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STUDIES ON PHYSICO-CHEMICAL PARAMETERS OF THE TWO LENTIC WATER BODIES OF DISTRICT DHANBAD, JHARKHAND.

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ABSTRACT
In the present study an attempt has been made to assess the physico chemical factors of two perennial lentic water bodies *viz*., Mandal talab and Raja Talab of district Dhanbad, Jharkhand. The evaluation of limnological factors were done during November 2021 to October 2022. A total of seventeen (17) parameters were taken into consideration for analysis. The average value of selected water parameters of Mandal – Raja Talab, the Temperature was 26.4ºC – 27.08ºC, Electrical Conductivity (EC) 822.41-1238.08 μ/cm, Dissolved oxygen (DO) 5.9 – 4.15 mg/L, pH 7.39 – 7.36, Alkalinity 123.08 – 211.4 mg/L, Total Dissolved Solids (TDS) 645.6 – 1049.9 mg/L, Total Suspended solids (TSS) 75.4 – 101.7 mg/L, Biological Oxygen Demand (BOD) 2.9 – 6.05 mg/L, Chemical Oxygen demand (COD) 34.8 – 81.18 mg/L, Total Hardness (TH) 127.6 – 268.2 mg/L, Calcium (Ca^{+}) 37.05 – 76.18 mg/L, Magnesium (Mg2+) 8.5 – 18.9 mg/L, Sodium (Na+) 35.1 – 78.9 mg/L, Potassium (K+) 25.16 – 69.41 mg/L, Chloride (Cl^{-}) 54.1 – 127.2 mg/L, Nitrate (NO_3^{-}) 1.85 – 8.12 mg/L and Phosphate (PO_4^{3-}) 1.28 – 1.89 mg/L respectively. Pearson's correlation coefficient values show high significant positive and negative relationship ($p < 0.05$ level).

INTRODUCTION

Water is elixir of life. Fresh water bodies are substantial for the sustainable development, economy, ecosystem and human well-being. Fresh water ecosystems have witnessed significant alterations over the years, which have had harsh influence on the ecosystems in a number of ways.

Suitability of water for its intended applications is mainly determined by its various physico-chemical factors (Shinde *et al.*, 2011). Physico-chemical and biological factors provide a broad picture to evaluate the quality of water bodies. The meteorological, geochemical, geomorphological and pollution factors define the physical and chemical factors of fresh water bodies (Mishra and Singh, 2021; Kar *et al*., 2010).

Seasonal changes and anthropogenic activities like urbanization, nutrient enrichments, pH imbalances, *etc*., have an impact on limnological properties and worsen the water quality and human well-being due to its evident high toxicity (Anazawa *et al*., 2004). Water resources have become contaminated by pollutants including bacteria, viruses, heavy metals nitrates and salts as a result of poor waste management for industrial, agricultural and residential discharges and inappropriate utilisation of limited resources (Onwughara *et al.*, 2013). In terms of water quantity and quality, the major challenges are inequitable distribution of water on the earth's surface and a rapid declining in the availability of potable fresh water (Boyd and Tucker, 1998) The water body is a eutrophic wetland with elevated level of nutrients and significant oxygen loss (Varughese *et al*., 2004). A predominance of anaerobic conditions over massive areas of eutrophic wetlands with frequent oxygen loss, which cause a rise in BOD and COD (Hutchinson, 1975; Pani and Mishra, 2000).

Water quality is defined by its physical, chemical and biological aspects. But some mathematical analysis about the inter-relationship among these parameters would reflect significance of quality of water (Hardgrave *et al*., 1994; He *et al*., 2001). Statistical correlation is the mathematical tool which has been used to develop to understand the relationship between the physico-chemical parameters (Brown *et al*., 1970; Bhandari and Nayal, 2008). The correlation helps in the investigation of the existence and degree of the direction of the relationship between two or more variables. (Tripathi *et al*., 2014). Another widely used statistical method for assessing surface or ground water quality is Water Quality Index (WQI) technique. It employs aggregation methods to convert voluminous limnological data into a single value or index.

The assessment of the physico-chemical properties of aquatic ecosystem is crucial for evaluating its productivity, utility, and other factors that affect the distribution, reproduction, composition, and feeding habits of species as well as their vertical and horizontal migration (Adebisi *et al*., 1981). The present study is an endeavour was made to evaluate the physico-chemical properties of two selected lentic water bodies (*viz*., Mandal Talab (S1) and Raja Talab (S2)) of district Dhanbad, Jharkhand and to understand the relationship between different limnological parameters by using Correlation coefficient method and Water Quality Index (WQI).

MATERIALS AND METHODS

Study area

Dhanbad district is located in the state of Jharkhand with a latitude 23º79′98" N and longitude 86º43′05" E. Dhanbad is

famous for its coal mining and also known as 'Coal Capital of India'.

The two perennial lentic water bodies were selected for limnological analysis, in which one site (Raja Talab, S2) located in the Jharia Coal-field area with a latitude 23º44'38" N and longitude 86º24'51" E while the other site (Mandal Talab, S1) located in the residential area of district Dhanbad with a latitude 23º48'49" N and a longitude 86º25'58" E.

Sampling and Analysis

Water samples were collected from selected water bodies for the physical and chemical analysis from November 2021 to October 2022. Samples were collected monthly between 8:00 AM to 11 AM. Water temperature, pH, and electrical conductivity were measured at the sampling sites using Celsius thermometer (0º C to 100ºC), portable conductivity and pH meter respectively.

Other parameters like Dissolved oxygen (DO), Alkalinity, Total Dissolved Solids (TDS), Total Suspended solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen demand (COD), Total Hardness (TH), Calcium (Ca^{+}) Magnesium (Mg2+) Sodium (Na+) Potassium (K+), Chloride (Cl^{-}), Nitrate (NO_3^{-}) and Phosphate (PO_4^{3-}) were analysed according to standard methods APHA, 2005.

Statistical Analysis

Pearson's Correlation Coefficient

Pearson's correlation coefficient, abbreviated as 'r,' is a statistical tool used to assess the extent of relationship between two continuous variables on the same interval.

The values of correlation coefficient lie between -1 and +1. The correlation is perfectly positive if the value (r) is +1 and perfectly negative, if the value (r) is -1 and no correlation between the variables, if the value (r) is 0. (Rodgers & Nicewander, 1988 and Magroliya *et al.,* 2018).

The Karl Pearson's Correlation Coefficient, r, was calculated by using the equation (Zaidi and Pal 2015; Karmakar and Singh, 2021).

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}\sqrt{n\sum y^2 - (\sum y^2)}}$$

where,

r = Karl Pearson's Correlation Coefficient

x & y = Two different variables

n = number of total observations

In this study, the correlation coefficient analysis is an endeavour to comprehend the nature of the linear relationship between the variables and helps to indicate the quality of water (Kumar *et al.,* 2005; P. Lilly Florence *et al.,*2012).

Water Quality Index (WQI)

Water quality index was proposed by Brown and his co-workers (Brown *et al*., 1972). Water quality index is a statistical method used to simplify complex limnological data into a single value and determine the quality status of water bodies whether the water suitable for drinking and other domestic purposes. WQI provides an important method for comprehending the interaction and quality of surface water for any intended use and provides a better understanding for water quality management as well as pollution control programmes (Sharma and Choudhary, 2016). In order to compute water quality index, Indian Standards (BIS, 2012) for drinking water have been taken into account (table 1).

