

Multivariate Water Quality Assessment of Renowned Pilgrim Spot, Gujarat, India: A Statistical Approach

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Abstract

Gomti Palustrine Habitat is one of the renowned pilgrimage ponds of Central Gujarat, India. In the present research, different statistical tests were applied to 21 water quality parameters to trace and delineate the status of water quality. The present study was undertaken for one year (December, 2012 to November, 2013) with monthly sampling covering three successive seasons (winter, summer, monsoon). Three permanent sampling stations (V1, V2, V3) were selected to cover the cross-sectional and diagonal regime of wetland. Ionic Signatures (IS) confirmed the wetland to be dominated with Ca and HCO₃⁻, indicating leaching of minerals from drainage basins. Index of Base Exchange (IBE) supported the enrichment of Na⁺ ions in the water regime owing to clay horizons. Exchangeable Sodium Ratio (ESR) (1.416 meq/l) and Sodium Absorption Ratio (SAR) (1.367 meq/l) found to be minimal referring to leaching and dissolution of salts during precipitation. Surface water quality is exhibited by low Salinity and low Sodicity zone, can be used for irrigation purpose. Principal Component Analysis (PCA) identified a reduced number of mean of 3 varifactors indicating that 93.35 % of temporal and spatial changes affect the water quality drastically. First factor from the factor analysis explained a total of 74.44 % among TH, HCO₃⁻, Mg, Cl, salinity and K⁺. One way ANOVA revealed that Sampling Site 2 is maximally loaded with aquatic pollutants, followed by Sampling Site 3 and Sampling Site 1 (Site description is given in the later section of the paper). These outcomes manifested prime necessity to restore the physical, chemical and biological integrity of water quality to revert the ecological balance of an aquatic ecosystem.



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Introduction

So far liminological studies have been mainly aimed to focus on deterioration of the water quality due to pollution only on the part of human consideration. Now-a-days, pilgrimage ponds visited by number of pilgrims are an addition to many folds to this devastation, which has now become a cause of global concern¹⁶. The productivity of the pond mainly depends on various abiotic and biotic components usually fluctuated by seasonal and varying degree of pollution³. Hydro-chemistry of water plays a paramount role in determining the distribution and pattern, and quantitative abundance of an aquatic ecosystem³⁶. Water quality assessment approach allows the physical, chemical, and biological characterization of the water to be considered in light of their probable impact on advantageous uses of the water by humans. For the past many years, investigators have studied the hydro-biological profile of many lentic ecosystems with the intent to assess the water quality^{34,32,12,31}. Recently,³⁸ reported the hydro-quality profile of pilgrimage wetland of Central Gujarat. In past, biotic components viz. occurrence of plankton of *Gomti* Palustrine Habitat (GPH) were investigated^{39,40}, but mere focus was paid on status of surface water quality for the aforesaid study area. Present study deals with the multivariate approach

to speculate the degree of fluctuations of significant hydro-chemical parameters of surface water at *Gomti* Palustrine Habitat (GPH), Central Gujarat, India, owing to non-point anthropogenic interventions, consequentially imparting pessimistic impact on aquatic body, which perhaps will help in plummeting human pressures distressing on the selected renowned pilgrimage freshwater spot aided with some conservation and management strategies.

Materials and Methods

Study Area

Gomti Palustrine Habitat (GPH)

Gomti Palustrine Habitat (GPH), Central Gujarat, India, is located between 22.59° N and 72.87° E; with an average humidity 52 %; winter temperature 19 °C and 33 °C during summer; mean elevation 37 meters above MSL, 8733 human population with 72 % literacy rate. The wetland covers an area of approximately 173 acres. From the spirituality point of view, this pilgrim spot is the most worshiped holy place of Lord Swaminarayana (the incarnation of Lord Krishna), solemnised with ancient galore and varying rituals, hence fetching the source of sacredness for the pilgrims from all over the State and the Country. (Fig. 1).



Fig. 1: Gomti Palustrine Habitat (GPH), Central Gujarat, India

Sampling Sites

Sampling Site V1

This Site is situated at the southern end of GPH adjacent to village (Vadtal). The mean water depth of this Site is around 6.096 m during monsoon; however, water level recedes during summer. The water at this Site is comparatively unpolluted than

the other two study Sites. The dominant macrophytes at this Site are *Hydrilla verticillata* (L.f.) Royle, *Azolla pinnata* R. Br., and *Ipomoea aquatica* Forsk. Fishing by the local anglers has been a regular activity therein. Sometimes, cattle wading and bathing is also noticed here.

Sampling Site V2

This Site is situated westwards to the wetland which is highly polluted with organic matter owing to its proximity to agricultural plots in addition to influent of raw sewage from nearby households. Amount of organic wastes frequently is dumped at this Site due to unchecked input of detergents and household wastes, generated from washing, bathing and cattle wading activities by the locales. Moreover, garlands, clothes, coconuts, etc. are also discarded in the form of temple wastes into this Site. The villagers use the water of this Site, mainly for washing clothes and utensils, and thus detergent wastes reaches to high amounts.

