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PRELIMINARY ASSESSMENT OF SURFACE WATER QUALITY OF TROPICAL PILGRIMAGE WETLAND OF CENTRAL GUJARAT, INDIA

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Abstract

The present paper highlights the preliminary investigation of physico-chemical characteristics of tropical pilgrimage wetland *viz*. Dakor Sacred Wetland (DSW), Anand District, Central Gujarat, India. As the existing water body is contaminated with domestic sewage influenced by anthropogenic interventions, an urgent need was felt to evaluate physico-chemical parameters such as Temperature, pH, Dissolved Oxygen (DO), Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Free CO_2, Phenolphthalein Alkalinity (PA), Total Alkalinity (TA), Carbonates, Bicarbonates, Total Hardness, Calcium Hardness, Magnesium Hardness, Chloride, Salinity, Sulphate, Phosphate, Nitrate, Sodium, and Potassium. The obtained data were correlated statistically to draw a conclusion about the surface water quality of tropical pilgrimage wetland. Moreover, the results manifested the need and prime necessity to restore the physical, chemical and biological integrity with viable and rigorous restoration and management strategies in order to maintain, preserve, conserve and to avert the ecological imbalance and disturbance in hydro-geo-chemical and hydro-biological cycles, which adversely affect the food chain and food web of the significant pond ecosystem.

Key Words: Tropical pilgrimage wetland, Dakor sacred wetland, surface water quality, physico-chemical properties, conservation and management strategies

Introduction

Wetlands are accredited as ecosystems harbouring high biological diversity; providing various beneficial and valuable assets for millions of people, but face incredible intimidation as a result of anthropogenic activities throughout the world **(Gopal and Chauhan, 2001)**. Wetlands receive surface water inputs from streams (surface run-off), precipitation, and overland flow and subsurface water inputs from surface infiltration, stream hyporheic zones, and ground water. These different inputs are important to wetland productivity because they contain markedly different quantities of transported nutrients **(Stanley and Ward, 1997)** and organic matter **(Mann and Wetzel, 1995).** Freshwater wetlands (lakes, *jheels*, ponds, etc.), have a variety of linkages for energy and nutrient exchange with surrounding watersheds and air-sheds **(Patra *et al.,* 2010).**The inland freshwater ecosystems are being increasingly subjected to greater stress from various human activities **(Wood and Gibson, 1974; Hemasundaram, 2003).** The physical and chemical properties of freshwater bodies are greatly impacted and characterized by climatic, geochemical, geo-morphological and pollution conditions ofsurface water quality **(Sahni and Yadav, 2012).** Scanty literature is available on trophic and pollution status of wetlands of India. Few studies were carried out on limnological aspects of certain freshwater bodies (**Naganandini and Hosmani, 1998; Pandey *et. al*., 2000; Patil** and **Tijare, 2001; Gupta** and **Shukla, 2006; Maitera *et al.*, 2011; Rakh *et al.*, 2011; Shah *et al.*, 2011; Yadav *et al.*, 2011). Nirmal Kumar (1990, 1991, 1992),** and **Nirmal Kumar** and **Rana (1989, 1994)** had meagrely studied the seasonal variations of physico-chemical properties of water, sediments, plankton, macrophytes diversity, productivity and density of static water. **Nirmal Kumar *et al*. (1991), Rana** and **Nirmal Kumar (1992), Nirmal Kumar** and **Rana (1994**), **Rana *et al*. (1995)** and **Nirmal Kumar *et al*. (2002, 2005, 2008)** have investigated different degrees of anthropogenic pressures in selected freshwater wetlands of Gujarat.

In past, biotic components *viz.* occurrence of phytoplankton, zooplankton and diversity of aquatic macrophytes at Dakor Sacred Wetland (DSW) were investigated **(Soni** and **Thomas, 2013a; Soni** and **Thomas, 2013c; Soni *et al*., 2013, *in press*)**, but less attention was paid on status of surface water quality for the aforesaid study site. The present paper delineates the preliminary assessment of surface water quality alongwith the anthropogenic pollution loads at Dakor Sacred Wetland (DSW). Besides, site-specific conservation and management strategies have also been elucidated to draw-out the eutrophication status and effects of anthropogenic inputs in the freshwater inland ecosystem.