Water quality index was calculated by using the equation as follows:

$$WQI = \sum WnQN / \sum Wn$$

Where,

Wn is the unit weight for n^{th} parameter

Qn is the sub index of n^{th} parameter.

For statistical analysis, the Pearson correlation method and the Water Quality Index (WQI) were used to examine various physical & chemical parameters with the help of Excel sheet.

RESULTS AND DISCUSSION

Monthly variation in the limnological parameters of above mentioned two fresh water bodies are being summed up in the table 2.

Water Temperature (WT)

Water temperature has a direct impact on water density, pH and Dissolved Oxygen; hence it plays a significant role in animal's ecophysiology and toxicity in any water ecosystem (Saikh and Yeragi, 2003). Water temperature ranged between 18º to 35º C in S1 and 17º to 36º C in S2. Maximum temperature was recorded during the month of June and minimum during January. In S1, water temperature shows high significant positive relationship ($p < 0.05$ level) with EC (r= 0.972), TDS (r= 0.45), TSS (r= 0.09), DO (r= 0.077), BOD (r= 0.022), COD (r= 0.034), Na+ (r= 0.04) K+ (r= 0.03), Cl^{-} (r= 0.082), whereas pH (r= -0.803), Alkalinity (r=-0.87), TH (r=-0.15), Ca^{2+} (r= -0.02) Mg2+ (r=-0.02), Nitrate (r= -0.28), Phosphate (r= - 0.67) shows significant negative relationship ($p < 0.05$ level).

In S2, water temperature shows high significant positive relationship ($p < 0.05$ level) with EC (r= 0.95), TDS (r=0.658), BOD (r= 0.294), Mg^{2+} (r= 0.112), Na+ (r= 0.067), K+ (r=0.017) Cl^{-} (0.043), whereas TSS (r = -0.069), pH (r= -0.92), Alkalinity (r= -0.495), DO (r= - 0.247), COD (-0.759), TH (- 0.004), Ca^{2+} (-0.228), Nitrate (-0.138) Phosphate (-0.655) shows significant negative relationship ($p < 0.05$ level). Madhab Borah *et al.,* 2011, also observed similar results as WT shows positive relationship with Conductance, TDS, DO, COD, N^{+}, K^{+}, Cl^{-}, whereas TH, alkalinity, Ca^{2+}, $Mg^{2+}$and nitrate. Similarly, Talukdar and Goswami, 2017; Mishra and Singh, 2021, shows similar observations.

EC (Electrical Conductivity)

EC is defined as the ability of an aqueous solution to convey electric current. This ability is influenced by the presence of ions, their total concentration, mobility, relative concentration.

Table 1: Indian Standards (IS:10500) for drinking water (BIS, 2012)

COD	-
Total Hardness (TH)	200 mg/L
Calcium (Ca2+)	75 mg/L
Magnesium (Mg 2+)	30 mg/L
Electrical Conductivity (EC)	300 μs/cm
Chlorides	250 mg/L
Nitrate	45 mg/L
Phosphate	-

[Table 2: Seasonal variations in Physico-chemical parameters of two selected perennial lentic water bodies during November 2021 to October 2022]

Parameters	Mandal Talab (S1) (Bartaand Pond)			Raja Talab (S2)		
	Range (Min. – Max.)	Mean	Standard Deviation	Range (Min. – Max.)	Mean	Standard Deviation
Temperature (ºC)	18ºC - 35ºC	26.416	5.567	17 – 36	27.083	6.082
EC (μ/cm)	678 - 956	822.41	95.505	1002 - 1584	1238.08	154.25
TDS (mg/L)	593 -706	645.666	39.839	899 - 1224	1049.92	89.74
TSS (mg/L)	63 - 89	75.416	7.452	85 – 128	101.75	13.369
pH	7.1 -7.7	7.391	0.206	6.9 – 7.9	7.366	0.264
Alkalinity (mg/L)	98 - 159	123.083	17.814	198 - 227	211.416	7.645
DO (mg/L)	4.9 – 6.8	5.908	0.58	3.7 – 4.5	4.15	0.25
BOD (mg/L)	1.9- 4.1	2.958	0.668	4.4 -8.1	6.05	1.279
COD (mg/L)	28.7 – 40.8	34.801	4.397	67.5 -93.4	81.183	9.678
TH (mg/L)	97 -150	127.666	14.705	240 - 310	268.25	22.058
Ca^{2+} (mg/L)	30.4 – 42.8	37.05	3.37	60.2 – 88.1	76.183	7.808
Mg^{2+} (mg/L)	5.103 – 12.75	8.507	2.603	5.9 – 33.9	18.905	9.471
Na^{+} (mg/L)	26 - 44	35.166	5.734	67.1 – 89.1	78.985	5.851
K^{+} (mg/L)	18 – 32	25.166	4.858	57.1 – 77.1	69.416	6.21
Cl^{-} (mg/L)	46.5 – 63.26	54.115	5.793	98 -152	127.25	16.646
Nitrate (mg/L)	1.41 – 2.5	1.857	0.354	5.21 – 12.33	8.122	2.04
Phosphate (mg/L)	0.51 – 2.1	1.287	0.452	0.87 – 2.99	1.89	0.715

EC of the two above mentioned ponds were noted between 678 μ/cm to 956 μ/cm in S1 and 1002 μ/cm to 1584 μ/cm in S2. The maximum EC concentration was recorded during summer season and lower concentration during winter season. Higher concentration during summer season may be due to high atmospheric temperature and a large evaporation process (Sandipan Pal *et al*., 2013).

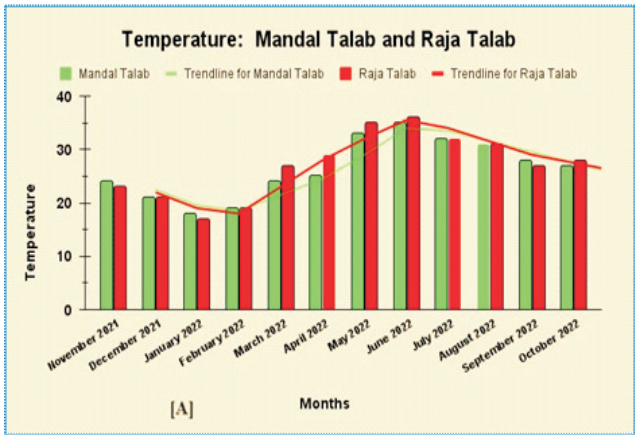
In S1, EC shows high significant positive relationship (<0.05 level) with TDS (r= 0.383), TSS (r=0.164), DO (r= 0.0124), BOD (r= 0.06), COD (r= 0.117), Mg2+ (r= 0.054), Na+ (r= 0.091), K+ (r= 0.081), Cl^{-} (r = 0.138) whereas pH (r= -0.795), Alkalinity (r = -0.84), TH (r=-0.056), Ca^{2+} (r= -0.166), Nitrate (r = -0.393), Phosphate (r=-0.67) shows significant negative relationship ($p < 0.05$ level). In S2, EC shows high significant positive relationship (<0.05 level) with TDS (r=0.47), BOD (r= 0.442), TH (r= 0.017), Mg2+ (r = 0.13), Na+ (r= 0.104), K+ (r = 0.094), Cl^{-} (r= 0.202), whereas EC shows significant negative relationship ($p < 0.05$ level) with TSS (r=- 0.123), pH (r=-0.94), Alkalinity (r=- 0.47), DO (r=-0.43), COD (r=- 0.613), Ca^{2+} (r=- 0.24), Nitrate (r=- 0.233), Phosphate (r=- 0.56). Karmakar and Singh, 2021 reported that EC shows positive relationship with TSS, TDS, DO, BOD, COD, Cl^{-}, Na^{+}, K^{+}, Mg^{2+} whereas Phosphate, Nitrate, shows negative relationship. Similar result was also observed by Madhab Borah *et al*., 2011.