Sampling Site V3

This Site is situated towards the northern side of the wetland. The floral aquatic plant species dominating the Site are *Eichhornia crassipes* (Mart.) Solms., *Lemna minor* L., *Ipomoea aquatica* Forsk., with uncommon occurrence of *Ceratophyllum demersum* L., *Najas minor* All. and *Marsilea quadrifolia* L. Dumping of plastic bottles and menace tourism wastes by local bus passengers are observed therein due to Site proximity near local bus stop and road transport network

Surface Water Sampling

The present study was undertaken for one year (December, 2012 to November, 2013) with monthly sampling, covering three successive seasons (winter, summer, monsoon). Three permanent sampling stations (V1, V2, V3) were selected to cover the cross-sectional and diagonal regime of wetland. Collection of surface water samples were done using pre-cleaned polyethylene bottles (two litres), filtered using 0.45 micron filters, and stored in ice boxes at 4 °C for further laboratory analysis. Standard protocol was adopted for surface water analysis^{44,19,11,1}.

Physico-chemical parameters including sulphate (SO_4^{2-}), phosphate (PO_4^{2-}), nitrate (NO_3^-), total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), total hardness (TH), calcium hardness (Ca), and magnesium hardness (Mg), were analysed, along with in-situ measurement of temperature (°C) and pH probe (LUTRON PH-201). Besides, dissolved oxygen (DO) was fixed on-site, and subsequently analysed using Alkali-Azide modification by Winkler's method⁴¹. sulphate and

phosphate were estimated by turbidimetric, and Stannous Chloride method, respectively. Nitrate concentration was determined by Brucine-Sulphate method prescribed by NPDES (National Pollutant Discharge Elimination System) and SDWA (Safe Drinking Water Act). Flame Photometric method was performed to estimate sodium and potassium concentrations, while alkalinity, chloride and salinity were quantified titrimetrically.

Statistical analysis is one of the best techniques for stipulating linear relationship between different variables (parameters)¹³. In order to quantitatively analyse and confirm the relationships amongst the variables, its scientific reliability was validated using Correlation Coefficient (r), Ion Signatures (IS), Index of Base Exchange (IBE), Sodium Absorption Ratio (SAR), Principal Component Analysis (PCA), and One Way ANOVA (Analysis of Variance), using PAST Software, Version 3.03, SPSS version 22.0, STATISTICA 9 and Aq.QA Software [Version 1.1.1 (1.1.5.1)].

Results and Discussion

Surface Water Quality

Analysis of hydro-chemical constituents of GPH at sampling points is shown in Table 1. Results indicated that pH increased from 7.50 to 7.53. TDS ranged between 163.61 to 175.28 ppm. According to⁶, surface water quality is of fresh type (TDS < 1000 ppm). DO ranged between 4.92-5.39 ppm, referring to a bit hypoxic condition of water body. TH fluctuated from 168.28 to 178.02 ppm, symbolizes the moderate hard water quality (TH > 300 ppm;⁴⁵. Cations and anions quantifications depicts that Ca^{2+} ranged between 153.95 to 163.27 ppm, Mg^{2+} (14.33 to 14.59 ppm), Na^+ (64.18 to 64.29 ppm), K^+ (7.52 to 8.57 ppm), HCO_3^- (214.21 to 221.88 ppm), Cl^- (105.61 to 111.34 ppm), SO_4^{2-} (19.12 to 24.27 ppm), PO_4^- (0.844 to 1.644 ppm), and NO_3^- (0.307 to 0.370 ppm). The concentration gradient of surface water of aquatic body is characterized as $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+ > \text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{PO}_4^- > \text{NO}_3^-$.

The outcomes of Aq.QA Software [Version 1.1.1 (1.1.5.1)] delineate the pilgrim wetland as a dominant water type (Na- HCO_3^- type). Na- HCO_3^- composition may be due to weathering of carbonaceous sandstones (consistent with geological signatures)

or may be due to interaction with schist, quartzite, and granite rocks. Exchangeable Sodium Ratio (ESR) is 1.416 meq/l, and Sodium Absorption Ratio (SAR) is 1.367 meq/l. The surface water quality of entire study area falls under C1-S1 low salinity-low sodicity zone⁴⁷, and low SAR (Sodium Absorption Ratio = $\text{Na}^+ / \{[\text{Ca}^{2+} + \text{Mg}^{2+}] / 2\} * 0.5$) zone. SAR is found to be lower indicating leaching and dissolution

of salts during precipitation⁴³. As the surface water quality is exhibited by low salinity and low sodicity zone, the water is of good water type, and can be used for irrigation purpose with little menace of exchangeable sodium⁴⁷. The impact of geological and anthropogenic activities on the hydro-chemistry of surface water can further be extrapolated with the help of scatter diagrams, ionic signatures⁴⁹.