Materials and Methods

Study Area

Dakor Sacred Wetland (DSW)

Dakor Sacred Wetland (DSW), District Anand, Central Gujarat, India, is the hot-spot tropical pilgrimage wetland, located at 22.75^0 N latitude and 73.15^0 E longitude, with an average elevation of 49 meters (~160 feet) above mean sea level; temperature ranges from lowest 12 ^{0}C (Winter) to highest 34 ^{0}C (Summer) **(World Weather Online, 2008)**.According to 2001 census, the human population of Dakor pilgrimage spot is around 23,784 with an average literacy rate of 76%. More than 70-80 lakhs devotees visit this sacred shrine annually **(Census Commission of India, 2004).** The study area is adjacent to one of the most worshiped temple of Deity Lord Krishna, and has also become the source of attraction for the people not only from India but from every corners of the world **(Figure 1).**

Figure 1. Holistic View of Dakor Sacred Wetland (DSW), Central Gujarat, India

Surface Water Sampling

Prior to selection of the study sites, the entire study area was inspected with vigilant observations aided either by walk or a canoe. After selecting the permanent sampling stations, the surface water samples were collected systematically from the sampling sites. The surface water samples were collected on monthly interval for a time period of nine months (December 2012 to August 2013). The collected surface water samples were stored in pre-cleaned two liter plastic bottles, and brought to the laboratory with precautions for further analysis. The samples were then filtered using 0.45 micron millipore filter and preserved **(Trivedy and Goel, 1986; Maiti, 2003; Gupta, 2004; APHA, 2012)**. The physico-chemical parameters such as temperature,pH, Acidity, Dissolved Oxygen (DO), Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS),Free CO_2, Phenolphthalein Alkalinity (PA), Total Alkalinity (TA), Carbonates, Bicarbonates, Total Hardness, Calcium Hardness, Magnesium Hardness, Chloride, Salinity, Sulphate, Phosphate, Nitrate, Sodium and Potassium were analyzed, following standard protocols as mentioned above**.** Of the aforesaid physico-chemical parameters, temperature, pH and DO were recorded on-site, whereas rest of the parameters were analyzed in laboratory using standard literatures.

Results and discussion

Physico-Chemical Parameters

Temperature

Water temperature is of enormous significance as it regulates various abiotic characteristics and biotic activities of an aquatic ecosystem recognized by many researchers **(Kataria *et al*., 1995; Iqbal and Kataria, 1995; Sharma and Sarang, 2004; Radhika *et al*., 2004).** It also symbolizes the dynamics of living organisms such as metabolic and physiological behaviour of aquatic habitat (**Sahni and Yadav, 2012)**. Temperature, therefore, has a direct effect on important factors such as growth, oxygen demand, food requirements and food conversion efficiency of the various biotic communities prevailing therein. The higher the temperature, the greater the requirement of oxygen and food, and the faster is the growth rate **(Boyd, 1990, 1998)**. During the present investigation, minimal variation was observed in surface water of DSW for all the study sites. The maximum temperature (33 ^{0}C) was noted in surface water of all the study sites during the peak summer season. Similar trend was observed by **Kumar *et al.* (2010)** in surface water of Sabarmati River and Kharicat canal, Ahmedabad, whereas minimum value (19 ^{0}C) was observed in peak winter at D2. The findings are well-substantiated with **Surana *et al*. (2010)** for Chimdi Lake, Nepal.

pH

pH of a water is controlled by relative quantity of bicarbonates and CO_2.It is also a causative factor influencing the biological activity of aquatic microflora. The principal component regulating pH in natural waters is the carbonate (**Zafar, 1966)**, comprises CO_2, H_2CO_3, and $HCO3^-$ **(APHA, 2012)**. Low values in pH are indicative at high acidity, which can be caused by the deposition of acid-forming substances in precipitation. A high organic content will tend to decrease the pH because of the carbonate chemistry **(Fella *et al*., 2013).** During the current research work, mere fluctuation was recorded in surface water of DSW at all the sampling sites. Highest value (8.95) of pH was observed in surface water of D3 in the month of May. Similar results were observed by **Sahni and Yadav (2012)** at Bharawas Pond, Rewari, Haryana. **Wani and Subla (1990)** reported that the pH value above 8 in aquatic body is produced by photosynthetic rate that demands more CO_2 than quantities furnished by respiration and decomposition, whereas minimum value (7.85) was observed in September at D3. Similar results were obtained by **Uzma *et al*. (2012)** in surface water of LalDiggi Pond, Aligarh.

Acidity

Peakconcentration of acidity (184 mg/L) was observed in the month of December at D1, whereas lowvalue (24 mg/L) was recorded in March at D3.The maximum and the minimum values at site D1, D2 and D3 were 20-168 mg/L, 32- 284 mg/L, 24-160 mg/L, respectively.

