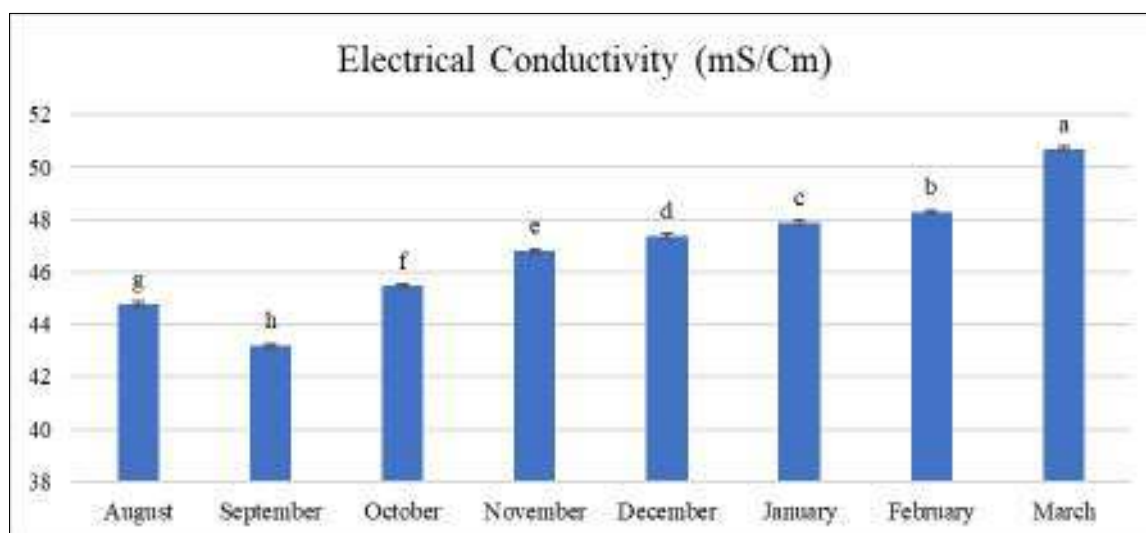


Fig 5: Monthly mean electrical conductivity variations at New Mangrol Fishing Port

