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Relationship Among the Physico-Chemical Parameters of Soil and Water in Different Wetland Ecosystems

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The quality of life in water bodies depends on their physico-chemical properties and biodiversity. These physico-chemical properties are being disturbed by continuous addition of industrial, municipal and agricultural wastes which make them unfit for different organisms. This study describes the physico-chemical factors in soil and water of all sampled wetlands and the relationship among them in wetland ecosystem. All these analysis were done by using analytical techniques as described by standard methods for examination of water and wastewater. Physico-chemical parameters of water and soil also interlinked and correlated among each other. Sometimes these parameters work as a cycle to maintain the equilibrium in the ecosystem. Higher level of research work is needed to control the source of pollution to wetlands. By controlling the physico-chemical parameters of habitat, the diversity, density and richness of various wetland dependent species can be controlled in wetland ecosystem.

Keywords: Physico-chemical parameters, Soil, Water, Wetland ecosystem.

INTRODUCTION

Water and soil are the two most important components of ecosystem. With the development of the society, the pollution is also increasing in soil and water from various sources. The quality of life in water bodies depends on their physico-chemical properties and biodiversity [1]. Various physico-chemical properties have different sources as well as different nature. The presence of chloride found due to deposition of salt by natural or from any effluent. Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural waters. Fluoride ions have dual significant in water supplies for which it should be within the limits. Sulphate ions usually found in natural waters due to its soluble nature in water. Most of them originate from the oxidation of sulphate ores. Phosphorous occurs in various form in natural water and wastewater. Conductivity is the capacity of water to carry an electric charge by ionized substances in the water. These inorganic ionized substances contribute to conductance. The capacity of water for precipitating soap is commonly known as hardness of water. The physical, chemical and biological activities in water body decide the dissolved oxygen level in water and wastewater [2].

These physico-chemical properties are being disturbed by continuous addition of industrial, municipal and agricultural wastes which make them unfit for different organisms [3-8]. Wetlands and water-bodies provide habitat for micro to macro organisms like invertebrate, fish, bird and many more [9]. Many researchers studied and described the stress on fish growth and reproduction due to several physico-chemical and biological factors [10]. The positive correlation among the chemical, physical and biological properties of soil was well known. The physical and chemical composition of soil is influenced by the deposition of different mineral, organic matter and pollutants from different sources [11], which ultimately affects water quality. Many organisms are considered as ecological indicators but birds are most sensitive health indicators of ecological conditions of an ecosystem [12].

Wetlands are used by birds for various purposes like breeding, nesting, roosting, foraging and social interaction with other organisms. By occupying several trophic levels in nutrient cycle of wetland, aquatic birds become an important component of wetland ecosystem. Though food chain is the main link between wetland quality and ecosystem health, water bird activities are the key indicator towards it [13].

Most of the birds feed on aquatic organisms as well as on soil macro invertebrate and water dependent vertebrates. So the physico-chemical parameters of water as well as soil of wetland habitat affect the distribution and abundance of water dependent organisms [14]. These changes in physico-chemical parameters continue in corresponding food web upto secondary production levels [7]. These interactions among water, soil and biodiversity describes the complexity of wetland ecosystems [15]. This study describes the physico-chemical factors of all sampled water-bodies and the relation among physico-chemical parameters of different wetland habitats with different anthropogenic pressure.

EXPERIMENTAL

This study was performed in different environmental segments of Odisha state of India. Eight different wetlands were identified from all over the state. The sampling site selection of those eight places from different districts of Odisha was due to their different exposure to contamination and sampling suitability. The district and geographical locations of all sampling sites are listed in Table-1 (Fig. 1).