Dissolved Oxygen

Dissolved Oxygen (DO) is an important parameter of aquatic systems, which is essential to aerobic metabolism of all aquatic organisms **(Wetzel, 1975)**. Dissolved oxygen concentration more than 5.00 mg/L favours good growth of flora and fauna **(Das, 2000**). It is one of the most important factors of the water quality, directly affecting survival and distribution of flora and fauna in an ecosystem **(Sahni and Yadav, 2012)**. Higher amount of DO (7.04 mg/L) was observed in the month of December at D1. Similar record was noted by **(Kiran, 2010)** for Bhadra Project, Karnataka, whereas lower value (1.21 mg/L) was recorded in February at D1. Low value of DO can be attributed by low population of planktons (**Soni and Thomas, 2013a, 2013b)**, and partly due to increased respiration. Changes in dissolved oxygen concentration at surface water are directly related to the changes in phytoplankton number **(Khan and Siddiqui, 1974)**.

Solids

The values of Total Dissolved Solids (TDS) in surface water of D1, D2 and D3 were 100-300 mg/L, 200-400 mg/L and 200-600 mg/L, respectively. Of which, the maximum total dissolved solids (600 mg/L) was recorded at D3 during hot scorching days.Similar trend was observed by **Narayan *et al*. (2007)** and **Jemi** and **Balasingh (2011)**, while it was found minimum (100 mg/L) at D1during colder months. The contents of Total Solids (TS) in surface water at sampling stations (D1, D2 and D3) were 600-1600 mg/L, 800-1400 mg/L and 800-1200 mg/L, respectively, with highest concentration (1600 mg/L) recorded at D1 during winter season, while least (600 mg/L) at D1 during summer season. According to **Trivedi *et al*. (1987)**, total solids in the most of the waters are organic in nature, which may pose serious problems of aquatic pollution. Total Suspended Solids (TSS) in surface waters at study sites (D1, D2 and D3) were 350-1400 mg/L, 400-1000 mg/L and 400-1000 mg/L, respectively, with high content (1400 mg/L) at D1 during winter, while low (350 mg/L) at D1 during summer season.

Free CO_2

Free CO_2 in water body is generally reported when the oxygen remains negligible or absent, mainly due to decomposition of organic matter by microbes in bottom, resulting in rapid production of free carbon dioxide **(Welch, 1952; Antwi** and **Danson, 1993).** Throughout the study period, the average concentration of Free CO_2 was observed maximum (35.20 mg/L) at D1 and minimum (17.60 mg/L) at D2. The absence or presence of free carbon dioxide in surface water is mostly governed by its utilization by algae and also through its diffusion of air **(Srivastav *et al.*, 2003).**

Phenolphthalein Alkalinity

Alkalinity denotes the buffering capacity of water and its ability to resist a change in pH and is the overall measure of the substance in water that has ‘acid-neutralizing ability’. Excessive alkalinity may cause eye irritation in humans and chlorosis in plants **(Sandhya *et al*., 2012).** Surface water with alkalinity less than 200 mg/L is potentially sensitive to heavy acid deposition. Alkalinity itself is not harmful to human beings; static water supplied with less than 100 mg/L of alkalinity is desirable for domestic purpose. Water has a pH greater than 8.3 is said to have ‘phenolphthalein alkalinity’, which is primarily due to the presence of carbonate or hydroxide ions. The desirable level of total alkalinity for drinking water should be below 200 ppm **(ISI, 1991).** In the present study, phenolphthalein alkalinity for all sampling sites ranged between 20-34 mg/L, 8-32 mg/L and 10-36 mg/L (D1, D2 and D3), respectively. Of which, maximum phenolphthalein alkalinity concentration was observed at D3 (36 mg/L) during summer season, and minimum (8 mg/L) was noted at D2 during winter season **(Soni, 2007)**.

Total Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids. Alkaline compounds in the water such as bicarbonates, carbonates, and hydroxides, remove H^+ ions and lower the acidity of water (which means increased pH), usually when combined with H^+ ions to make a new compound **(Godfrey, 1988)**. In absence of a new compound, acid-neutralizing capacity would cause an immediate change in pH. Measuring alkalinity is important in determining acidic pollution of aquatic ecosystem from rainfall or wastewater, and is the best measure to analyse the sensitivity of the watercourse to acid inputs (**River Watch Network, 1992; EPA, 2012**). The carbonates and bicarbonates are the major components of alkalinity of surface water **(Muhammad *et al*., 2000).** Total alkalinity is measured by measuring the amount of acid (e.g. sulphuric acid) needed to bring the sample to a pH of 4.2. At this pH, all the alkaline compounds in the sample are 'used up'. The values of TA in surface water at sampling stations (D1, D2 and D3) were 101-300 mg/L, 107-284 mg/L and 104-228 mg/L, respectively. Of which, the maximum total alkalinity concentration (300 mg/L) was recorded at D1 during summer season, while minimum (101 mg/L) was noted at D1 during winter season. Identical drift was observed by **Sahni and Yadav (2012)** in Bharswada Pond, Haryana, **Garg *et al*. (2006, 2009)** in Harsi and Ramsagar Reservoirs, **Verma *et al.*(2012)** in Chandola Lake, Eastern Ahmedabad.