Table 1: Physico-chemical constituents of surface water at sampling points

Parameters	V1	V2	V3	Mean	S.D.
Temperature (°C)	25.67	26.90	26.58	26.38	±0.641
pH	7.50	7.53	7.52	7.52	±0.014
DO	5.39	4.92	5.11	5.14	±0.234
TS	293.46	308.01	299.82	300.43	±7.292
TSS	129.85	132.72	130.67	131.08	±1.481
TDS	163.61	175.28	169.15	169.35	±5.838
Free CO ₂	9.02	8.43	8.80	8.75	±0.299
TA	214.21	221.88	219.56	218.55	±3.932
Bicarbonates	214.21	221.88	219.56	218.55	±3.932
TH	168.28	178.02	173.96	173.42	±4.895
Ca	153.95	163.27	159.37	158.86	±4.685
Mg	14.33	14.75	14.59	14.56	±0.211
Chloride	105.61	111.34	109.24	108.73	±2.901
Salinity (ppt)	0.1908	0.2012	0.1974	0.1964	±0.005
Sulphate	19.12	24.27	19.69	21.03	±2.821
Phosphate	0.844	1.644	1.220	1.236	±0.400
Nitrate	0.397	0.307	0.370	0.358	±0.046
Sodium	64.18	64.29	64.24	64.24	±0.053
Potassium	7.52	8.57	8.20	8.10	±0.532

*All the values are expressed in ppm, except pH

Ionic Trends

Overall scenario of the ionic trends of water quality is well-depicted (Fig. 2). All the water quality parameters were reported to be significantly higher at Site 2, followed by Site 3 and least at Site 1. Except for few parameters (Free CO₂, NO₃²⁻ and DO), reverse trend was noticed. The lesser content of DO at Sites 2 and 3 can be attributed by the fact that higher concentration of nutrients at these sites adversely affects the solubility of oxygen in water². Content of DO was observed to be high in the colder season, which can be ascribed to low atmospheric and water temperature, indirectly increasing the solubility of oxygen in water. These findings are in agreement with the investigation of¹⁶⁻²⁴. Similarly,

free CO₂ concentration was found to be higher in the winter season, which might be due to low temperature and high rate of decomposition⁸. Similar trend was well-corroborated with the findings of¹⁵.

Higher concentration of Free CO₂ at Site 1 was due to excessive content of organic loading in surface waters of a particular site. The term “solids” refers to the total amount of organic and inorganic materials in water¹⁴, of which Total Suspended Solids (TSS) refers to an indicator parameter referring to the amount of organic pollution²⁰. Concentration of solids was observed higher in warmer months due to the evaporative loss of water and subsequent increase in solute concentration in surface water⁴⁸.

Gradual depletion during the hotter months is due to the sedimentation of salt particles with low content of suspended organic matter³⁵. Total alkalinity in surface water is mainly due to salts of carbonates, bicarbonates and hydroxides²⁸. Increase in carbonates and bicarbonates leads to increase in the concentration of alkalinity²⁵. Temporary hardness was noted to be elevated during the warmer months due to an increase in temperature, which eventually

leads to high rate of evaporation of surface water, and decomposition and solubility of calcium and magnesium ions, thus concentrating the salts⁹. Temporal concentration of chloride recorded to be higher in summer season due to higher pollution level, owing to low water depth leading to an increase in concentration of organic matter^{26,42}. These findings were well- corroborated with the findings of^{48,20}.