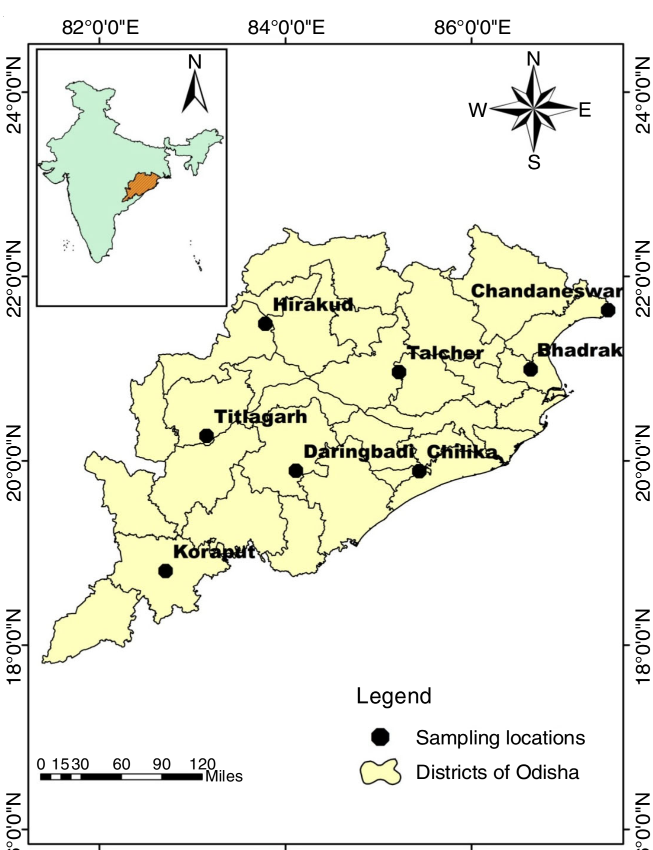

Fig. 1. Map of study area showing location of sampling sites

TABLE-1
SAMPLING LOCATIONS OF DIFFERENT DISTRICTS OF ODISHA STATE OF INDIA WITH LATITUDE AND LONGITUDE

Sampling point	Location	Latitude	Longitude	District
1	Chilika	85°26'19.55"	19°53'16.78"	Khurda
2	Hirakud	83°48'53.73"	21°28'56.03"	Bargarh
3	Bhadrak	86°38'11.24"	20°59'30.4"	Bhadrak
4	Chandaneswar	87°28'7.29"	21°38'1.03"	Balasore
5	Talcher	85°13'20.03"	20°57'43.74"	Angul
6	Daringbadi	84°6'47.91"	19°53'34.36"	Kandhamal
7	Titlagarh	83°9'10.26"	20°16'18.96"	Bolangir
8	Koraput	82°42'41.17"	18°48'16.2"	Koraput

The sampling of water was conducted thrice during the year in different seasons like pre-monsoon, monsoon and post-monsoon. The physico-chemical parameters like total hardness (TH), calcium hardness (CaH), magnesium hardness (MgH), chloride, fluoride, sulphate, alkalinity, phosphate, nitrate, pH, conductivity, oxidation reduction potential (ORP), dissolved oxygen (DO), salinity and total dissolved solid (TDS) were investigated.

Chloride concentration was estimated using argentometric method. Nitrate was investigated by phenol disulphonic acid (PDA) method. The colorimetric method (SPANDS) was used for analysis of fluoride concentration. Turbidimetric method was used for sulphate concentration analysis. Stannous chloride method was used to investigate phosphate concentration. Alkalinity of the sample was estimated by titration method. Hardness was measured by EDTA method, while Winkler′s method was used for the determination of dissolve oxygen. Other parameters like pH, ORP and salinity were estimated by electrode method.

All these analysis were done by using analytical techniques as described by standard methods for examination of water and wastewater [2] while some of them are recorded in field condition before taking the samples in tightly capped polypropylene plastic bottles to the laboratory. The statistical analysis and graphs were done with MS-EXCEL, correlation and its scatter-plot was done using corr-plot in the programme R version 3.4.4. In addition, all the data were estimated at $p < 0.05$ level of significance.

RESULTS AND DISCUSSION

Examination of water: This study describes that 15 parameters were analyzed and taken for correlation. The parameters were total hardness, calcium hardness, magnesium hardness, chloride, fluoride, sulphate, alkalinity, phosphate, nitrate, pH, conductivity, oxidation reduction potential (ORP), dissolve oxygen (DO), salinity and total dissolved solid (TDS).

The concentration comparison in every season of different location of every parameter is illustrated in Fig. 2. The mean ± SD of all parameters at each sampling site is described in Table-2. The correlations among them are shown in Table-3. The corr-plot and scatter-plot of these parameters are given in Figs. 3 and 4, respectively.