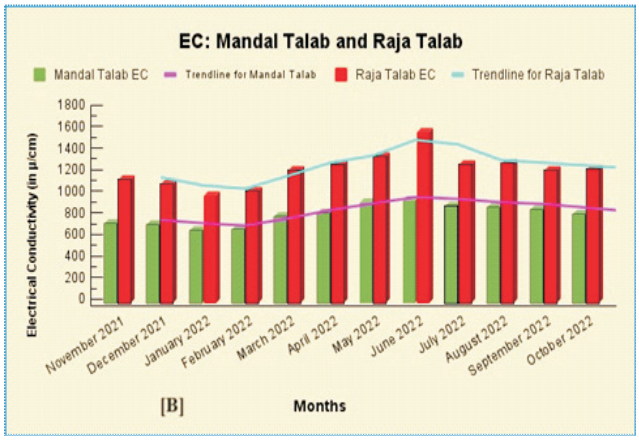
The higher concentration of EC increases with higher TDS concentrations, as it indicates the presence of higher salt and ion concentrations (Shuchun *et al*., 2010; Perlman, 2014). However, TDS and EC are not directly linearly correlated, as EC depends on the activity of specific dissolved ions and ionic strength (Hem, 1985 and Siosemarde et al., 2010).

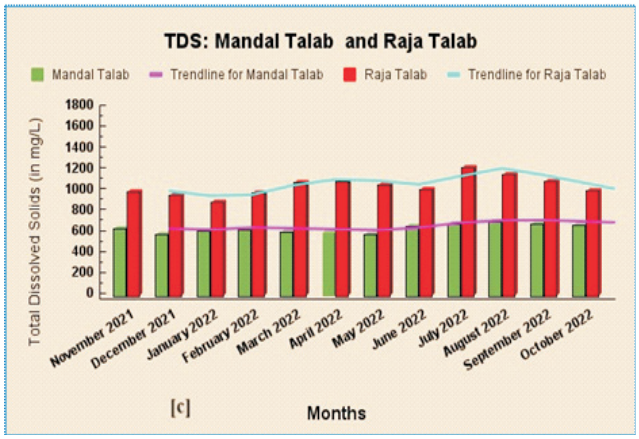
TDS (Total Dissolved Solids)

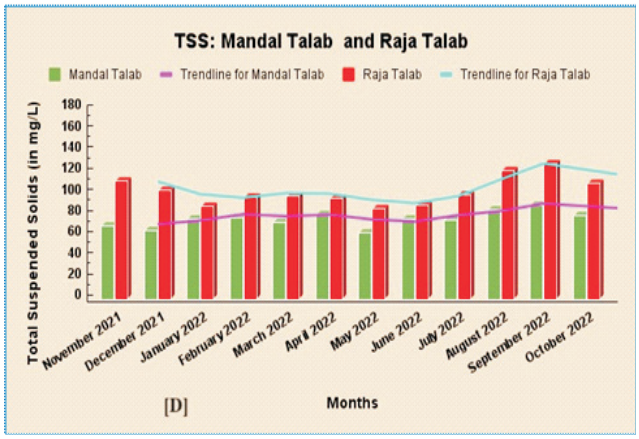
TDS was ranged between 593mg/L to 706 mg/L in S1 (Mandal Talab) and 899 mg /L to 1224 mg / L in S2 (Raja Talab). The maximum TDS values in Raja Talab indicate its pollution status, which may be the result of mining operations, the leaching of soil contaminants, or the discharge of domestic sewage and drainages.

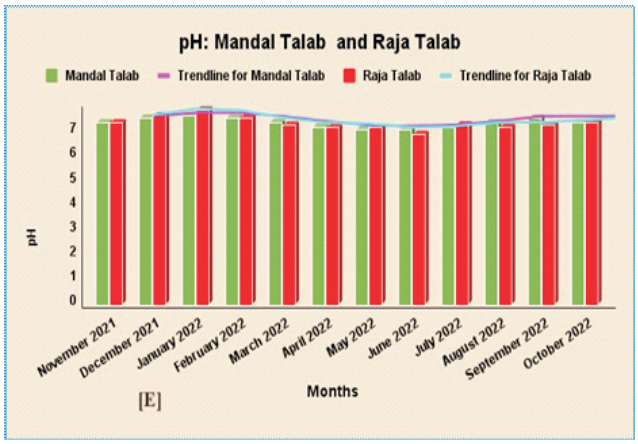
In S1, TDS shows high significant positive relationship (<0.05 level) with TSS (r= 0.739), DO (r= 0.797), Nitrate (r= 0.130) whereas pH (r=- 0.019), Alkalinity (r=- 0.359), BOD (r=-0.649), COD (r=- 0.507), TH (r=- 0.498), Ca^{2+} (r=- 0.422), Mg2+ (r=- 0.349), Na+ (r=- 0.647), K+ (r=-0.65), Cl^{-} (r=-0.209), Phosphate (r=- 0.679) shows high significant negative relationship ($p < 0.05$ level). In S2, TDS shows high significant