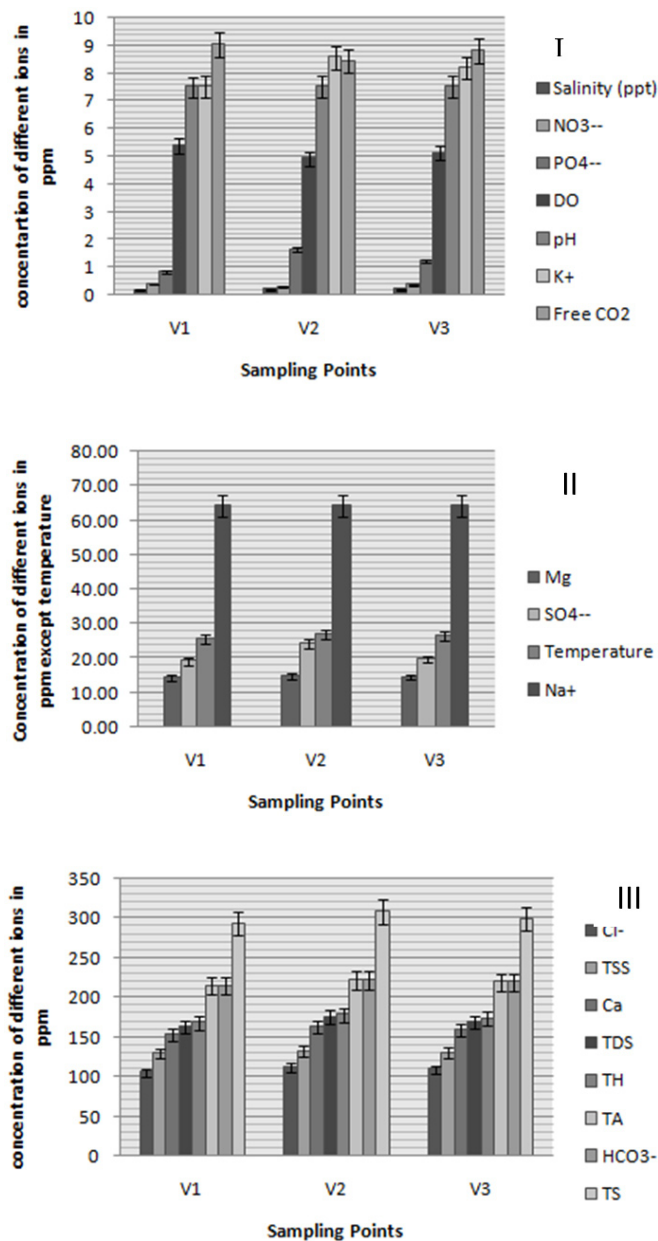


Fig. 2: Spatial trend of physico-chemical parameters of surface water at sampling points

In case of nutrient concentration, sulphate reported to be maximum in the summer season, which might be due to higher evaporation rate as per⁹. Spatial heterogeneity indicated average concentration of sulphate to be higher at Site 2 compared to other sites due to an increase in bathing and washing practices by local inhabitants as well as pilgrims. This finding was also supported by³³. Phosphate is one of the limiting and basic nutrients of the static waters⁴⁶. Presence of phosphate in water indicates pollution through domestic sewage, agricultural run-off and certain biological processes²⁷. In the present study, the content of phosphate was estimated to be higher

in dry seasons with the decline in the water level. Decomposing of organic matter, human indulgence, and loading of domestic sewage through point and non-point sources make the hydric water to be more phosphate rich⁴. Results points towards increasing concentration of phosphate ion at Site 2 compared to other sites, and during dry seasons its concentration increased with gradual decrease during the colder months. Nitrate in the present study was found to be eventually increasing during the colder months due to higher rate of biotic components viz. aquatic macrophytes and plankton community as earlier reported³⁸ (Fig. 3.) (Table 1).

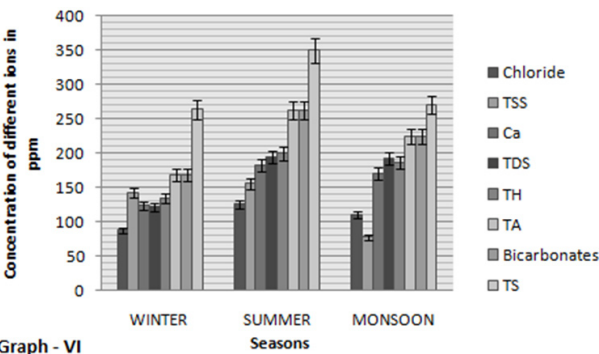
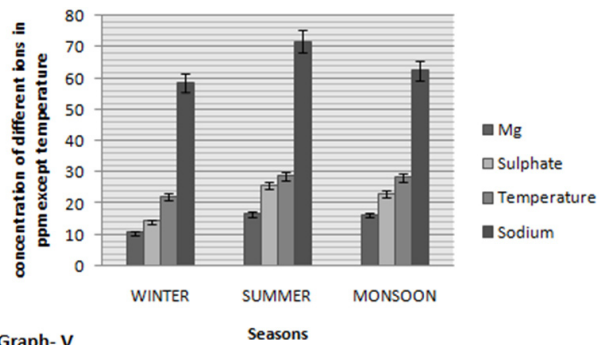
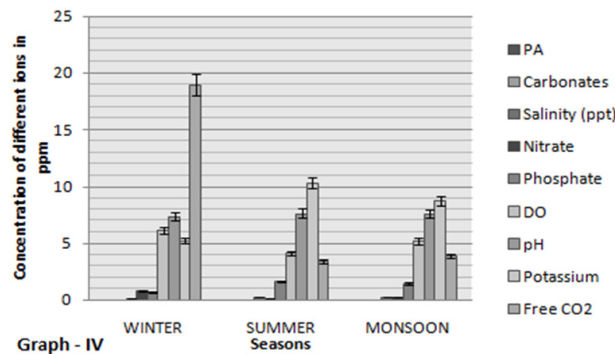