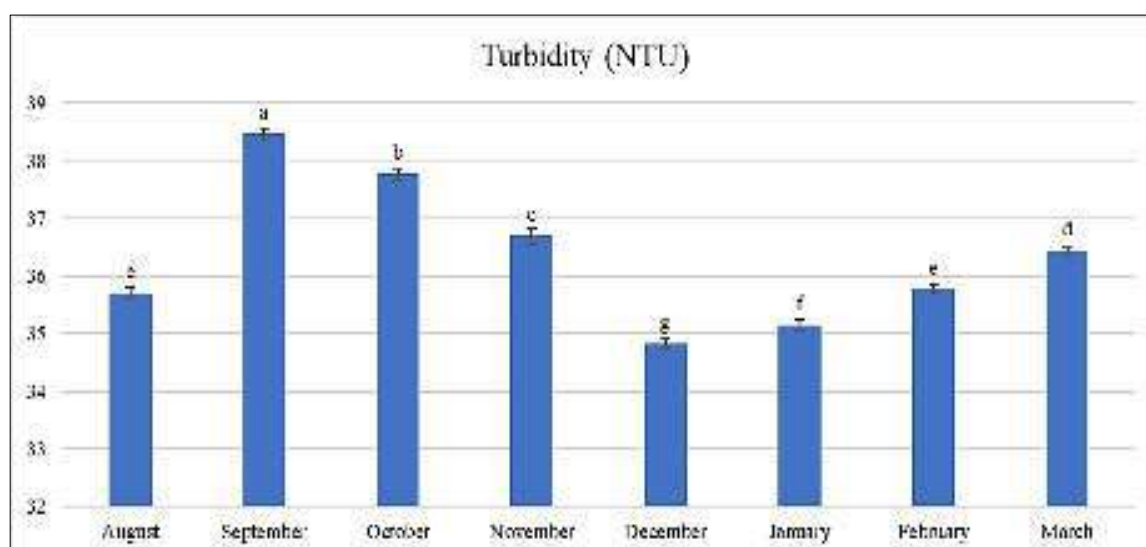


Fig 6: Monthly mean Turbidity variations at New Mangrol Fishing Port

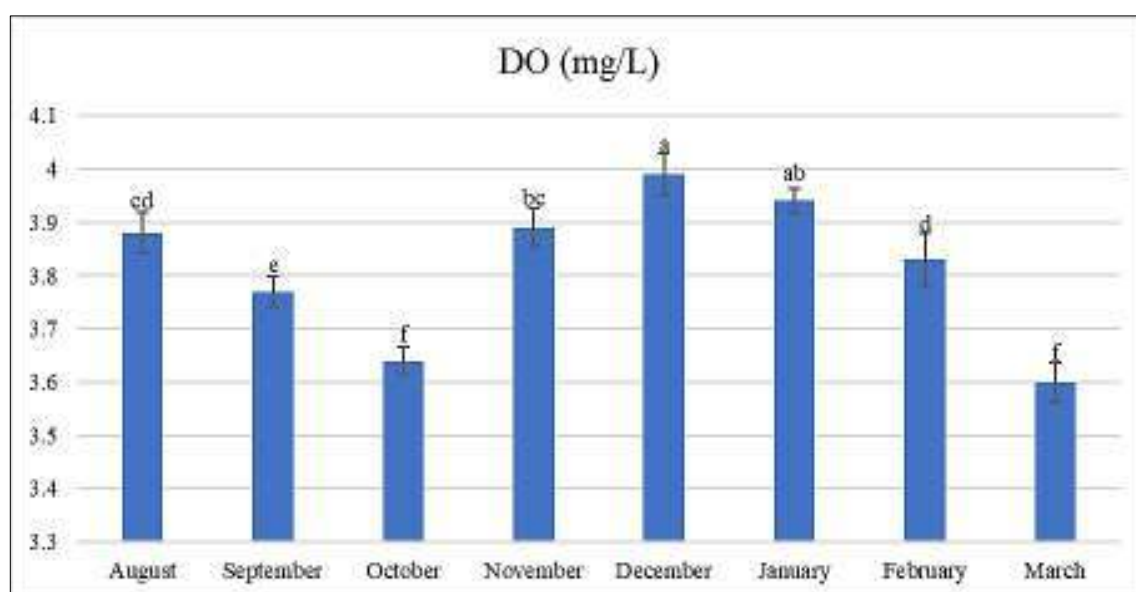


Fig 7: Monthly mean DO variations at New Mangrol Fishing Port

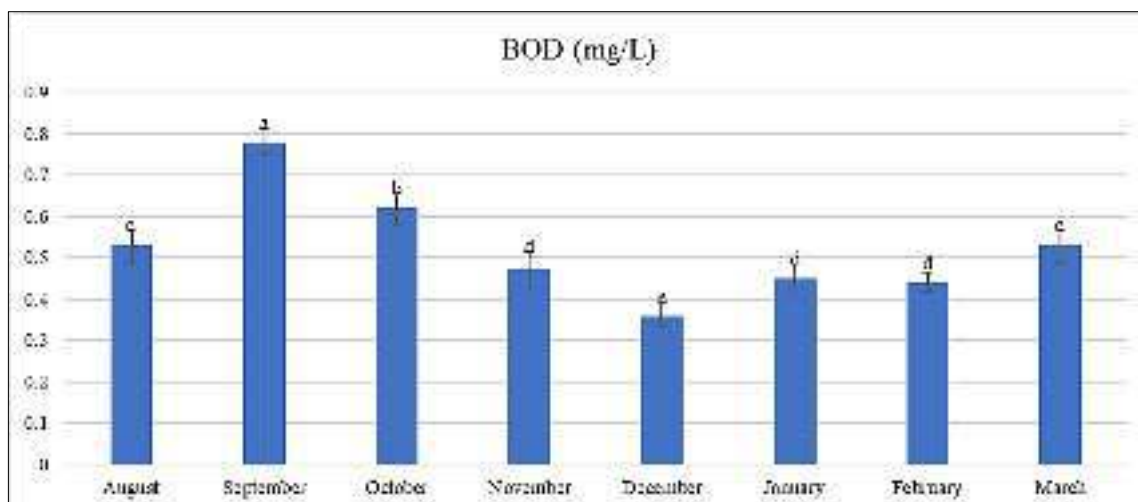


Fig 8: Monthly mean BOD variations at New Mangrol Fishing Port

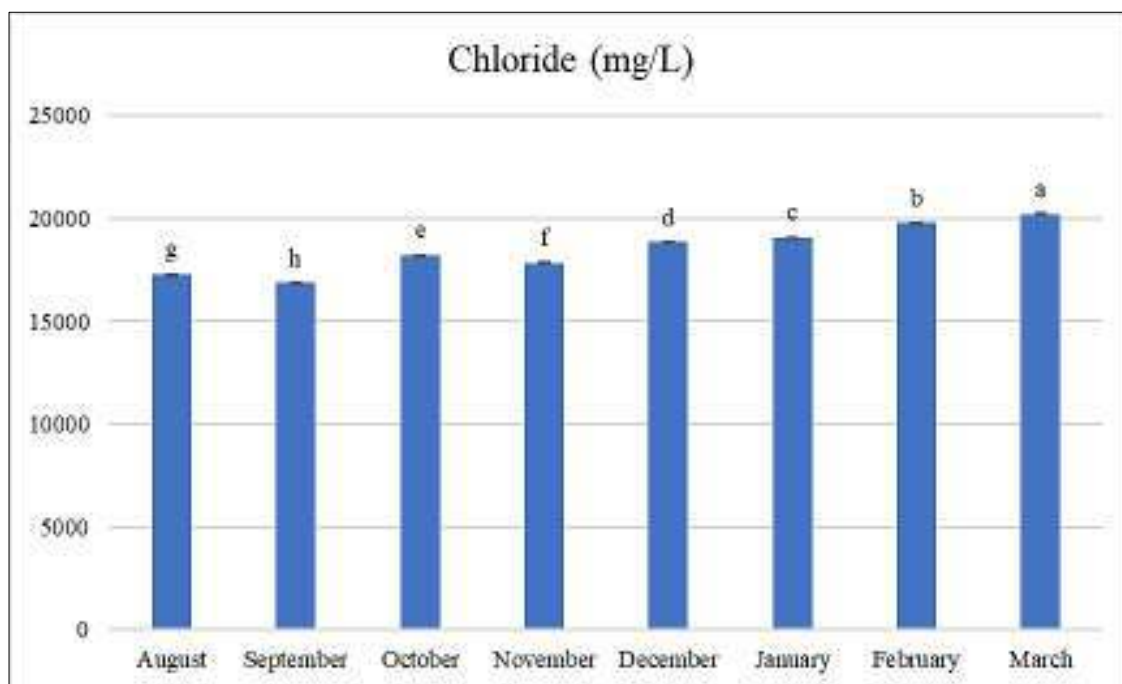


Fig 9: Monthly mean chloride variation at New Mangrol Fishing Port