Present study revealed that the chloride concentration in water varies nearly in between seasons. It was slightly higher

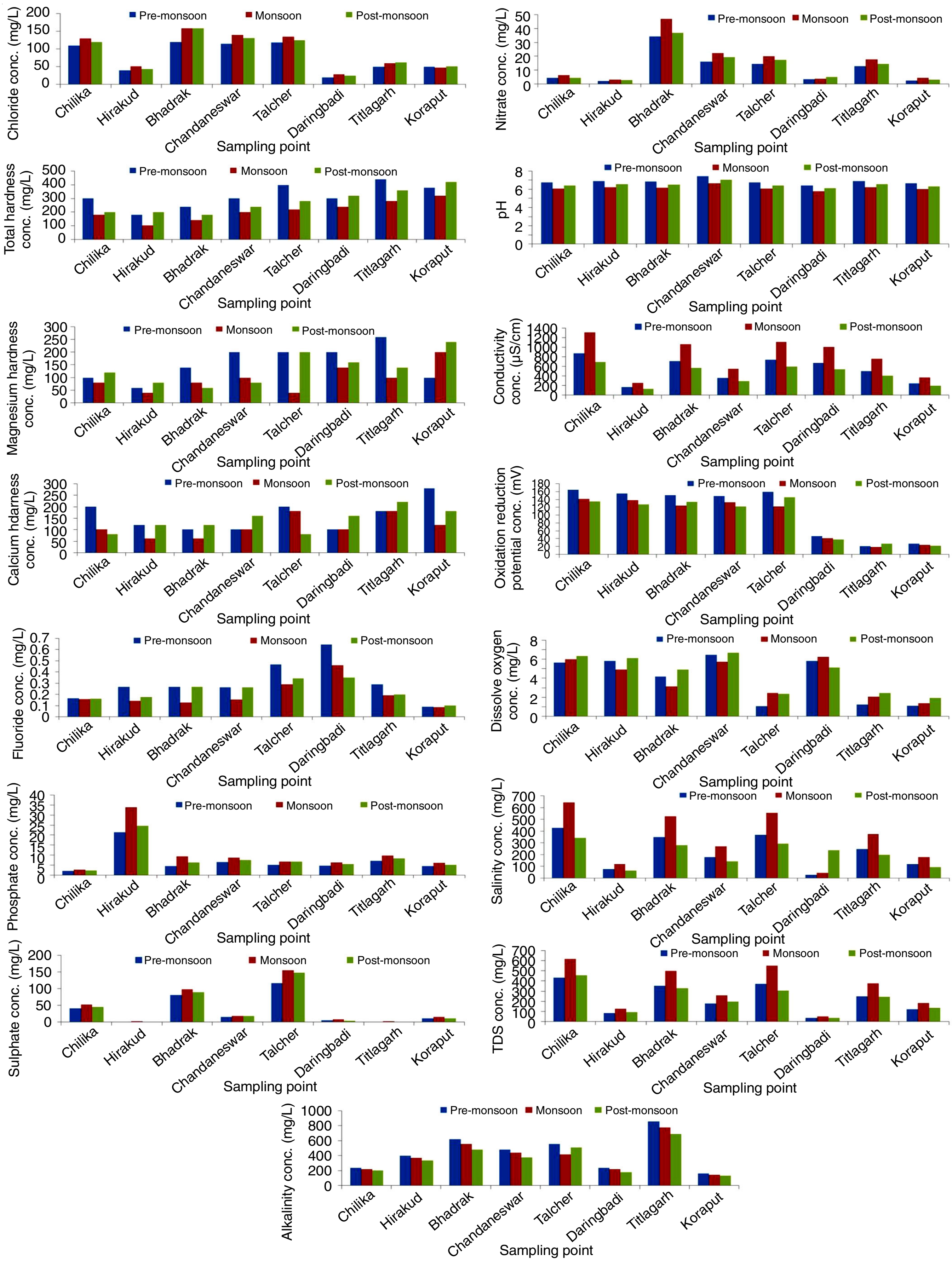

Fig. 2. Concentration of physico-chemical parameters in water of every season at each sampling site