Carbonates

Whenever pH touches 8.3, the presence of carbonates is indicated. It is measured by titration with standardized hydrochloric acid using phenolphthalein as an indicator. Below pH 8.3, the carbonates are converted into equivalent amount of bicarbonates. The titration can also be done pH metrically or potentiometrically **(Patil *et al*., 2012)**. The mean carbonate values for surface water at study stations (D1, D2 and D3) were 24-40.8 mg/L, 9.6-128 mg/L and 12-43.20 mg/L, respectively. Of which, maximum concentration was estimated at D2 (128 mg/L) during summer season, and minimum (9.60 mg/L) was noted at D2 during winter months. Same tendency was observed by **Sahni and Yadav (2012)** in Bharswada Pond, Haryana, **Garg *et al*. (2006, 2009)** in Harsi and Ramsagar Reservoirs, and **Verma *et al.* (2012)** in Chandola Lake, Karnavati.

Bicarbonates

It is measured by titration with standardized hydrochloric acid using methyl orange as an indicator. Methyl orange turns yellow below pH 4.0. At this pH, the carbonic acid decomposes produce carbon dioxide and water **(Patil *et al*., 2012).** The highest and the lowest values of bicarbonates of surface water for all study stations (D1, D2 and D3) were 34.16-190.32 mg/L, 48.80-204.96 mg/L and 78.08-200.08 mg/L, respectively. Of which, maximum concentration (204.96 mg/L) at D2 during pre-monsoon period, and minimum (34.16 mg/L) was noted at D1 during post winter phase.

Total Hardness

High amount (590 mg/L) of total hardness was observed in the month of January at D3, whereas low value (116 mg/L) was recorded in March at D2. The resultant impact could be due to higher rate of precipitation of water during summer season intermingled by shrinkage of hydrological regime of the water body **(Niroula *et al.*, 2010)**.

Calcium Hardness

Calcium and magnesium play an important role in antagonizing the toxic effects of various ions in neutralizing excess acid produced **(Munawar, 1970).** Calcium is found in greater abundance in all natural waters as its main source is weathering of rocks in the form of leachate **(Jemi** and **Balasingh *et al*., 2011)**. In aquatic environment, calcium serves as one of the vital micronutrients for most of the organisms. The low and the high values of calcium hardness of surface water at D1, D2 and D3 were 84-361 mg/L, 63-384 mg/L and 73.59-357 mg/L, respectively. Of which,the high content (384 mg/L) was reported at D2 during winter, and minimum (63 mg/L) was noted at D2 during hot summer days. These fluctuations may be due high amount of dissolved organic matter **(Tucker, 1958)**.

Magnesium Hardness

Magnesium is usually found to be associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium **(Venkatasubramani and Meenambal, 2007)**. Magnesium is essential for chlorophyll growth,which acts as a limiting factor for the considerable growth of phytoplankton **(Dagaonkar and Saksena, 1992)**. The lowest and the highest contents of magnesium hardness in surface water of all study stations (D1, D2 and D3) were 6.52-22.30 mg/L, 5.07-23.53 mg/L and 5.65-25.35 mg/L, respectively. Of which, the peak gradient (25.35 mg/L) was observed at D3 during winter, and low content (5.07 mg/L) was recorded at D2 during summer days. Similar trend was also investigated by **Prasath *et al*. (2013)**. High concentration of magnesium might be due to seepage of anthropogenic or domestic waste, or might be owing to cationic exchange with Na^+.

However, low value of magnesium hardness does not impacted by pollution, but might be due to reverse cationic exchange with Na^+ **(Thompson *et al.*, 1999)**

Chloride

Chloride is one of the important indicators of pollution **(Pathak *et al.*, 2012)**. The major anthropogenic sources of chloride in surface waters are deicing salt, urban and agricultural run-off, and discharges from municipal wastewater plants, industrial plants, and the drilling of oil and gas wells (**Dickman and Gochnauer 1978; Sonzogni *et al*., 1983; Birge *et al*., 1985**). The fluctuating contents of chloride in surface water of D1, D2 and D3 were 66.65- 95.01 mg/L, 73.74-87.92 mg/L and 70.91-104.94 mg/L, respectively. Of which, elevated concentration (104.94 mg/L) was documented at D3 during summer, and depleted content (66.65 mg/L) was determined at D1 during winter. The present investigation is very well-corroborated with the findings of **Sahu *et al.* (2007)**. Higher chloride amount may be due to increased temperature, moderate depth of water and sewage mixing. Lower concentration of the same was observed in winter, as observed by **(Sahni and Yadav, 2012)**.