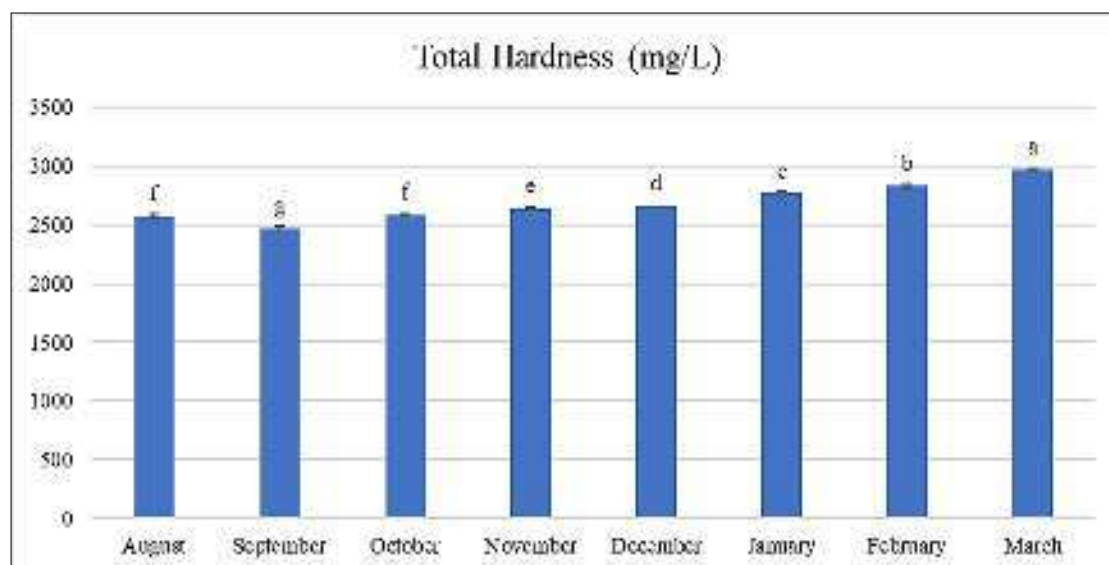


Fig 10: Monthly mean total hardness variations at New Mangrol Fishing Port

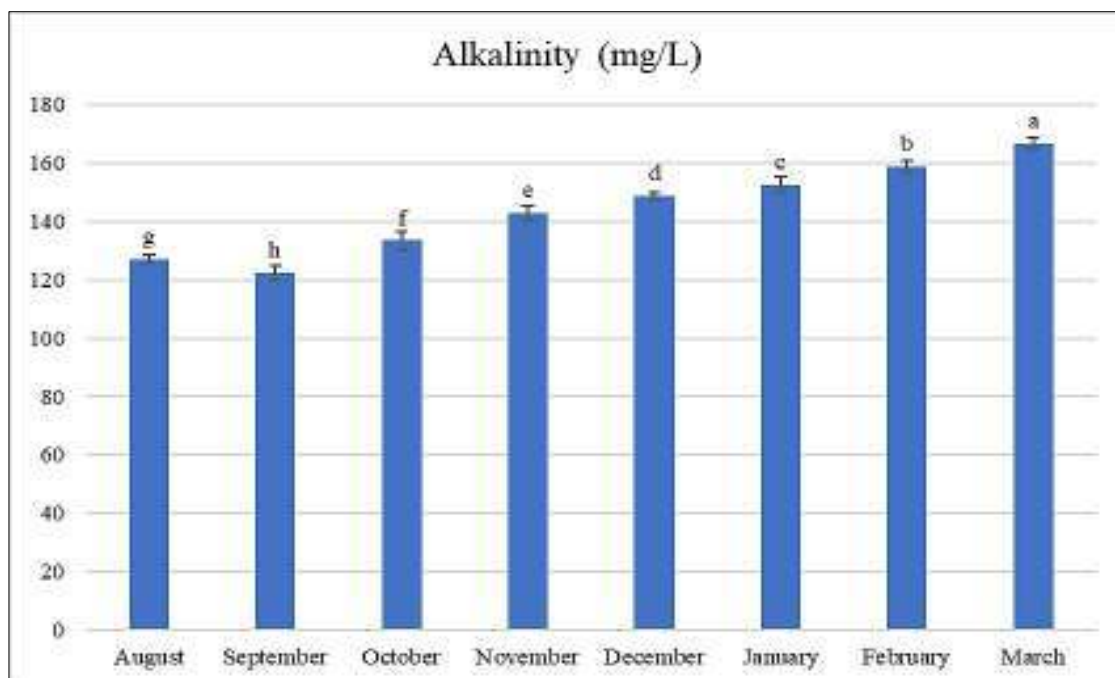


Fig 11: Monthly mean alkalinity variations at New Mangrol Fishing Port

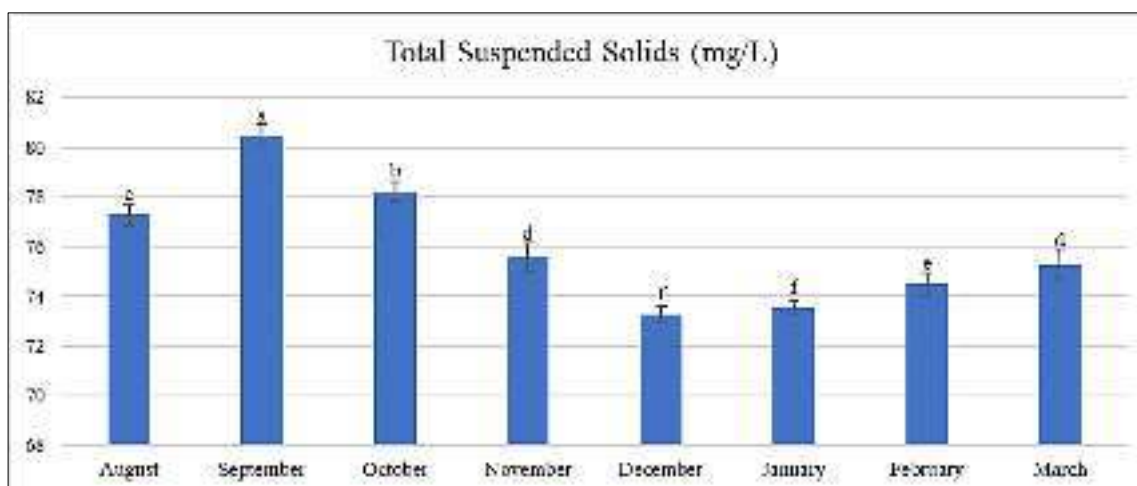


Fig 12: Monthly mean TSS variations at New Mangrol Fishing Port

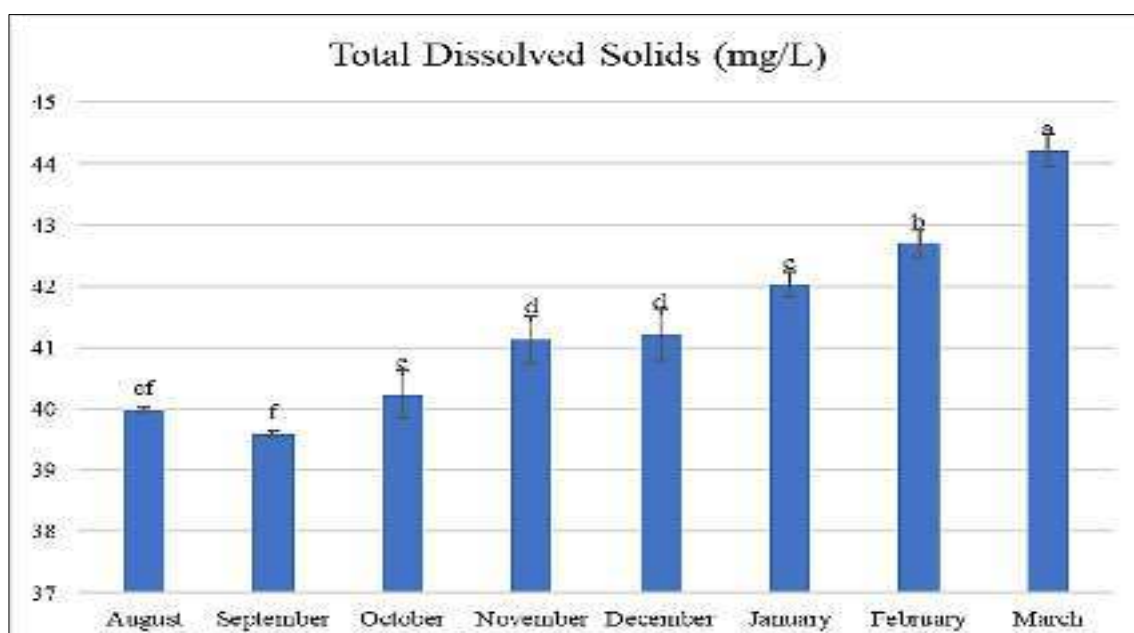