Fig. 3: Temporal trend of physico-chemical parameters of surface water over different seasons

Table 2: Co-relational matrix (r) among physico-chemical variables

	Temperature	pH	DO	TS	TSS	TDS	Free CO ₂	TA	HCO ₃ ⁻	TH	Ca	Mg	Cl ⁻	Salinity (ppt)	SO ₄ ²⁻	PO ₄ ³⁻	NO ₃ ⁻	Na ⁺	K ⁺
Temperature	1.000																		
pH	0.949	1.000																	
DO	-0.987	-0.988	1.000																
TS	0.941	1.000	-0.983	1.000															
TSS	0.870	0.981	-0.938	0.986	1.000														
TDS	0.954	1.000	-0.990	0.999	0.978	1.000													
Free CO ₂	-0.914	-0.995	0.968	-0.997	-0.995	-0.993	1.000												
TA	0.999	0.964	-0.994	0.957	0.894	0.968	-0.933	1.000											
HCO ₃ ⁻	0.999	0.964	-0.994	0.957	0.894	0.968	-0.933	1.000	1.000										
TH	0.984	0.990	-1.000	0.986	0.944	0.992	-0.971	0.992	0.992	1.000									
Ca	0.984	0.990	-1.000	0.986	0.944	0.992	-0.972	0.992	0.992	1.000	1.000								
Mg	0.991	0.983	-1.000	0.978	0.929	0.986	-0.961	0.996	0.996	0.999	0.999	1.000							
Cl ⁻	0.993	0.980	-0.999	0.975	0.923	0.983	-0.956	0.997	0.997	0.998	0.998	1.000	1.000						
Salinity (ppt)	0.993	0.980	-0.999	0.975	0.923	0.983	-0.956	0.997	0.997	0.998	0.998	1.000	1.000	1.000					
SO ₄ ²⁻	0.768	0.930	-0.861	0.940	0.984	0.924	-0.962	0.799	0.799	0.869	0.870	0.848	0.840	0.840	1.000				
PO ₄ ³⁻	0.953	1.000	-0.989	0.999	0.979	1.000	-0.994	0.967	0.967	0.992	0.992	0.985	0.983	0.983	0.926	1.000			
NO ₃ ⁻	-0.877	-0.983	0.943	-0.988	-1.000	-0.980	0.997	-0.900	-0.900	-0.948	-0.949	-0.934	-0.928	-0.928	-0.981	-0.981	1.000		
Na ⁺	0.979	0.993	-0.999	0.990	0.952	0.995	-0.977	0.988	0.988	1.000	1.000	0.998	0.996	0.996	0.882	0.995	-0.956	1.000	
K ⁺	0.994	0.977	-0.998	0.971	0.917	0.980	-0.951	0.998	0.998	0.997	0.997	0.999	1.000	1.000	0.831	0.979	-0.922	0.995	1.000

Temperature influences all the variables in the lentic ecosystem directly or indirectly. Here, temperature is positively correlated with all the variables except DO, free CO₂ and NO₃²⁻. The inverse relationship between DO and temperature is well documented in the literature of^{22,17}. A significant positive correlation was computed between DO, free CO₂ and NO₃²⁻, indicating all three parameters are interrelated with one another, influenced by their presence there in. Negative correlation between free CO₂ and nitrate with all other hydro-chemical parameters is in agreement with the investigation of^{f23}. Solid contents of the surface water were positively correlated with all other parameters except DO, free CO₂ and NO₃²⁻. The obtained results from the correlation matrix are parallel with the findings of^{f37}. Calcium and magnesium neutralizes the excess amount of acids present in the water body. This is justified by the high positive correlation in case of TH, and Ca-Mg hardness with alkalinity⁵. The chloride content of water was positively correlated with almost all parameters except DO, free CO₂ and NO₃²⁻. These findings matched the study of⁸. Nutrients were significantly positively correlated with the all other variables except DO, Free CO₂, which is in agreement with the findings of^{f21} (Table 2).

Ionic Signatures

The hydro-chemical data for two of the sampling sites with respect to Ca⁺ and Mg⁺ ions (alkaline earth elements) / HCO₃⁻ lies on the equiline for 66 % of the sampling points, suggesting that both alkalinity and alkalis concentration are balancing each other in

congruent manner, while for 33 % the ionic profile is lying above the equiline depicting excess of alkalinity is balancing alkalis (Fig A). The plotting of the ionic data of alkaline earth element to TC (Total Cations) shows that the chemical data for all the study sites lies exactly on the equiline emphasizing on the finding that increase in concentration of alkaline earth elements corresponds to simultaneous increase in the concentration of Total Cations (TC) (Fig B). This indicates a linear relationship between alkalis and cations indicating these ions to be leached from the minerals from the aquifers. The relative abundance of chloride ion to SO₄²⁻ is due to the enrichment of water. These ionic signatures from the chemical data refer more strongly to the dominance of Ca:HCO₃ ions in the hydric regime (Fig. 4. A to G). The ionic signature of Na⁺:Ca²⁺ for all study sites is less than a unit indicating the concentration of the alkali earth elements is more than the alkalis concentration.