Salinity

Salinity refers to total concentration of all ions in water. The minimum and maximum contents of salinity in surface water of all study stations (D1, D2 and D3) were 120.41-171.65 mg/L, 133.22-158.84 mg/L and 128.10-189.59 mg/L, respectively. Of which, the peak value (189.59 mg/L) was observed at D3 during colder days, and negligible amount (120.41 mg/L) was reported at D1 during pre-winter phase, as reported by **(Sahni and Yadav, 2012)**. The fluctuation in salinity is probably due to fluctuation in total solids in conformity to the dispersed distribution of salts in the water **(Salam *et. al*., 2000)**.

Nutrients (*Phosphate, Sulphate, Nitrate)*

All organisms require nitrogen for the basic process of life to synthesize protein for growth and reproduction. The presence of nitrates in the water is suggestive of some bacterial actions and growth **(Majumder *et. al.*, 2006).** The main cause of nitrate is agricultural run-off and decomposition of organic matter. The elevated inflow of water and resultant land drainage cause steep rise in nitrate content in pond water **(Hemant, 2012)**. During the study period, nitrate concentration was high (47.06 mg/L) at D1 during winter months, while it was low (5.48 mg/L) in April at D2. This could be due to voluminous rainfall, sedge grass dormancy, and impeded microbial and bacterial activities **(Balogh *et al*., 2006)**.

Phosphate is an important nutrient maintaining the fertility of water body (**Sahni and Yadav, 2012)**.The low and the high values of phosphate in water of all study sites (D1, D2 and D3) were 0.08-3.28 mg/L, 0.08-3.53 mg/L and 0.12- 4.88 mg/L, respectively. Of which, the utmost concentration (4.88 mg/L) was estimated at D3 during summer, and lower amount (0.08 mg/L) was noted at D1 and D2 during winter season. Elevated concentration of phosphates during dry season may be due to low level of water and high rate of evaporation **(Kamal *et al.,* 2007)**. **Sahni and Yadav (2012)** had observed similar findings in waters of Mouri River and Bharaswas Pond.

The lowest and the highest contents of sulphate in surface water of all sampling stations (D1, D2 and D3) were 6.58-14.99 mg/L, 6.51-18.17 mg/L and 5.54-19.7 mg/L, respectively. Of which,the high amount (19.97 mg/L) was recorded at D3 during post-summer, and low content (5.54 mg/L) was noted at D3 during winter season. Sulphate content of surface water of DSW showed steep rise in winter months. Similar trend was observed by **Tucker (1958)**. Peak increase of sulphate in winter, and its sudden drop in monsoon could be due to the fact that the sulphates of water are derived from sulphides produced during organic decay in the bottom deposits, by oxidation in winter and in early spring, and that a proportion of sulphates are reduced when the pond becomes anaerobic in summer **(Mann, 1958; Schmidt *et al.,* 1991)**.

Sodium

Sodium is a monovalent cation, commonly present in water. This ion does not produce hardness to water. However, significantamountof sodium ion in water may cause alteration in its taste; as well it may make the water unsuitable for irrigation purposes. Sodium plays a significant role in human body. It relates to functions of nervous system, membrane system, and excretory system **(Hamaidi *et al*., 2013).** In surface waters of D1, D2 and D3, the contents of sodium were ranged from 56.76-68.92 mg/L, 52.70-72.97 mg/L and 54.73-70.95 mg/L, respectively. Of which,the maximum concentration (72.97 mg/L) was estimated at D2 during post-summer, and minimum (52.70 mg/L) at site D2 during post-winter season. At DSW, the sodium concentration was found within the permissible limit (100 mg/L) **(WHO, 2006).**

Potassium

The minimum and the maximum values of potassium at all study sites (D1, D2 and D3) ranged from 3.95-11.84 mg/L, 3.95-7.89 mg/L and 3.95-11.84 mg/L, respectively. Of which, highest amount (11.84 mg/L) was noted at D1 and D3 during rainy days, and minimum (3.95 mg/L) was observed at all the study sites during post-winter phase. As per **WHO (2006)**, the potassium concentration in waters of DSW was within the permissible range (10 mg/L) **(Table 1, Figures 2, 3, 4)**.