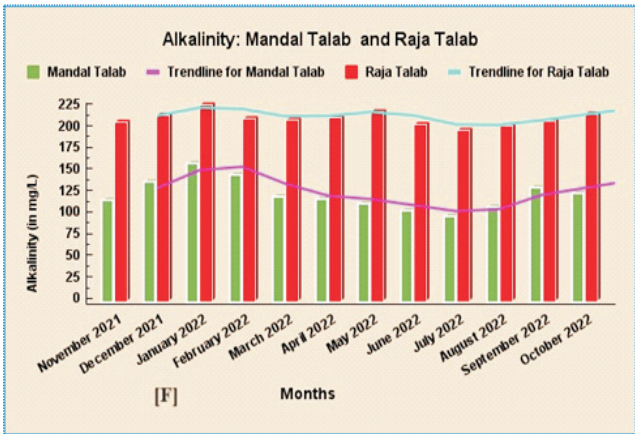










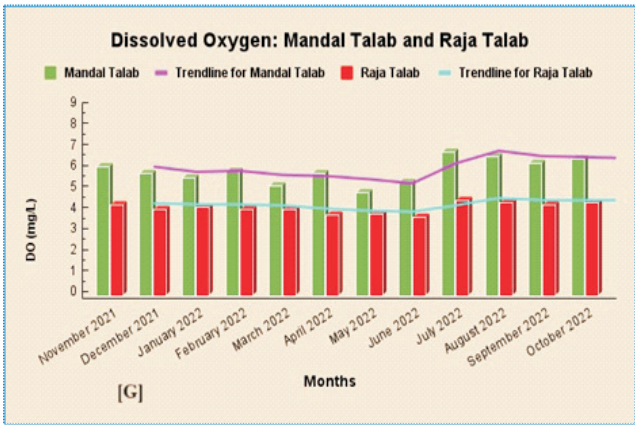


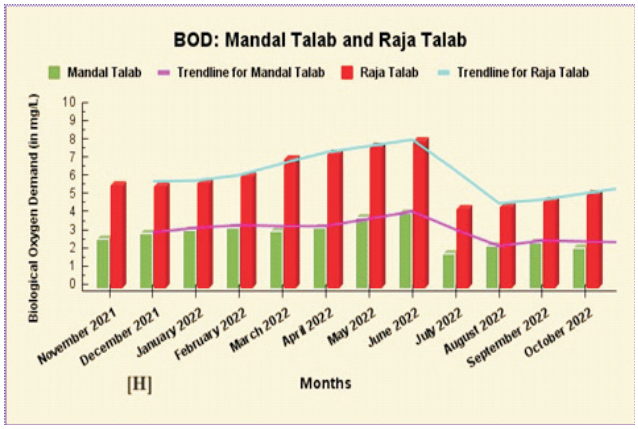
positive relationship with ($p < 0.05$ level), with TSS ($r = 0.305$), DO ($r = 0.29$), Ca^{2+} ($r = 0.22$), Nitrate ($r = 0.26$), whereas pH ($r = -0.604$), Alkalinity ($r = -0.75$), BOD ($r = -0.283$), COD ($r = -0.764$), TH ($r = -0.18$), $Mg2+$ ($r = -0.215$), $Na+$ ($r = -0.345$), $K+$ ($r = -0.396$), Cl^- ($r = -0.54$), Phosphate ($r = -0.702$) shows significant negative relationship ($p < 0.05$ level). Similarly, Shinde *et al.,* 2011 reported similar observations.

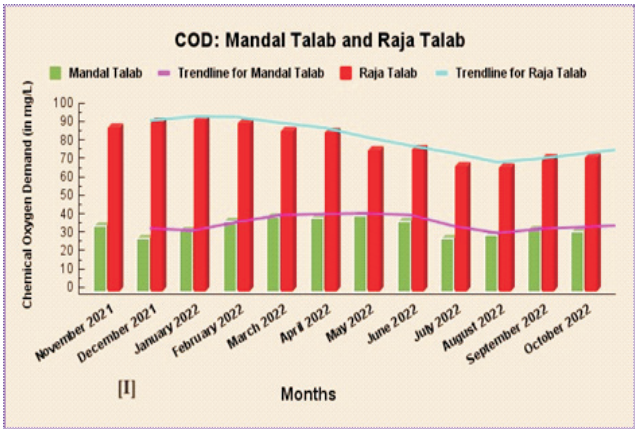
TSS (Total Suspended Solids)

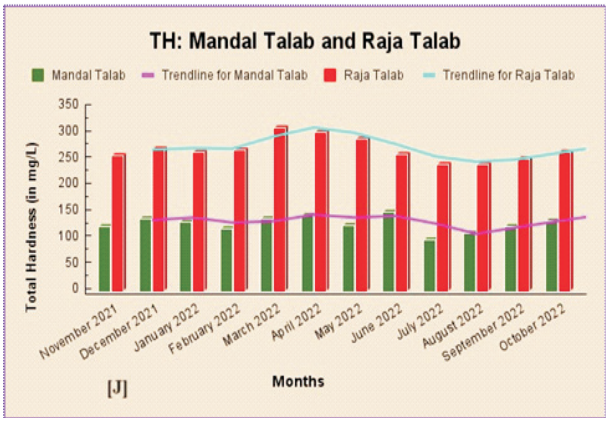
The value of measured TSS varied from 63 mg/L to 89 mg/L in S1 and 85 mg /L to 128 mg/L in S2. Maximum concentration of TSS was observed during monsoon season and lower during post- monsoon in both sites. Higher values of total suspended solids during the monsoon season may be due to the addition of sand, mud, etc. mixed in the surface water from siltation, heavy precipitation, and surface runoff (Shinde *et al.,* 2011**).**

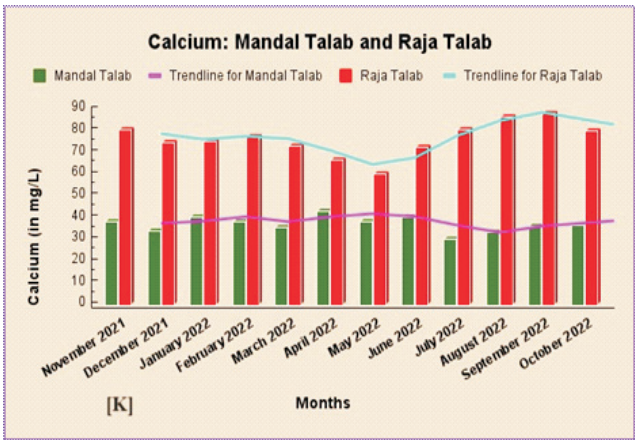
In S1 TSS shows high significant positive relationship ($p < 0.05$ level) with pH ($r = 0.226$), Alkalinity ($r = 0.040$), DO ($r = 0.564$), Ca^{2+} ($r = 0.007$), Nitrate ($r = 0.059$), whereas BOD ($r = -0.405$), COD ($r = -0.198$), TH ($r = -0.157$), $Mg2+$ ($r = -0.221$), $Na+$ ($r = -0.503$), $K+$ ($r = -0.461$), Cl^- ($r = -0.066$), Phosphate ($r = -0.344$) shows significant negative relationship ($p < 0.05$ level).