TABLE-2
MEAN ± SD OF ALL VARIABLES OF WATER FROM ALL SAMPLING SITES

	Chilika	Hirakud	Bhadrak	Chandaneswar	Talcher	Daringbadi	Titlagarh	Koraput
Chloride (mg/L)	119.73 ± 9.80	44.87 ± 5.77	146.03 ± 22.11	128.8 ± 12.67	126.57 ± 8.17	24.3 ± 4.40	57.27 ± 6.54	49.53 ± 1.75
Total hardness $CaCO_3$ (mg/L)	226.67 ± 64.29	160.00 ± 52.92	186.67 ± 50.33	246.67 ± 50.33	300.00 ± 91.65	286.67 ± 41.63	360.00 ± 80.00	373.33 ± 50.33
Calcium hardness (mg/L)	126.67 ± 64.29	100.00 ± 34.64	93.33 ± 30.55	120.00 ± 34.64	153.33 ± 64.29	120.00 ± 34.64	193.33 ± 23.09	193.33 ± 80.83
Magnesium hardness (mg/L)	100.00 ± 20.00	60.00 ± 20.00	93.33 ± 41.63	126.67 ± 64.29	146.67 ± 92.38	166.67 ± 30.55	166.67 ± 83.27	180.00 ± 72.11
Fluoride (mg/L)	0.16 ± 0.00	0.19 ± 0.06	0.22 ± 0.08	0.23 ± 0.06	0.37 ± 0.09	0.49 ± 0.15	0.23 ± 0.06	0.09 ± 0.01
Sulphate (mg/L)	46.16 ± 5.17	1.30 ± 0.12	89.50 ± 8.14	16.76 ± 1.44	140.66 ± 20.54	5.25 ± 1.31	1.41 ± 0.22	11.90 ± 1.68
Alkalinity	221.33 ± 18.04	370.00 ± 30.00	553.33 ± 70.24	433.33 ± 50.33	496.67 ± 70.95	213.33 ± 30.55	776.67 ± 85.05	148.00 ± 12.00
Phosphate (mg/L)	2.35 ± 0.35	26.61 ± 6.48	6.72 ± 2.49	7.57 ± 1.14	6.14 ± 1.01	5.45 ± 0.82	8.33 ± 1.25	5.18 ± 0.78
Nitrate (mg/L)	4.90 ± 1.02	2.49 ± 0.41	39.51 ± 6.75	19.22 ± 3.19	17.26 ± 2.86	3.94 ± 0.75	14.99 ± 2.58	3.22 ± 1.01
pH	6.42 ± 0.34	6.57 ± 0.35	6.54 ± 0.34	7.08 ± 0.37	6.45 ± 0.34	6.13 ± 0.32	6.59 ± 0.35	6.37 ± 0.34
Conductivity (μs/cm)	962.50 ± 315.49	188.10 ± 61.65	785.40 ± 257.44	402.60 ± 131.96	819.50 ± 268.61	742.50 ± 243.37	556.60 ± 182.44	272.80 ± 89.42
ORP (mv)	147.11 ± 15.58	140.56 ± 14.12	136.40 ± 13.49	134.69 ± 13.53	142.74 ± 19.04	42.10 ± 4.23	22.48 ± 4.40	24.93 ± 2.50
DO (mg/L)	5.98 ± 0.35	5.60 ± 0.62	4.04 ± 0.88	6.27 ± 0.52	1.94 ± 0.77	5.71 ± 0.57	1.89 ± 0.60	1.43 ± 0.42
Salinity	473.00 ± 155.04	88.00 ± 28.84	385.00 ± 126.19	198.00 ± 64.90	407.00 ± 133.41	105.00 ± 117.15	275.00 ± 90.14	132.00 ± 43.27
TDS (mg/L)	498.13 ± 100.56	98.40 ± 21.70	391.20 ± 92.04	209.19 ± 41.20	407.07 ± 128.19	38.40 ± 8.47	287.60 ± 73.14	142.80 ± 31.48