Fig 13: Monthly mean TDS variations at New Mangrol Fishing Port

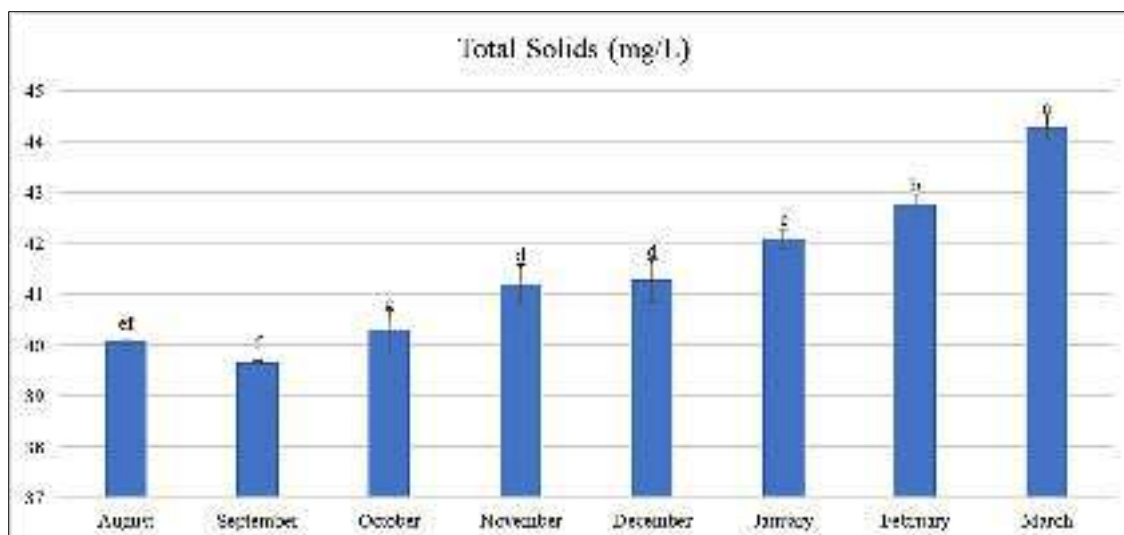


Fig 14: Monthly mean total solids variations at New Mangrol Fishing Port

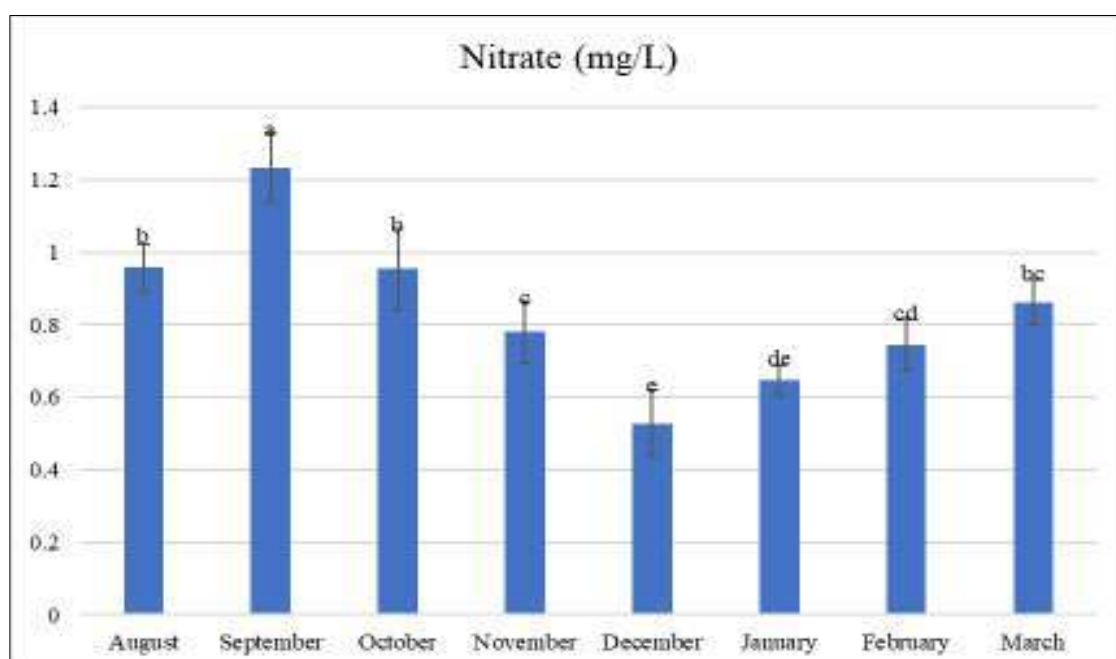


Fig 15: Monthly mean nitrate variations at New Mangrol Fishing Port

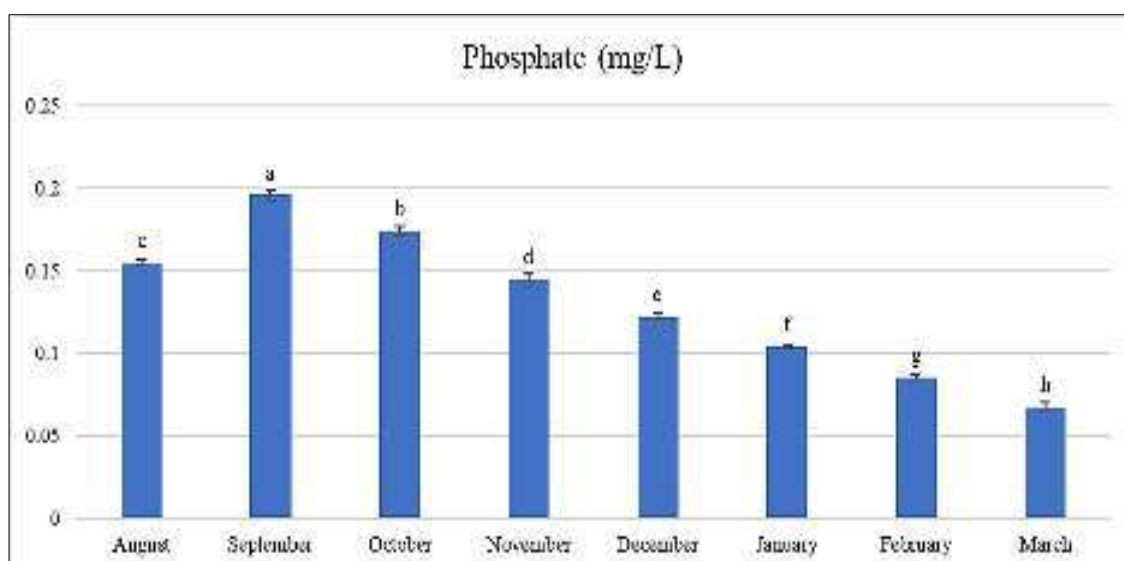


Fig 16: Monthly mean phosphate variations at New Mangrol Fishing Port