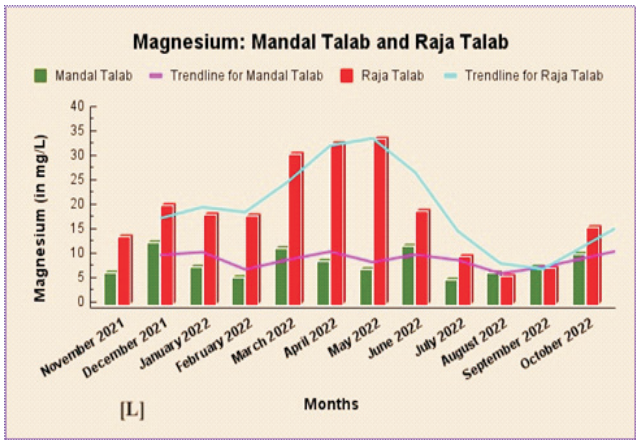










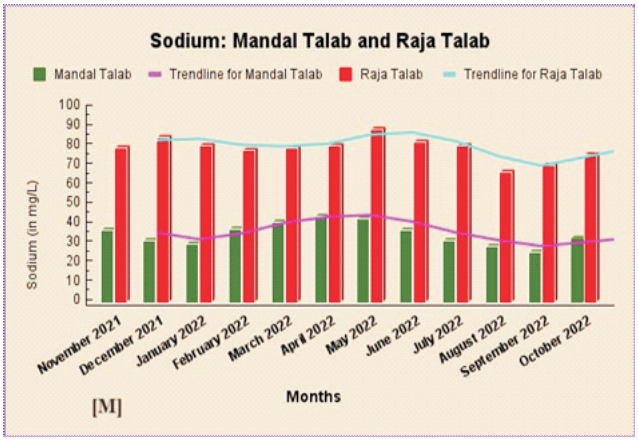


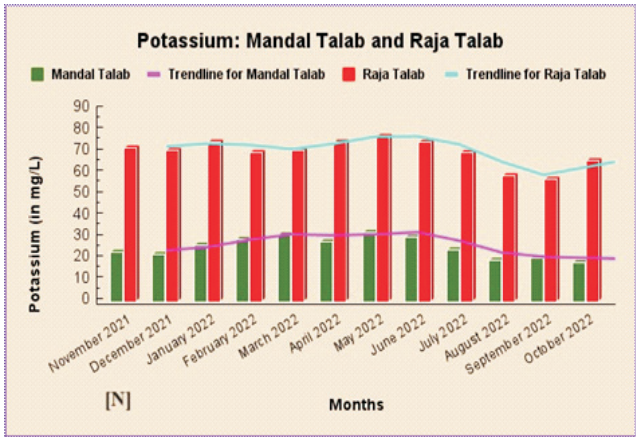
In S2, TSS shows high significant positive relationship ($p < 0.05$ level) with DO ($r = 0.62$), Ca^{2+} ($r = 0.836$), Nitrate ($r = 0.709$), whereas pH ($r = -0.05$), Alkalinity ($r = -0.367$), BOD ($r = -0.71$), COD ($r = -0.401$), TH ($r = -0.51$), $Mg2+$ ($r = -0.707$), $Na+$ ($r = -0834$), $K+$ ($r = -0.915$), Cl^- ($r = -0.863$), Phosphate ($r = -0.445$) shows significant negative relationship ($p < 0.05$ level).

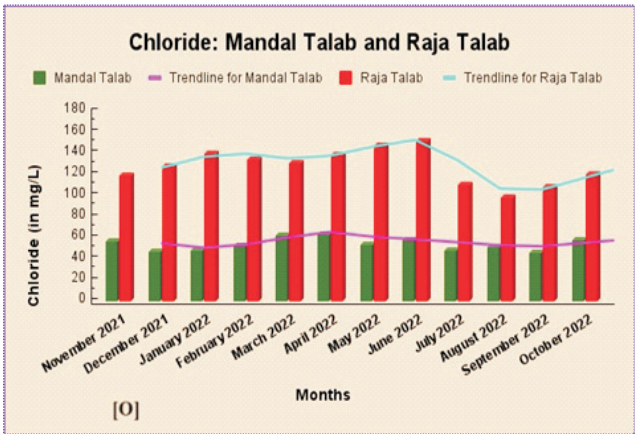
pH

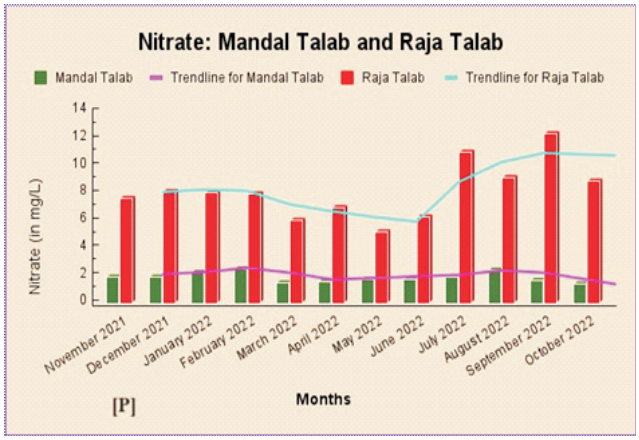
Potential of Hydrogen is a measurement of acidic and alkaline Nature of any aqueous solution. The pH ranged from 7.1 to 7.7 and 6.9 to 7.9 in S1(Mandal talab) and S2 (Raja Talab) respectively. Minimum pH was recorded during summer season and maximum during winter season. Low pH during the summer season may be caused by the release of more free carbon dioxide as a result of bacterial respiration at high temperatures, as well as an increase in the rate of decomposition of organic waste deposited (Hussain *et al.*, 2021).

In S1, pH shows high significant positive relationship ($p < 0.05$ level) with Alkalinity ($r = 0.865$), Do ($r = 0.197$), Nitrate ($r = 0.392$), Phosphate ($r = 0.408$), whereas pH shows significant negative relationship ($p < 0.05$ level) with BOD ($r = -0.27$), COD ($r = -0.379$), TH ($r = -0.084$), Ca^{2+} ($r = -0.093$),









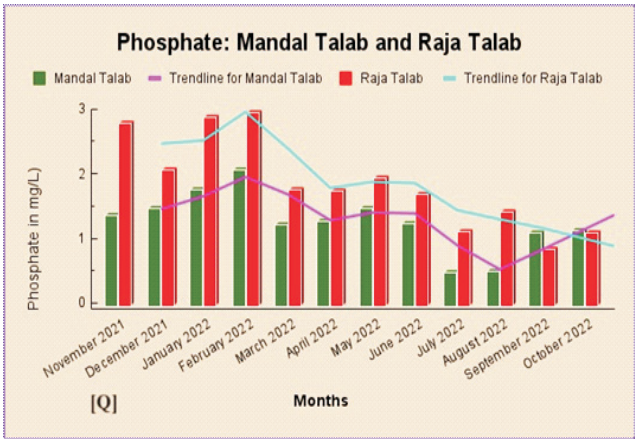


Figure 1: Comparative graphical representation of monthly variations in the limnological parameters of two selected ponds {Mandal Talab (S1) & Raja Talab (S2)} viz., [A] Temperature; [B] Electrical Conductivity (EC); [C] Total Dissolved Solids (TDS); [D] Total Suspended Solids (TSS); [E] pH; [F] Alkalinity; [G] Dissolved Oxygen (DO); [H] Biological Oxygen Demand (BOD); [I] Chemical Oxygen Demand (COD); [J] Total Hardness (TH); [K] Calcium (Ca^{2+}); [L] Magnesium (Mg^{2+}); [M] Sodium (Na^{+}); [N] Potassium (K^{+}); [O] Chloride (Cl^{-}); [P] Nitrate (NO_3^{-}); [Q] Phosphate (PO_4^{3-})]

Mg2+ (r=-0.043), Na+ (r=-0.574), K+ (r=-0.406), Cl^{-} (r=-0.486). Similarly, according to Indu *et al.*, 2015, pH shows positive relationship with DO whereas EC, TDS, BOD, COD, Na^{+}, K^{+}, Mg^{2+}, Cl^{-}, *etc.* In S2 shows high significant positive relationship ($p < 0.05$ level) with Alkalinity (r= 0.611), DO (r= 0.343), COD (r= 0.627, Ca^{2+} (r= 0.124), Na+ (r=0.079), K+ (r= 0.054), Nitrate (r= 0.164), Phosphate (r=0.559) whereas shows significant negative relationship with BOD (r=-0.371), TH (r=-0.043), Mg2+ (r=-0.087), Cl^{-} (r=-0.037) ($p < 0.05$ level). Tripathi *et al.*, 2014 observed similar results.

Alkalinity

Alkalinity is the ability to neutralize acid or also defined as buffering capacity of any water body. The range of alkalinity in S1, lies between 98 to 159 mg/L while in S2, ranged between 198 mg/L to 227 mg/L. Alkalinity was maximum during post monsoon and minimum during monsoon and pre-monsoon. The higher values of alkalinity during the winter indicate a greater ability of the surface water to support algal growth and other aquatic life in this season. Similar result was also observed by Mishra and Singh, 2021 and Parashar *et al.*, 2006.