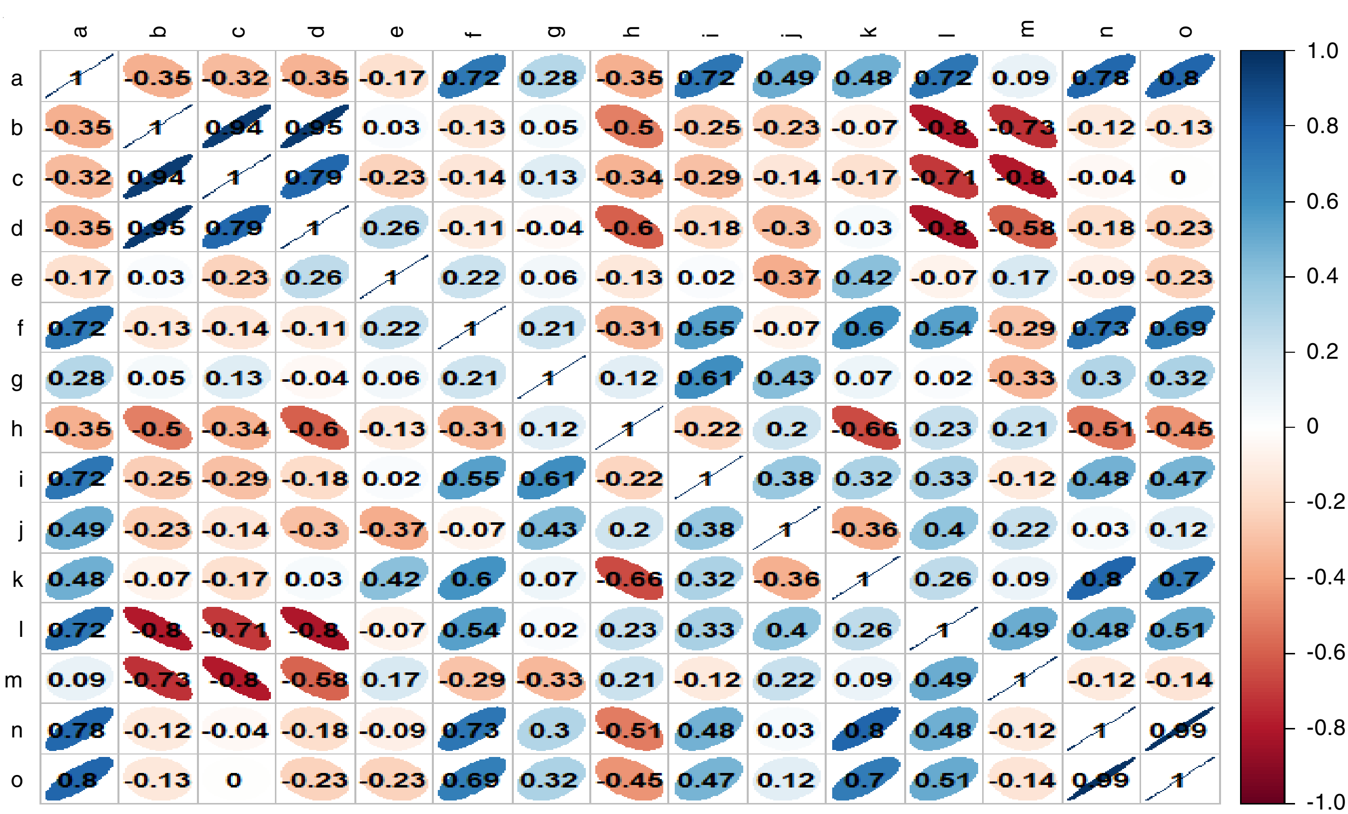

Fig. 3. Corr-plot showing correlations among all physico-chemical parameters of water with colour gradient (a) chloride, (b) TH, (c) CaH, (d) MgH, (E) flouride, (f) sulphate, (g) alkalinity, (h) phosphate, (i) nitrate, (j) ph, (k) conductivity, (l) ORP, (m) DO, (n) salinity, (o) TDS

TABLE-3
CORRELATION OF DIFFERENT PARAMETERS OF WATER

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
a	1														
b	-.354	1													
c	-.320	.940**	1												
d	-.349	.950**	.787*	1											
e	-.160	.040	-.218	.271	1										
f	.716*	-.129	-.138	-.108	.217	1									
g	.281	.046	.131	-.037	.066	.210	1								
h	-.352	-.503	-.341	-.599	-.142	-.312	.124	1							
i	.724*	-.250	-.293	-.184	.027	.548	.613	-.216	1						
j	.494	-.232	-.139	-.293	-.358	-.068	.425	.197	.383	1					
k	.484	-.067	-.169	.033	.421	.599	.074	-.656	.316	-.356	1				
l	.723*	-.800*	-.707*	-.801*	-.073	.542	.021	.226	.326	.394	.259	1			
m	.094	-.725*	-.796*	-.584	.164	-.290	-.326	.213	-.116	.223	.086	.492	1		
n	.780*	-.116	-.038	-.176	-.082	.728*	.298	-.513	.478	.029	.799*	.483	-.119	1	
o	.797*	-.127	-.005	-.226	-.222	.687	.318	-.448	.467	.122	.699	.507	-.142	.988**	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).
(a) chloride, (b) TH, (c) CaH, (d) MgH, (E) flouride, (f) sulphate, (g) alkalinity, (h) phosphate, (i) nitrate, (j) pH, (k) conductivity, (l) ORP, (m) DO, (n) salinity, (o) TDS

Fig. 4. Cluster analysis in the form of Scatter plot matrices showing concentrations of physico-chemical parameters of water

in monsoon and post-monsoon than the pre-monsoon. The dumping of sewage, human excreta, and animal organic waste as well as waste from industries can contribute to the chloride concentration in water and soils [6,16]. Total hardness was found highest in pre-monsoon among all seasons in most of the sampling sites and less in the monsoon season. It may be due to the dilution of water in rainy season. Calcium hardness also showed similar result like magnesium hardness. Calcium concentration varies due to discharge of swage and low due to the good unpoll-uted water quality of nature [17]. Chandaneswar was the only exception where the concentration of calcium hardness was higher in post-monsoon. Magnesium hardness was found higher in pre-monsoon and post-monsoon seasons than monsoon in most of the sampling sites. The higher concentration of magnesium hardness in monsoon supports the increasing amount of rainfall and sewage entry from other sources to the aquatic ecosystem [18].