Index of Base Exchange (IBE) was further stipulated to study the compositional changes of surface water⁴⁶. The negative value of IBE i.e. IBE I (Cl⁻:Na⁺+K⁺: Cl) and IBE II (Cl⁻:Na⁺+K⁺: HCO₃⁻) support the enrichment of Na⁺ in water profile owing to prolific clay horizons. The excess amount of Na⁺ ions over K⁺ ions is due to the greater resistance of K⁺ ions to weathering and its absorption to clay minerals²¹. The hydrological regime is dominated by Ca and HCO₃⁻, an indication that the composition is controlled by mineral components leached from the rocks of the drainage basins⁴⁷.

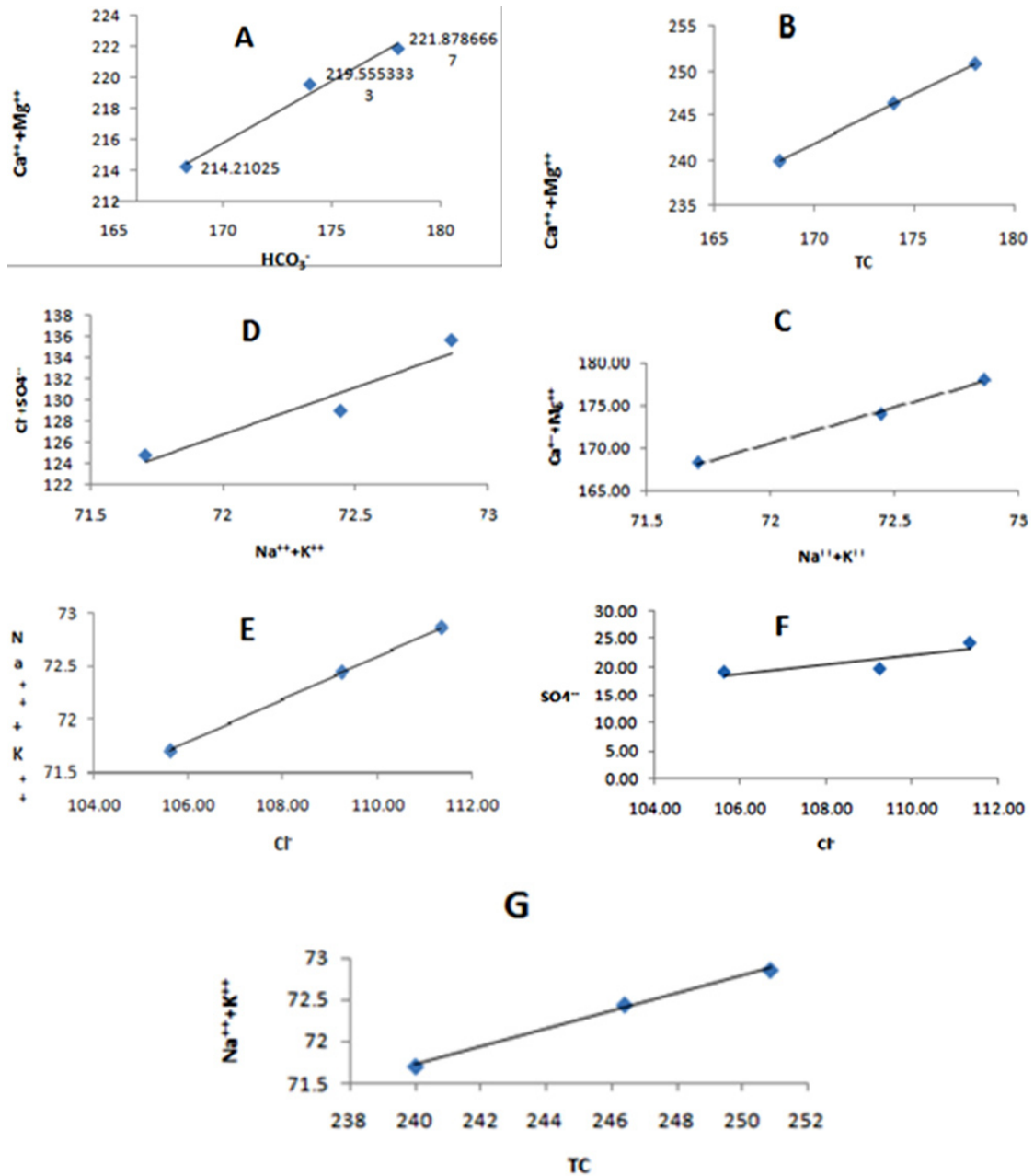


Fig. 4: (A to G). Scatter plots of surface water

One Way Analysis Of Variance (ANOVA)

One way Analysis of Variance (ANOVA) among all the studied variables (physico-chemical parameters) of water at all three sampling points indicates that all three study sites differed significantly in context of their nutrient concentration of freshwater wetland.