In S1, alkalinity shows high significant positive relationship ($p < 0.05$ level) with BOD (r= 0.114), TH (r=0.207), Ca^{2+} (r=0.302), Mg2+ (r=0.046), Nitrate (r=0.305), Phosphate

(r = 0.746), whereas DO (r = - 0.16), COD (r = - 0.05), Na+ (r = - 0.244), K+ (r = - 0.057), Cl^- (r = - 0.314) shows high significant negative relationship ($p < 0.05$ level).

In S2, alkalinity shows high significant positive relationship ($p < 0.05$ level) with BOD (r = 0.264), COD (r = 0.55), TH (r = 0.413), Mg2+ (r = 0.452), Na+ (r = 0.357), K+ (r = 0.368), Cl^- (r = 0.499), Phosphate (r = 0.456). whereas DO (r = - 0.235), Ca^{2+} (r = - 0.434), Nitrate (r = - 0.356) shows high significant negative relationship ($p < 0.05$ level). Madhab Borah *et al.,* 2011; Elayaraj and Selvaraju, 2014, reported similar findings. A positive correlation with Ca^{2+} and Mg^{2+} indicates the influence of carbonates and bicarbonates of calcium and magnesium on the concentration of alkalinity (Hemant Kumar N. K. *et al.*, 2015).

DO (Dissolved Oxygen)

A vital component of every aquatic environment, DO is essential to fish and other aquatic organisms' development, survival, reproduction, behaviour, and metabolism. (Bhatnagar *et al.*, 2004). The concentration of dissolved oxygen in any aquatic ecosystem is determined by the water temperature, duration of photoperiod and mixing and aeration of the water.

Dissolved oxygen ranged from 4.9 mg/L to 6.8 mg/L in S1 while 3.7 mg/L to 4.5 mg/L in S2.

In both sites, higher concentration of DO was observed during monsoon and post monsoon and lower concentration was recorded during summer season. Higher concentration of DO during monsoon and post- monsoon may be because of low temperature and shorter duration of sunlight. Lower concentration might be caused by the high temperatures, which encourage a high rate of microbial respiration and the rapid breakdown of organic matters (Hussain *et al.*, 2021).

In S1, DO shows high significant positive relationship ($p < 0.05$ level) with Nitrate (r = 0.205) whereas BOD (r = -0.896), COD (r = - 0.757), TH (r = - 0.626), Ca^{2+} (r = - 0.556), Mg2+ $^{2+}$ (r = - 0.419), Na+ (r = - 0.644), K+ (r = - 0.828), Cl^- (r = - 0.325), Phosphate (r = - 0.592) shows high significant negative relationship ($p < 0.05$ level). In S2, DO shows high significant positive relationship ($p < 0.05$ level) with Ca^{2+} (r = 0.765), Nitrate (r = 0.734), whereas BOD (r = - 0.936), COD (r = - 0.362), TH (r = - 0.614), Mg2+ (r = - 0.732), Na+ (r = - 0.579), K+ (r = -0.642), Cl^- (r = - 0.864), Phosphate (r = - 0.251) shows high significant negative relationship ($p < 0.05$ level). Madhab Borah *et al.,* 2011, observed that DO shows positive relationship with WT, pH, EC, TDS, whereas, shows negative relationship with TH, alkalinity, nitrate, Ca^{2+}, Mg^{2+}. Elayaraj and Selvaraju, 2014 also observed similar results.

BOD (Biological Oxygen Demand)

BOD, or biochemical oxygen demand, is a measurement of the quantity of oxygen that microorganisms use to break down organic waste matters. The value of BOD is ranged between 1.9 mg/L to 4.1 mg/L in S1 while 4.4 mg/L to 8.1 mg/L was recorded in S2.

In S1, BOD shows high significant positive relationship ($p < 0.05$ level) with COD (r = 0.735), TH (r = 0.666), Ca^{2+} (r = 0.707), Mg2+ (r = 0.358), Na+ (r = 0.609), K+ (r = 0.806), Cl^- (r = 0.306), Phosphate (r = 0.618) whereas DO (r = -0.896),

Table 3: Correlation Matrix (Pearson's correlation method) among the physico-chemical parameters of Mandal Talab (S1) during November 2021 to October 2022.

	TEMP	*EC*	*TDS*	*TSS*	*pH*	*Alka linity*	*DO*	*BOD*	*COD*	*TH*	*Ca+*	*Mg2+*	*Na+*	*K+*	*Cl-*	*Nitrate*	*Phos phate*
TEMP	1																
EC	0.971	1															
TDS	0.447	0.383	1														
TSS	0.089	0.164	0.739	1													
pH	-0.803	-0.795	-0.019	0.226	1												
Alkalinity	-0.872	-0.836	-0.359	0.04	0.865	1											
DO	0.077	0.012	0.797	0.564	0.197	-0.16	1										
BOD	0.022	0.059	-0.649	-0.405	-0.279	0.114	-0.896	1									
COD	0.034	0.117	-0.507	-0.198	-0.379	-0.053	-0.757	0.735	1								
TH	-0.146	-0.056	-0.498	-0.157	-0.084	0.207	-0.626	0.666	0.473	1							
Ca+	-0.225	-0.166	-0.422	0.007	-0.093	0.302	-0.556	0.707	0.677	0.693	1						
Mg2+	-0.023	0.054	-0.349	-0.221	-0.043	0.046	-0.419	0.358	0.115	0.825	0.166	1					
Na+	0.04	0.091	-0.647	-0.503	-0.574	-0.244	-0.644	0.609	0.83	0.403	0.509	0.151	1				
K+	0.027	0.08	-0.65	-0.461	-0.406	-0.057	-0.828	0.806	0.809	0.343	0.464	0.103	0.778	1			
Cl-	0.082	0.138	-0.209	-0.066	-0.486	-0.314	-0.325	0.306	0.669	0.527	0.495	0.331	0.751	0.391	1		
Nitrate	-0.286	-0.393	0.13	0.059	0.392	0.305	0.205	-0.041	-0.277	-0.48	-0.144	-0.544	-0.297	-0.048	-0.453	1	
Phosphate	-0.672	-0.668	-0.679	-0.344	0.408	0.746	-0.592	0.618	0.474	0.444	0.625	0.118	0.34	0.464	0.06	0.182	1

Table 4: Correlation Matrix (Pearson's correlation method) among the physico-chemical parameters of Raja Talab (S2) during

	TEMP	EC	TDS	TSS	pH	Alkalinity	DO	BOD	COD	TH	Ca+	Mg2+	Na+	K +	Cl-	Nitrate	Phosphate
TEMP	1																
EC	0.945	1															
TDS	0.658	0.468	1														
TSS	-0.069	-0.123	0.305	1													
pH	-0.915	-0.94	-0.604	-0.056	1												
Alkalinity	-0.495	-0.474	-0.754	-0.367	0.611	1											
DO	-0.247	-0.431	0.299	0.62	0.343	-0.235	1										
BOD	0.294	0.441	-0.282	-0.71	-0.371	0.264	-0.936	1									
COD	-0.759	-0.613	-0.763	-0.4	0.627	0.55	-0.362	0.351	1								
TH	-0.004	0.017	-0.183	-0.51	-0.043	0.413	-0.614	0.73	0.485	1							
Ca+	-0.228	-0.241	0.219	0.836	0.124	-0.434	0.765	-0.843	-0.351	-0.757	1						
Mg2+	0.111	0.13	-0.215	-0.707	-0.087	0.452	-0.732	0.835	0.451	0.945	-0.929	1					
Na+	0.067	0.103	-0.345	-0.834	0.079	0.357	-0.579	0.654	0.432	0.511	-0.852	0.715	1				
K +	0.017	0.094	-0.396	-0.915	0.054	0.368	-0.642	0.738	0.528	0.547	-0.864	0.742	0.914	1			
Cl-	0.043	0.202	-0.54	-0.863	-0.037	0.499	-0.864	0.901	0.51	0.612	-0.848	0.771	0.79	0.857	1		
Nitrate	-0.138	-0.232	0.364	0.709	0.164	-0.356	0.734	-0.865	-0.453	-0.706	0.825	-0.813	-0.649	-0.767	-0.785	1	
Phosphate	-0.655	-0.555	-0.702	-0.445	0.559	0.456	-0.251	0.287	0.835	0.197	-0.298	0.261	0.384	0.541	0.459	-0.491	1

November 2021 to October 2022.