Fluoride concentration was found highest in pre-monsoon season than other seasons. In monsoon, the concentration was low in all sampling sites except Daringbadi, where it was little higher in monsoon than the post-monsoon. Phosphate concentration was found nearly equal in all three seasons but in monsoon it was found highest. The runoff from agricultural fields and anthropogenic pressure increases the phosphate concentration in monsoon [19]. Sulphate was also found like the pattern of phosphate. It varied with the presence of industrial activity near the wetland [20].

Nitrate concentration was found highest in monsoon. It may be due to the runoff from the soil and agricultural field in rainy season [14]. The pH concentration was found little higher in pre-monsoon. The reason can be attributed due to the uptake of carbon dioxide by photosynthe-sizing organism in pre-monsoon is higher which increases the pH [15]. Moreover, dilution of water, low temperature and decomposition of organic matter in monsoon, can be the reason for low pH [21]. In monsoon, the conductivity was found higher in all sampling sites. Present findings were supported by other studies [22] where it described as the higher concentration of dissolved solids in water during monsoon season. The oxidation reduction potential (ORP) concentration was found higher in pre-monsoon than other seasons in water. Dissolved oxygen (DO) concentration varies in all seasons but in most of the places, DO was higher in post-monsoon, which can be due to vary in seasons with the anthropogenic pressure like industrial and human activities [2]. Salinity was found higher in monsoon in all sampling site, moreover coastal areas were found with high salinity. Total dissolved solids (TDS) was also found high in the monsoon due to the runoff from inland water [3,19]. Alkalinity was found higher in pre-monsoon and post-monsoon due to the presence of carbonates and bicarbonates [23].

Correlation among all the parameters of water were tested with Pearson′s correlation (r) test and found to be highly correlated with each other (Table-3). The significance level was found very high between TH and CaH (r = 0.94, $p < 0.01$), TH and MgH (r = 0.95, $p < 0.01$), salinity and TDS (r = 0.98, $p < 0.01$). Chloride concentration was found significant with sulphate (r = 0.71, $p < 0.05$), nitrate (r = 0.72, $p < 0.05$), conductivity (r = 0.72, $p < 0.05$), salinity (r = 0.78, $p < 0.05$), TDS (r = 0.79, $p < 0.05$). Total hardness was found significant with ORP (r = –0.80, $p < 0.05$) and DO (r = –0.72, $p < 0.05$). The significance level between CaH with MgH (r = 0.78, $p < 0.05$), ORP (r = –0.70, $p < 0.05$), DO (r = –0.79, $p < 0.05$). MgH was found significant with ORP (r = –0.80, $p < 0.05$). Sulphate was positively correlated with salinity (r = 0.72, $p < 0.05$). Conductivity and salinity were positively correlated with high significance (r = 0.79, $p < 0.05$). This correlation among all parameters is described in colour gradient for easier representation (Fig. 3).

The cluster analysis clearly describes the physico-chemical structures in Fig. 4, which represents the concentration plot on relation with each other among all parameters. All the 15 parameters of water were described in cluster format among X-axis and Y-axis. Taking the seasons as variable the concentration of each parameter is described. Though some parameters were high in pre-monsoon, some were high in post monsoon. So, cluster plot described the variety in all plots as the seasonal data.

Examination of soil: This study describes the 9 parameters of soil were analyzed and taken for correlation. The parameters were total hardness (TH), calcium hardness (CaH), magnesium hardness (MgH), chloride, fluoride, sulphate, alkalinity, phosphate and nitrate. The concentration comparison in every season of different locations of every parameter is illustrated in Fig. 5. The mean ± SD of all parameters at each sampling site is described in Table-4 and the correlations among them are shown in Table-5. The scatter plot of this correlation is shown in Fig. 7.