Table 1. Comparative Account of Different Physico-Chemical Parameters at DSW

Parameters	D1	D2	D3	Mean
Temperature	30.64	30.25	30.16	30.35
pH	8.54	8.54	8.52	8.53
Acidity	64.60	75.20	77.40	72.40
DO	4.28	4.66	4.58	4.51
TS	955.00	975.00	943.20	957.73
TSS	741.00	692.00	637.20	690.07
TDS	214.00	283.00	306.00	267.67
Free CO2	35.20	26.40	17.60	26.40
PA	27.40	23.90	25.20	25.50
TA	161.60	163.00	159.60	161.40
Carbonate	32.88	37.64	30.24	33.59
Bicarbonate	130.30	140.54	133.22	134.69
TH	322.20	301.20	301.40	308.27
Ca	185.01	146.79	138.18	156.66
Mg	13.96	13.35	13.46	13.59
Chloride	82.96	80.69	84.09	82.58
Salinity	149.88	145.78	151.93	149.19
Sulphate	13.45	14.06	13.69	13.73
Phosphate	1.28	1.06	1.70	1.35
Nitrate	30.21	25.54	22.64	26.13
Sodium	61.05	59.31	60.32	60.23
Potassium	6.47	5.68	6.47	6.21

**Values are expressed in mg/L. except Temperature and pH*

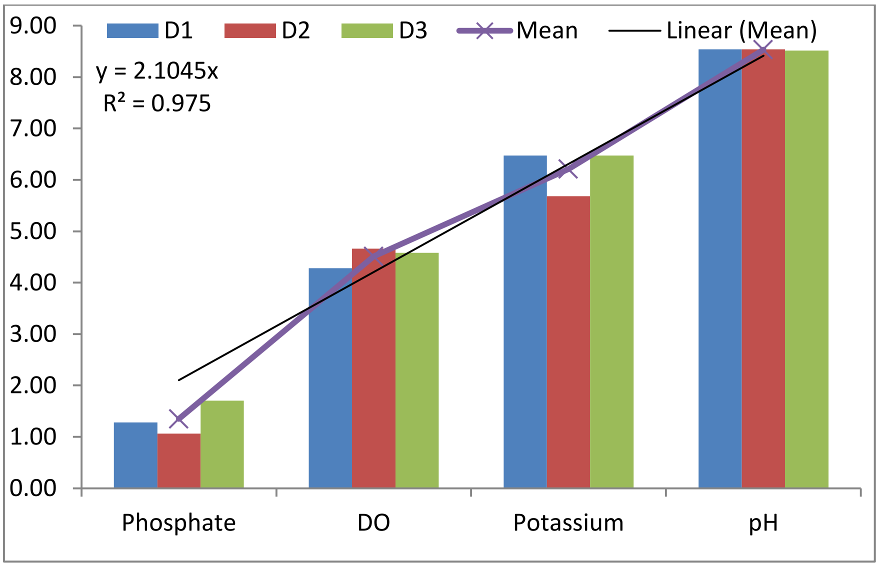

Figure 2

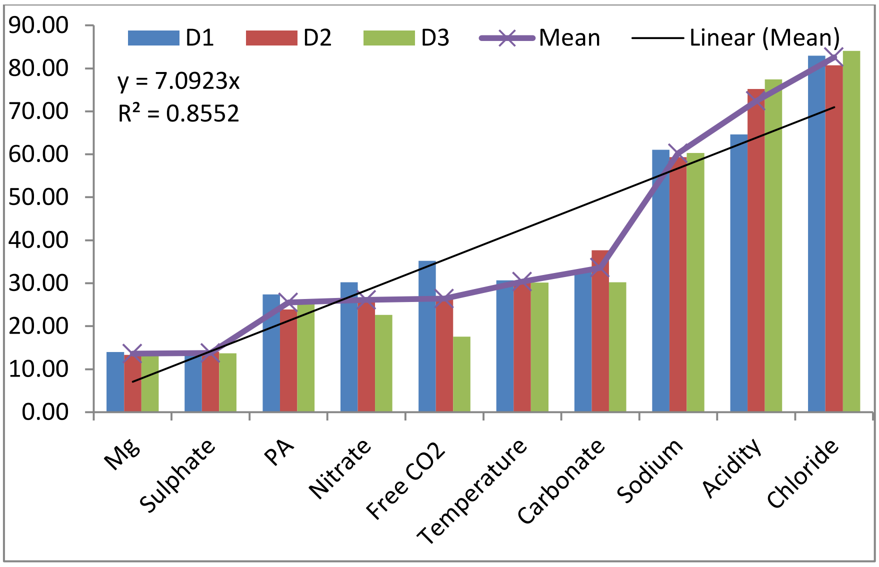

Figure 3

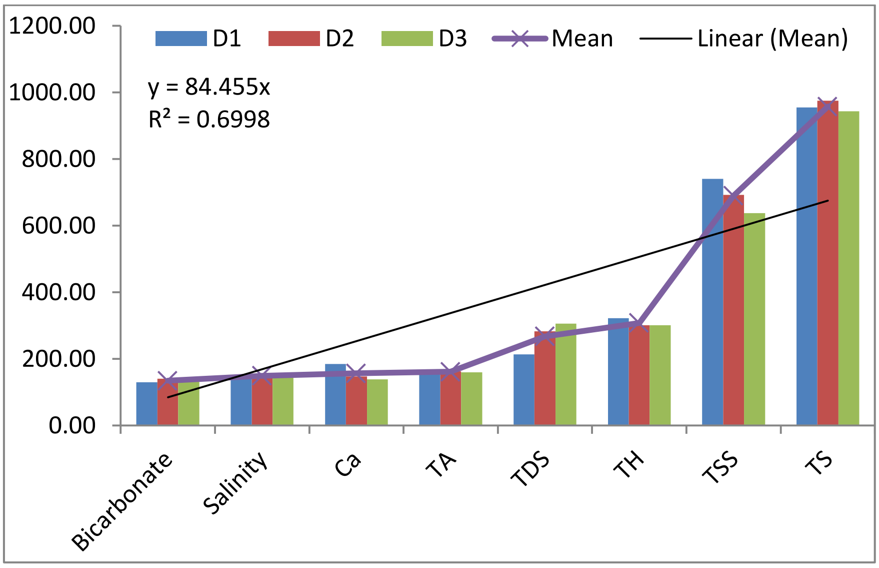

Figure 4

Figures 2, 3, 4. Graphical Representation of Physico-Chemical Parameters at DSW

Correlation Approach

Correlation studies between different variables are very helpful tool in promoting research and opening new frontiers of knowledge. The study of statistical correlation decreases the chance of ambiguity associated with decision making **(Mahanada *et al*., 2010).** The correlation coefficient (r) among various physico-chemical parameters for surface water was calculated for the studied pilgrimage wetland (DSW). Temperature showed positive correlation with acidity, total dissolved solids, bicarbonate, total hardness, chloride, phosphate, highly affected by calcium hardness (r=0.931). On the contrary, pH exhibited the negative correlation with almost all the parameters except total hardness (r=0.935). Positive correlation was also depicted between acidity with parameters such as total solids, total dissolved solids, total alkalinity, bicarbonate, calcium hardness, salinity, and nitrate. Acidity showed the highest correlation with chloride (r=0.945). Moreover, dissolved oxygen exhibited positive correlation with sulphate (r=0.939) except bicarbonate, total hardness, calcium hardness, chloride and phosphate. Total solids were found to be positively correlated maximally by Nitrate (0.987), whereas total suspended solids and total dissolved solids were almost positively correlated by allthe parameters but highest by Magnesium (0.993) and Bicarbonate (0.933) respectively. Free CO_2 was found to be positively correlated with all the parameters except bicarbonate, salinity, sulphate and phosphate. Except total hardness, magnesium and phosphate, total alkalinity was positively correlated with all the parameters, with highest correlation with salinity (r=1.000). Salinity and sulphate was positively correlated with rest of the parameters except phosphate. Nitrate showed positive correlation with sodium, whereas phosphate was negatively correlated with all the parameters (**Table 2)**.