Nitrate (r=- 0.041) shows significant negative relationship ($p < 0.05$ level). In S2, BOD shows high significant positive relationship ($p < 0.05$ level) with COD (r= 0.351), TH (r= 0.73), Mg2+ (r= 0.835), Na+ (r= 0.654), K+ (r= 0.738), Cl^- (r= 0.901), Phosphate (r=0.287) whereas DO (r=- 0.936), Ca^{2+} (r=- 0.843), Nitrate (r=- 0.865) shows significant negative relationship ($p < 0.05$ level). Similar observations also reported by Karmakar and Singh, 2021; Elayaraj and Selvaraju, 2014. BOD shows significant negative correlation with DO in both sites, so, the greater the BOD, the more rapidly oxygen is reduced in any aquatic ecosystem. Similar to the effects of low dissolved oxygen, excessive BOD also causes stress and ultimately leads to the death of aquatic organisms.

COD (Chemical Oxygen Demand)

COD ranges from 28.7 mg/L to 40.8 mg/L in S1 while the concentration of COD in S2 ranges between 67.5 mg/L to 93.4 mg/L. Higher concentration of COD was observed, which correlated with low dissolved oxygen.

In S1 shows high significant positive relationship ($p < 0.05$ level) with TH (r= 0.473), Ca^{2+} (r= 0.677), Mg2+ (r= 0.115), Na+ (r= 0.83), K+ (r= 0.809), Cl^- (r= 0.669), Phosphate (r= 0.474) whereas Nitrate (r=- 0.277) shows significant negative relationship ($p < 0.05$ level). In S2 shows high significant positive relationship ($p < 0.05$ level) with pH (r=0.485), Mg2+ (r= 0.451), Na+ (r= 0.432), K+ (r= 0.528), Cl^- (r= 0.51), Phosphate (r= 0.835), whereas Ca^{2+} (r=- 0.351), Nitrate (r=- 0.453) shows significant negative relationship ($p < 0.05$ level). Indu *et al.,* 2015; Karmakar and Singh, 2021, observed similar results.

TH (Total Hardness)

The concentration of Total Hardness at S1, ranged oscillated from 97 mg/L to 150 mg/L while 240 mg/L to 310 mg/L were recorded in S2. The higher concentration of TH during the summer season may be due to reduced water volume, an increased rate of evaporation at high temperatures, and the high loading of organic materials and detergents (Rajagopal *et al.,* 2010). And lower values during the rainy season may be due to dilution.

In S1, TH shows significant positive relationship ($p < 0.05$ level) with Ca^{2+} (r= 0.693), Mg2+ (r= 0.825), Na+ (r= 0.403), K+ (r= 0.343), Cl^- (r= 0.527), Phosphate (r= 0.444), whereas Nitrate (r=- 0.48) shows significant negative relationship ($p < 0.05$ level).

In S2, TH shows high significant positive relationship ($p < 0.05$ level) with Mg2+ (r= 0.945), Na+ (r= 0.511), K+ (r=0.547), Cl (r=0.612), Phosphate (r= 0.197), whereas Ca^{2+} (r=- 0.757), Nitrate (r=- 0.706) shows significant negative relationship ($p < 0.05$ level). Sharma *et al.,*2016 reported that TH shows positive relationship with Na^+, Mg^{2+}, whereas shows negative relationship with WT, TDS, pH, nitrate, Potassium. Madhab *et al.,* 2011, observed similar findings. Total hardness shows significant positive correlation with Ca^{2+} Mg^{2+} and Cl^- in both sites. Therefore, it is believed that the presence of CaCl2, CaSO4, MgCl2, and MgSO4 is mostly responsible for the hardness of water samples (Ramarao and Ramdas, 2009).

Calcium (Ca^{2+})

The concentration of calcium (Ca^{2+}) in S1 and S2 were recorded between 30.4 mg/L to 42.8 mg/L and 60.2 mg/L to

88.1 mg/L respectively. In S1, Calcium shows significant positive relationship ($p < 0.05$ level) with Mg2+ (r= 0.166), Na+ (r= 0.509), K+ (r= 0.464), Cl^- (r= 0.495), Phosphate (r= 0.625), whereas Nitrate (r=- 0.144) shows significant negative relationship ($p < 0.05$ level). Similar results were also reported by Madhab Borah *et al.,* 2011; Qureshimatva Umerfaruq *et al.,* 2015. In S2 Calcium shows high significant positive relationship ($p < 0.05$ level) with Nitrate (r= 0.825) whereas Mg2+ (r=- 0.929), Na+ (r=- 0.852), K+ (r=- 0.864), Cl^- (r=- 0.848), Phosphate (r=- 0.298) shows significant negative relationship ($p < 0.05$ level). Similarly, Sharma *et al.,* 2016, reported similar observations.

Magnesium (Mg^{2+})

Magnesium and calcium are the most widespread elements in naturally occurring surface water. They primarily occur as carbonates, bicarbonates, and carbon dioxide, which are important sources of inorganic carbon for aquatic ecosystem producers (Elayaraj and Selvaraju, 2014). Magnesium in the present study were found ranging between 5.103 mg/L to 12.75 mg/L in S1 while 5.9 mg/L to 33.9 mg/L in S2.

In S1, magnesium shows significant positive relationship ($p < 0.05$ level) with Na+ (r= 0.151), K+ (r= 0.103), Cl^- (r= 0.331), Phosphate (r= 0.118), whereas nitrate (r=- 0.544) shows significant negative relationship ($p < 0.05$ level). In S2, magnesium shows significant positive relationship ($p < 0.05$ level) Na+ (r= 0.715), K+ (r= 0.742), Cl^- (r= 0.771), Phosphate (r= 0.261) whereas Nitrate (r=- 0.813) shows significant negative relationship ($p < 0.05$ level). Karmakar and Singh, 2021, reported that Mg^{2+} shows positive relation with EC, pH, BOD, COD, Cl^-, PO_4^{3-}, Na^+, K^+, Ca^{2+}, whereas, shows negative relationship with nitrate.

Sodium (Na^+)

The values of measured sodium varied from 26 mg/L to 44 mg/L in S1 while the values of sodium ranges from 67.1 to 89.1 mg/L were recorded in S2. In S1, Sodium shows significant positive relationship ($p < 0.05$ level) with K+ (r=0.778), Cl^- (r=0.751), phosphate (r=0.34), whereas Nitrate (r=- 0.297) shows significant negative relationship ($p < 0.05$ level). In S2, Sodium shows significant positive relationship ($p < 0.05$ level) with K+ (r= 0.914), Cl^- (r= 0.79), Phosphate (r= 0.384) whereas Nitrate (r=- 0.649) shows significant negative relationship ($p < 0.05$ level). Similarly, Sharma *et al.,* 2016, found similar results.