Present study revealed that the chloride concentration in soil was found only in Chilika and Chandaneswar. These two are the coastal sampling sites. It may be due to the influence of seawater. Total hardness was found highest in pre-monsoon

TABLE-4
MEAN ± SD OF ALL VARIABLES OF SOIL FROM ALL SAMPLING SITES

Sampling point	Chilika	Hirakud	Bhadrak	Chandaneswar	Talcher	Daringbadi	Titlagarh	Koraput
Chloride	511.65 ± 14.34	0.00 ± 0.00	0.00 ± 0.00	36.00 ± 12.266	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Total hardness	566.67 ± 94.52	580.00 ± 105.83	393.33 ± 94.52	406.67 ± 70.24	366.67 ± 41.63	546.67 ± 133.17	686.67 ± 147.42	613.33 ± 102.63
Calcium hardness	200.00 ± 60.00	186.67 ± 23.09	233.33 ± 61.10	186.67 ± 23.09	240.00 ± 60.00	226.67 ± 30.55	293.33 ± 11.55	273.33 ± 64.29
Magnesium hardness	366.67 ± 41.63	393.33 ± 100.66	160.00 ± 34.64	220.00 ± 52.92	126.67 ± 23.09	320.00 ± 158.75	393.33 ± 136.14	340.00 ± 52.92
Fluoride	0.05 ± 0.01	0.45 ± 0.12	0.09 ± 0.02	0.09 ± 0.02	0.22 ± 0.09	0.05 ± 0.02	0.14 ± 0.08	0.19 ± 0.04
Sulphate	57.75 ± 9.92	1.62 ± 0.28	57.69 ± 10.14	89.88 ± 57.54	146.33 ± 25.47	142.54 ± 8.02	167.43 ± 19.07	146.16 ± 11.25
Alkalinity	80.00 ± 20.00	236.67 ± 25.17	166.67 ± 30.55	380.00 ± 20.00	580.00 ± 111.36	260.00 ± 20.00	973.33 ± 98.33	766.67 ± 90.18
Phosphate	13.89 ± 6.95	22.80 ± 11.49	7.51 ± 3.14	8.26 ± 4.13	21.82 ± 10.55	15.67 ± 7.83	11.21 ± 6.67	34.56 ± 20.79
Nitrate	19.40 ± 11.42	47.27 ± 37.24	33.87 ± 18.86	17.95 ± 13.17	24.73 ± 8.37	6.62 ± 4.30	65.63 ± 41.09	8.56 ± 5.61