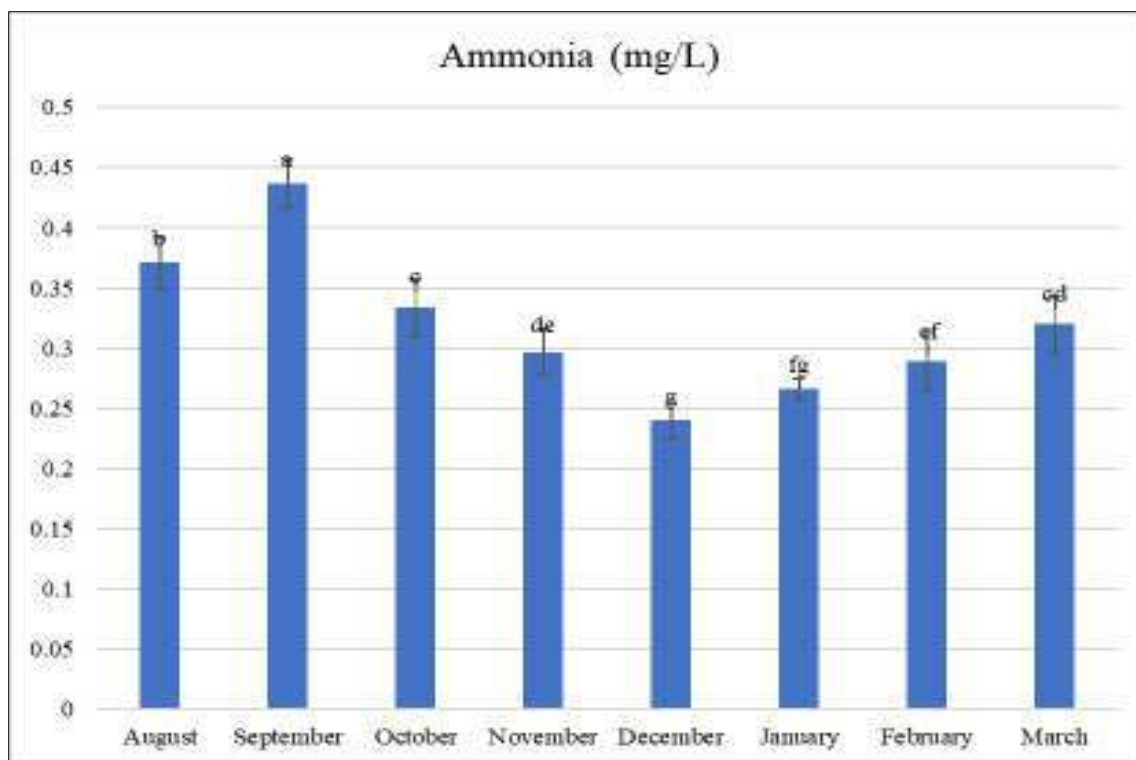


Fig 17: Monthly mean ammonia variations at New Mangrol Fishing Port

Conclusion

Harbour waters are dynamic systems influenced by natural processes and human activities, and they play a vital role in supporting fisheries and coastal livelihoods. The present study was conducted from August 2024 to March 2025 to assess the physico-chemical and microbial characteristics of water in Mangrol Harbour, with particular emphasis on New Mangrol Fishing Port. Noticeable monthly variations were observed across all sampling stations, largely governed by monsoonal patterns and anthropogenic inputs. Parameters such as temperature, salinity, conductivity, total dissolved solids, total solids, chloride, total hardness, and alkalinity exhibited higher values during March due to increased evaporation and reduced freshwater inflow. In contrast, turbidity, biochemical oxygen demand, nutrients, total suspended solids, and microbial indicators peaked in September, reflecting enhanced surface runoff and organic pollution following the monsoon. Dissolved oxygen showed seasonal fluctuation, with minimum levels recorded in March and maximum levels in December. The pH remained moderately alkaline throughout the study period, with slight seasonal variation. Overall, the results indicate that the water quality at New Mangrol Fishing Port is satisfactory and within acceptable limits for harbour activities. However, increasing anthropogenic pressure necessitates regular monitoring to ensure sustainable use and long-term environmental health of the harbour ecosystem.

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