Potassium (K^+)

The concentration of potassium at S1, ranged from 18 mg/L to 32 mg/L while 57.1 mg/L to 77.1 mg/L in S2 were recorded during November 2021 to October 2022.

In S1, Potassium shows significant positive relationship ($p < 0.05$ level) with Cl^- (r= 0.391), Phosphate (r= 0.464), whereas Nitrate (r=- 0.048) shows significant negative relationship ($p < 0.05$ level). In S2, Potassium shows significant positive relationship ($p < 0.05$ level) with Cl^- (r= 0.857), Phosphate (r= 0.541), whereas Nitrate (r=- 0.767) shows significant negative relationship ($p < 0.05$ level). Indu *et al.,* 2015 observed similar observations as K^+ shows positive relation with EC, Cl^-, Na^+, Mg^{2+}, PO_4^{3}, BOD, COD, while pH, DO shows negative relationship with K^+.

Chloride (Cl^-)

Chloride is one of the most crucial factors in determining the quality of the water. Due to its rapid reaction with other compounds in water, readily dissolved chlorine is hazardous

Table 5: Calculated WQI (Water Quality Index) for the two water bodies i.e. Mandal Talab (S1) and Raja Talab (S2).

	Parameters	BIS STD. (Sn)	K = 1/" 1/Sn	Wn = K/Sn	Qn = Vn/Sn x100	WnQn
	pH	8.5	2.463847	0.289864	26	7.536475
Mandal Talab (S1)	DO	5	2.463847	0.492769	90	44.34925
	EC	300	2.463847	0.008213	274.1389	2.251455
	Alkalinity	200	2.463847	0.012319	61.54167	0.758146
	TDS	500	2.463847	0.004928	129.1333	0.63633
	TH	200	2.463847	0.012319	63.83333	0.786378
	Ca^{2+}	75	2.463847	0.032851	49.4	1.622854
	Mg^{2+}	30	2.463847	0.082128	28.35917	2.329089
	Cl^-	250	2.463847	0.009855	21.646	0.21333
	NO_3^-	45	2.463847	0.054752	4.127778	0.226005
				" Wn = 1		" WnQn = 60.7093
	Parameters	BIS STD. (Sn)	K = 1/" 1/Sn	Wn = K/Sn	Qn = Vn/Sn x100	WnQn
Raja Talab (S2)	pH	8.5	2.463847	0.289864	24	6.956746
	DO	5	2.463847	0.492769	109	53.71187
	EC	300	2.463847	0.008213	412.6944	3.389387
	Alkalinity	200	2.463847	0.012319	105.7083	1.302246
	TDS	500	2.463847	0.004928	209.9833	1.034734
	TH	200	2.463847	0.012319	134.125	1.652318
	Ca^{2+}	75	2.463847	0.032851	101.5778	3.336962
	Mg^{2+}	30	2.463847	0.082128	63.01667	5.175448
	Cl^-	250	2.463847	0.009855	50.9	0.501639
	NO_3^-	45	2.463847	0.054752	18.05	0.988277
				" Wn = 1		" WnQn = 78.0496

Table 6: Categories for Water Quality Status developed by Brown *et al.*, 1972.

Water Quality Index	Water Quality Status	Possible applications
0-25	Excellent	Drinking, Irrigation and Industrial
26-50	Good	Drinking, Irrigation and Industrial
51-75	Poor	Irrigation and Industrial
76 - 100	Very Poor	Irrigation
>100	Unfit for Consumption	Proper treatment required before use

to the majority of aquatic species (Padmanabh and Belagali, 2007). The values of chloride varied from 48.5 mg/L to 63.26 mg/L in S1 while in S2, Chloride oscillated between 98 mg/L 152 mg/L. In S1 Chloride shows significant positive relationship ($p < 0.05$ level) with Phosphate ($r = 0.06$), whereas Nitrate ($r = -0.453$) shows significant negative relationship ($p < 0.05$ level). In S2 Chloride shows significant positive relationship ($p < 0.05$ level) with Phosphate ($r = 0.459$), whereas nitrate ($r = -0.785$) shows significant negative relationship ($p < 0.05$ level). Similar results were also reported by Karmakar *et al.,* 2021; Qureshimatva Umerfaruq *et al.,* 2015.

Nitrate (NO_3^-)

In S1 (Mandal talab), the values of nitrate were recorded between 1.41 mg/L to 2.5 mg/L while 5.21 mg/L to 12.33 mg/L in S2 (Raja Talab). In aquatic bodies, excessive algal blooms may be caused by elevated nitrate concentrations. In Raja Talab (S2), the nitrate concentration was higher than Mandal Talab (S1). The principal sources of nitrate in these water bodies may be due the incorporation of organic and decaying matters, fertilisers, municipal and untreated domestic sewages. In S1 Nitrate shows significant positive relationship ($p < 0.05$ level) with Phosphate ($r = 0.182$). In S2 Nitrate shows significant positive relationship ($p < 0.05$ level) with Phosphate ($r = -0.491$). According to Shinde *et al.,* 2011, NO_3^- shows positive relationship with TDS, TSS, PO_4^{3-} while shows negative relation with WT, Cl^-.

Phosphate (PO_4^{3-})

The range of phosphate lies between 0.51 mg/L to 1.8 mg/L in S1 (Mandal Talab) and 0.87 mg/L to 2.99 mg/L in S2 (Raja Talab) during November 2021 to October 2022. The maximum value was recorded in January and minimum in July in S1 while in S2, maximum value was recorded during February and minimum in September. Phosphate is thought to be the essential limiting factor that causes freshwater systems to become eutrophic (Rabalais, 2002).

Water Quality Index (WQI)

Water quality index is a mathematical way to understand the quality status of any aquatic ecosystem. As seen in Table 5, WQI is computed in a few steps.

Water quality index indicates the status of water quality in five categories, as indicated in Table 6.

Calculated values of WQI indicate that both water bodies fall into the poor to very poor-quality category. Raja talab shows a higher WQI value, *i.e.*, 78.05, while Mandal talab shows 60.71, which is comparatively lower than Raja talab. The Water Quality Index (WQI) is a numerical representation of the overall water quality, suitable for any intended purpose. According to the WQI values, both S1 (Mandal Talab) and S2 (Raja Talab) were not suitable for drinking purpose. Both the water bodies need proper treatment before any intended use.

CONCLUSION

The present study gives a detailed account on the monthly variations in the physico-chemical parameters of two perennial ponds *viz*, Mandal Talab (S1) and Raja Talab (S2). On the basis of comparative analysis of monthly variations, it can be concluded that the seventeen limnological parameter were found to be in higher concentration in S2 than S1. The concentration of Dissolved oxygen (DO), Alkalinity, Total Dissolved Solids, (TDS), and Total Hardness (TH) of Raja Talab (S2) exceeding the desirable limit as proposed by BIS, 2012 and WHO, 2006. The correlation coefficient indicates positive and negative significant correlation between the selected seventeen physical and chemical parameters. WQI values represents the poor water quality of both the water bodies. Both the sites *i.e.*, S1 and S2 were not suitable for drinking purpose. The present research will provide a scientific and methodological measures for quality assured monitoring and more effective management of the water bodies.

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