Table 2. Correlation Coefficient (r) of Physico-Chemical Parameters of Surface Water (DSW)

PARAMETERS	Temperature	pH	Acidity	DO	TS	TSS	TDS	Free CO2	PA	TA	Carbonate	Bicarbonate	TH	Ca	Mg	Chloride	Salinity	Sulphate	Phosphate	Nitrate	Sodium	Potassium
Temperature	1.000																					
pH	-0.017	1.000																				
Acidity	0.760	-0.663	1.000																			
DO	-0.964	-0.248	-0.561	1.000																		
TS	-0.012	-1.000	0.640	0.277	1.000																	
TSS	-0.449	0.901	-0.922	0.196	-0.888	1.000																
TDS	0.191	-0.985	0.783	0.075	0.979	-0.963	1.000															
Free CO2	-0.542	-0.831	0.134	0.745	0.847	-0.508	0.721	1.000														
PA	-0.650	-0.749	0.000	0.828	0.768	-0.388	0.622	0.622	1.000													
TA	-0.353	-0.929	0.339	0.588	0.940	-0.678	0.851	0.585	0.941	1.000												
Carbonate	-0.940	0.357	-0.936	0.816	-0.329	0.726	-0.514	0.352	0.352	0.013	1.000											
Bicarbonate	0.420	-0.915	0.909	-0.165	0.902	-1.000	0.971	-0.277	0.417	0.701	-0.910	1.000										
TH	0.338	0.935	-0.354	-0.575	-0.945	0.689	-0.859	0.862	-0.935	-1.000	0.357	-0.712	1.000									
Ca	0.931	-0.381	0.945	-0.801	0.354	-0.744	0.537	0.939	-0.327	0.013	-0.944	0.723	-0.973	1.000								
Mg	-0.550	0.845	-0.961	0.309	-0.828	0.993	-0.925	0.768	-0.277	-0.587	0.962	-0.989	0.662	-0.817	1.000							
Chloride	0.931	-0.381	0.945	-0.801	0.354	-0.744	0.537	0.354	-0.327	0.013	-0.944	0.723	-0.973	1.000	-0.817	1.000						
Salinity	-0.350	-0.931	0.343	0.585	0.941	-0.680	0.853	-0.327	0.939	1.000	-0.346	0.703	0.215	0.017	-0.590	0.017	1.000					
Sulphate	-0.997	0.099	-0.811	0.939	-0.070	0.520	-0.271	-0.388	0.585	0.275	0.809	-0.493	0.998	-0.958	0.617	-0.958	0.272	1.000				
Phosphate	0.413	0.903	-0.277	-0.640	-0.916	0.628	-0.815	-0.650	-0.961	-0.998	0.280	-0.652	-0.282	0.052	0.533	0.052	-0.998	-0.337	1.000			
Nitrate	-0.174	-0.981	0.507	0.429	0.987	-0.802	0.933	0.991	0.862	0.983	-0.510	0.820	0.035	0.197	-0.726	0.197	0.984	0.093	-0.969	1.000		
Sodium	-0.674	-0.727	-0.032	0.845	0.747	-0.358	0.596	0.417	0.999	0.929	0.029	0.387	0.564	-0.358	-0.246	-0.358	0.928	0.611	-0.951	0.845	1.000	
Potassium	-0.946	0.342	-0.930	0.826	-0.314	0.715	-0.500	0.000	0.367	0.030	0.929	-0.693	0.982	-0.999	0.792	-0.999	0.026	0.969	-0.095	-0.155	0.397	1.000