Moreover, ANOVA interpretation for the dataset indicates that nutrient content was maximum at Site 2 (F = 0.557, p = 0.862), moderate at Site 3 (F = 0.516, p = 0.892), and the least at Site 1 (F = 0.463, p = 0.925) (Table 3).

Table 3: One Way Analysis of Variance (ANOVA) for different sampling points

Sampling Point	F	P-value	F crit
V1	0.463	0.925	1.831
V2	0.557	0.862	1.831
V3	0.516	0.892	1.831

Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) for the surface water of GPH is shown in Tables 4 and 5. It includes the loadings of component matrix, Eigen-values for each component, percent, and cumulative percent of variance for each component. It depicts that the first three principal components together accounts for 93.35 % of total variance in the dataset, of which first component is 74.44 %, second component is 9.841% and third component is 9.077 % of total variance. The concentration of TH, HCO₃²⁻, Mg, Cl, Salinity and K⁺ shows high positive loadings (0.780-0.799), whereas the concentration of TS, TDS, TH, Ca and PO₄²⁻ have low positive

loadings (0.184-0.455) and moderate positive loading pH (0.558) for the first component.

In the second component, temperature, pH, DO, TDS, TH, Mg, Cl, salinity, SO₄²⁻, PO₄²⁻ and NO₃²⁻ showed low positive loadings (0.003-0.408). For the third component, pH, TDS, TH, Ca, PO₄²⁻ and Na⁺ depicts high positive loadings (0.797-0.924), moderate loadings (0.486-0.656) was observed between temperature, TS, TA, HCO₃²⁻, Mg, Cl, Salinity, SO₄²⁻ and K₊. The high positive loading between TH, HCO₃²⁻, Mg, Cl, Salinity and K⁺ suggest that first component is related with various hydro-chemical processes. In this case, high positive loading between K⁺ and Cl⁻ ions results in more weathering in the sampling area. The positive loading of K⁺ and Mg⁺ ions for the first component indicates weathering of Feldspar and Ferro-magnesium minerals along with anthropogenic sources^{51,30}. The concentration of TH and HCO₃²⁻ suggests that most of the hardness in the water is an ephemeral source. Moderate loading of TDS and NO₃²⁻ in the surface water samples is the indication of man-made pollution due to domestic waste^{7,50,52}(Fig. 5 and Fig. 6.; Table 4 and Table 5).

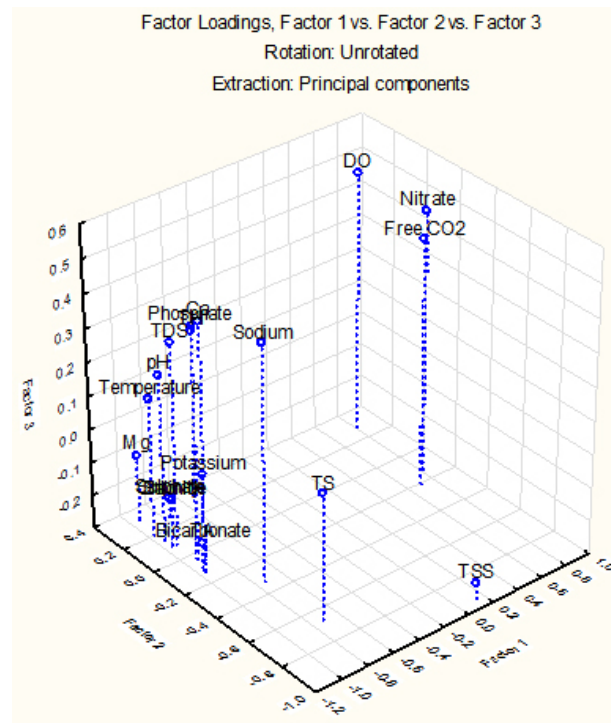


Fig. 5: Factor Loading of Various Chemical Data

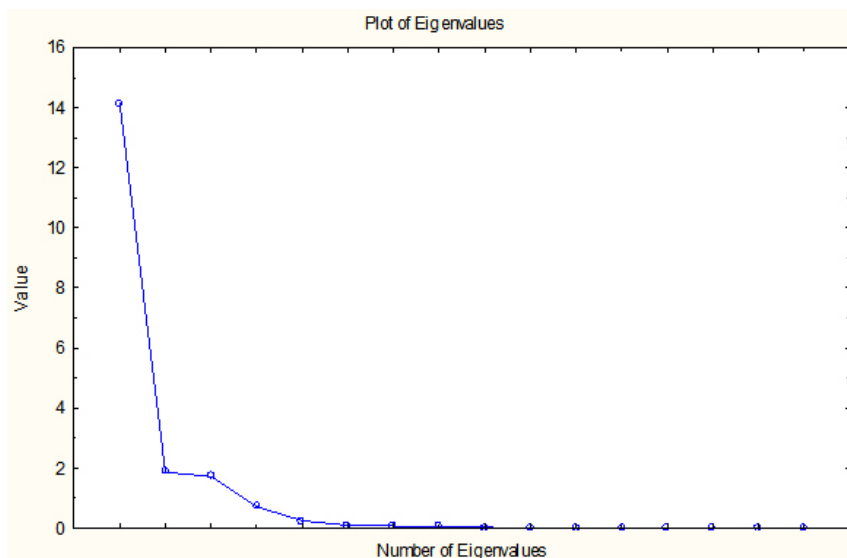


Fig. 6: Eigen Plots

Table 4: Principal component matrix of physico-chemical data

Principal Components				
Parameters	I	II	III	
Temperature	0.634	0.190	0.733	
pH	0.558	0.152	0.797	
DO	-0.850	0.408	-0.273	
TS	0.329	-0.662	0.656	
TSS	-0.101	-0.974	-0.144	
TDS	0.455	0.129	0.855	
Free CO ₂	-0.833	-0.081	-0.161	
TA	0.799	-0.191	0.542	
HCO ₃ ⁻	0.799	-0.191	0.542	
TH	0.374	0.017	0.917	
Ca	0.333	-0.004	0.931	
Mg	0.784	0.257	0.551	
Cl	0.780	0.062	0.486	
Sa	0.780	0.062	0.486	
SO ₄ ²⁻	0.791	0.025	0.555	
PO ₄ ²⁻	0.367	0.025	0.924	
NO ₃ ²⁻	-0.935	0.003	-0.217	
Na	0.184	-0.258	0.854	
K	0.657	-0.158	0.697	
% age of variance explained by component	74.444	9.841	9.077	
Cumulative % age of variance	74.444	84.286	93.363	

Table 5: Component wise loadings of dataset

Component Wise Loadings						
Chemical Variables	First Component		Second Component		Third Component	
	Positive	Negative	Positive	Negative	Positive	Negative
Temperature	-	-	Low	-	Moderate	-
pH	Moderate	-	Low	-	High	-
DO	-	High	Low	-	-	Low
TS	Low	-	-	Moderate	Moderate	-
TSS	-	Low	-	High	-	Low
TDS	Low	-	Low	-	High	-
Free CO ₂	-	High	-	Low	-	Low
TA	High	-	-	Low	Moderate	-
HCO ₃ ⁻	High	-	-	Low	Moderate	-
TH	Low	-	Low	-	High	-
Ca	Low	-	-	Low	High	-
Mg	High	-	Low	-	Moderate	-
Cl	High	-	Low	-	Moderate	-
Sa	High	-	Low	-	Moderate	-
SO ₄ ²⁻	High	-	Low	-	Moderate	-
PO ₄ ²⁻	Low	-	Low	-	High	-
NO ₃ ²⁻	-	High	Low	-	-	Low
Na	-	-	-	Low	High	-
K	Moderate	-	-	Low	Moderate	-

* >0.75: High loading, 0.5-0.75: Moderate loading, <0.5: Low loading²¹

Conclusion

Water of GPH lentic ecosystem is dominated with NaHCO₃⁻ ions. The scatter plots, ionic signatures and statistical analyses (Correlation Matrix, ANOVA, PCA) strongly indicates that the first component is mostly driven by high rate of weathering of Feldspar and Ferro-magnesium minerals, precarious anthropogenic sources (domestic wastes and rustic sewage) and immense ion exchange. Surface water of GPH can be categorized as hardness from temporary sources. Low SAR indicates that the water can be used for irrigation purpose too for revival of adjacent agricultural ecosystems for upliftment of livelihood patterns of indigenous inhabitants. The present study suggests that assemblage of significant physic-chemical variables determine and evaluate the status of water quality, which is an indication of inclined degree of pollution resultant from unrestrained sources of

physical, chemical and biological pollutants sourced through anthropogenic sectors. Analysing the surface water quality is an obligatory propaganda for sustainable development and economy growth through managerial planning by implementing sectoral remedial measures to mitigate the adverse effects of poor water quality on human health as well as biotic community prevailed therein. Thus, a strong light should be thrown along with some strict and mandatory actions to conserve, manage and protect such natural assets to prolong the sacredness of a particular site. Management should also prohibit the access and use of such areas of regional importance by traditional communities. Conservation agencies, Government departments and local working groups (NGOs) should receive the support from local inhabitants to work in unison manners to challenge the threats affecting the cultural resources of such sacred natural wetlands.

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