The findings of the present study revealed that among all the study sites of DSW, D3 was found to be less polluted, followed by moderate degree of pollution at D2, whereas D1 was intensely polluted by anthropogenic pollution loads from point and non-point sources. These observations in terms of anthropogenic wastes could be remarked as draw-out conclusions for the studied pilgrimage wetland to determine the degree of aquatic pollution therein, which may be due to on-loads and off-loads of metals from identified (predominant aquatic macrophytes) and unidentified anthropogenic sources **(Nirmal Kumar *et al*., 2008)**, domestic wastes, temple wastes by devotees, improper drainage pattern of the area, uncontrolled agricultural run-off, as well as intensification of obnoxious nutrients dispersed erratically in waters probably due to ferry services and other unidentified causative factors **(Table 3)**.

Table 3.Descriptive Statistics of Physico-Chemical variables at DSW

Descriptive Statistics	D1	D2	D3	DSW
Mean	147.12	146.69	143.15	146.85
Standard Error	52.08	51.72	49.56	50.90
Median	46.97	48.48	45.28	46.91
Standard Deviation	244.29	242.58	232.47	238.74
Sample Variance	59679.88	58845.67	54043.05	56996.81
Kurtosis	6.40	6.84	6.81	6.74
Skewness	2.57	2.60	2.57	2.59
Range	955.00	975.00	943.20	956.38
Minimum	0.00	0.00	0.00	1.35
Maximum	955.00	975.00	943.20	957.73
Sum	3236.72	3227.21	3149.22	3230.78
Count	22.00	22.00	22.00	22.00
Largest(1)	955.00	975.00	943.20	957.73
Smallest(1)	0.00	0.00	0.00	1.35
Confidence Level (95%)	108.31	107.55	103.07	105.85

Conservation and Management Strategies

Unfortunately, in recent time many sacred natural sites including rustic wetlands are facing threats, as they are subjected to a wide range of anthropogenic pressures by external and internal sources, such as illegal destruction and exploitation of natural habitats. The intervening factors also include adverse impacts from vicinity areas, encroachment by outsiders, disrespectful tourism, wetland-dependant communities, degradation of neighboring environments, reduction of the availability of lands, and depleting resources for tribal peoples. Sometimes, such important wetlands have also been inadvertently integrated in legally declared protected areas by governments, without recognition of the local community values and of the traditional beliefs, practices, skills and knowledge that have sustained the associated locations, cultures and resources therein. Thus, a strong light should be thrown alongwith 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. Certain conservation agencies and local traditional groups should receive the support to work in unison manners to challenge the threats affecting the cultural resources of such sacred natural wetlands. Such agencies should also recognize the cultural and spiritual dimensions inclusive of their designated boundaries, and recognize the rights and interests of the communities to continue its utilization to maintain their cultural and spiritual realizations and reverences. National and international organizations should also identify the potential skills and knowledge that local and indigenous communities have in managing such natural resources and areas associated with sacred natural sites. Furthermore, the effective action in support of the preservation and effective management of sacred natural wetlands will have a large impact on enhancing the biodiversity conservation, as well as the long-term vitality of the cultures that have cared for them.

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