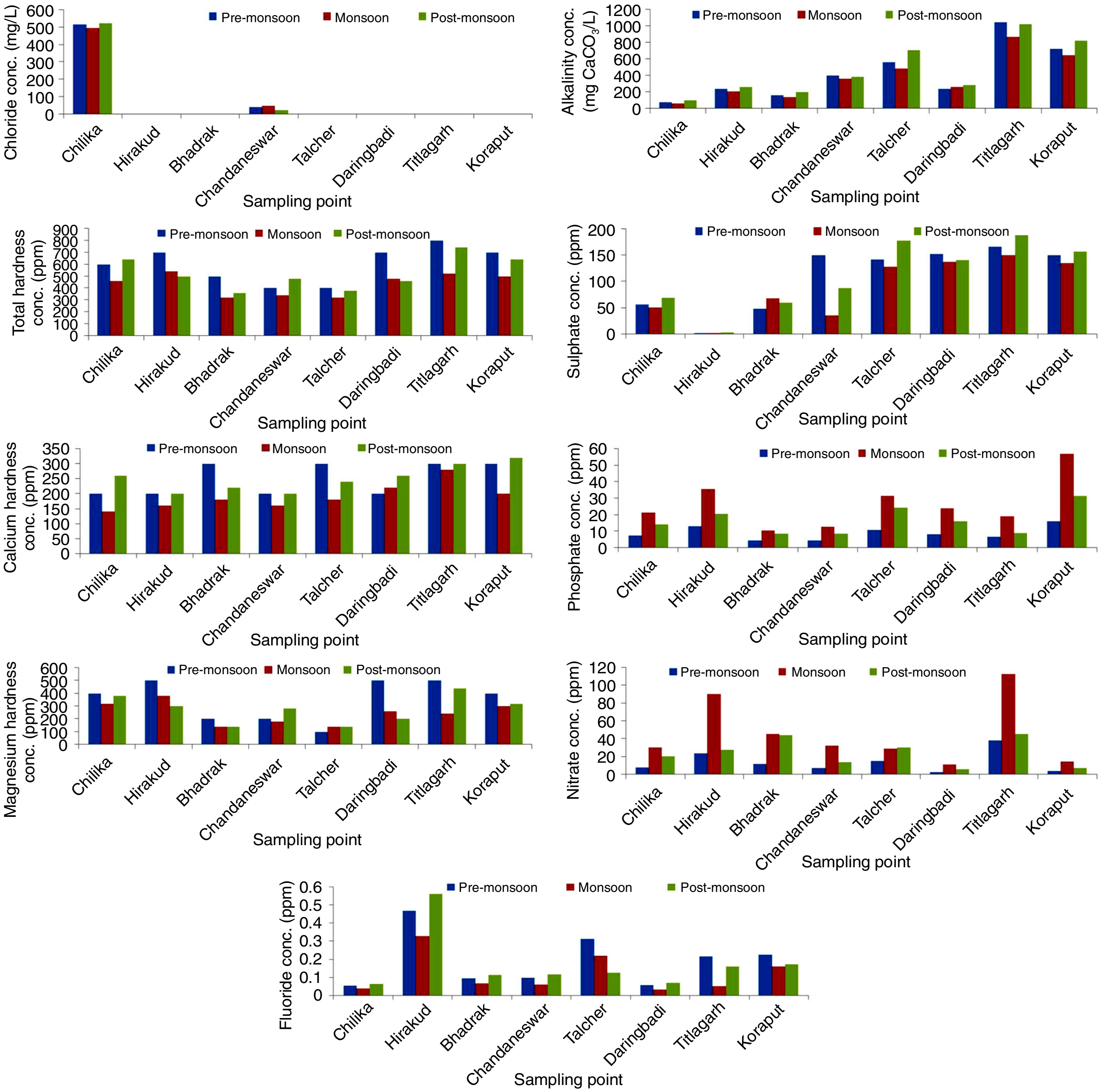

Fig. 5. Concentration of physico-chemical parameters of soil of every season at each sampling site

TABLE-5
CORRELATION OF DIFFERENT PARAMETERS OF SOIL AMONG THEMSELVES

	a	b	c	d	e	f	g	h	i
a	1								
b	.135	1							
c	-.345	.422	1						
d	.275	.943**	.096	1					
e	-.353	.151	-.151	.222	1				
f	-.308	.165	.775*	-.104	-.403	1			
g	-.460	.404	.824*	.141	.105	.756*	1		
h	-.165	.309	.256	.246	.520	.174	.302	1	
i	-.188	.336	.265	.272	.409	-.134	.369	-.294	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).
(a) Chloride, (b) TH, (c) CaH, (d) MgH, (E) Flouride, (f) Sulphate, (g) Alkalinity, (h) Phosphate, (i) Nitrate

among all seasons in most of the sampling sites and less in the monsoon season. It may be due to the dilution of salty water in rainy season. Magnesium hardness was found higher in pre-monsoon and post-monsoon seasons than monsoon in most of the sampling sites. Calcium hardness also behaved like magnesium hardness. Fluoride concentration was found highest in pre-monsoon season than other seasons. In monsoon, the concentration was low in all sampling sites except Talcher, where it was little higher in monsoon than the post-monsoon. Phosphate concentration was found highest in monsoon among all sampling sites. Sulphate was found with very low differences. In pre-monsoon and post-monsoon, the concentration of alkalinity was found higher than monsoon. Nitrate concentration was found highest in monsoon. It may be due to the runoff from the soil in rainy season.

Correlation among all parameters of soil were tested with Pearson's correlation (r) test and found to be highly correlated with each other (Table-5). The significance level was found very high between TH and MgH (r = 0.94, $p < 0.01$). The significance level between CaH with sulphate (r = 0.77, $p < 0.05$), alkalinity (r = 0.82, $p < 0.05$). Sulphate was positively correlated with alkalinity (r = 0.75, $p < 0.05$). This correlation among all the parameters is described in colour gradient for easier representation (Fig. 6). This cluster analysis clearly describes the physico-chemical structures in Fig. 7. All the 9 parameters of soil were described in cluster format among X-axis and Y-axis. Though some parameters were high in pre-monsoon and some others were also high in post-monsoon. So, the cluster plot described the variety in all plots as the seasonal data.

With physico-chemical variables, various components of avian diversity like species richness, bird abundance and diversity also differ in different locations with seasons [14,24]. The water depth plays an important role in plant diversity and cause prompt changes in fish, amphibians, invertebrates which ultimately leads to waterbird community [17]. Many aquatic plant species distribution is influenced by changes in water chemistry [25] which ultimately related to the species diversity and abundance who depends on those aquatic plants and weeds [24]. Slightly

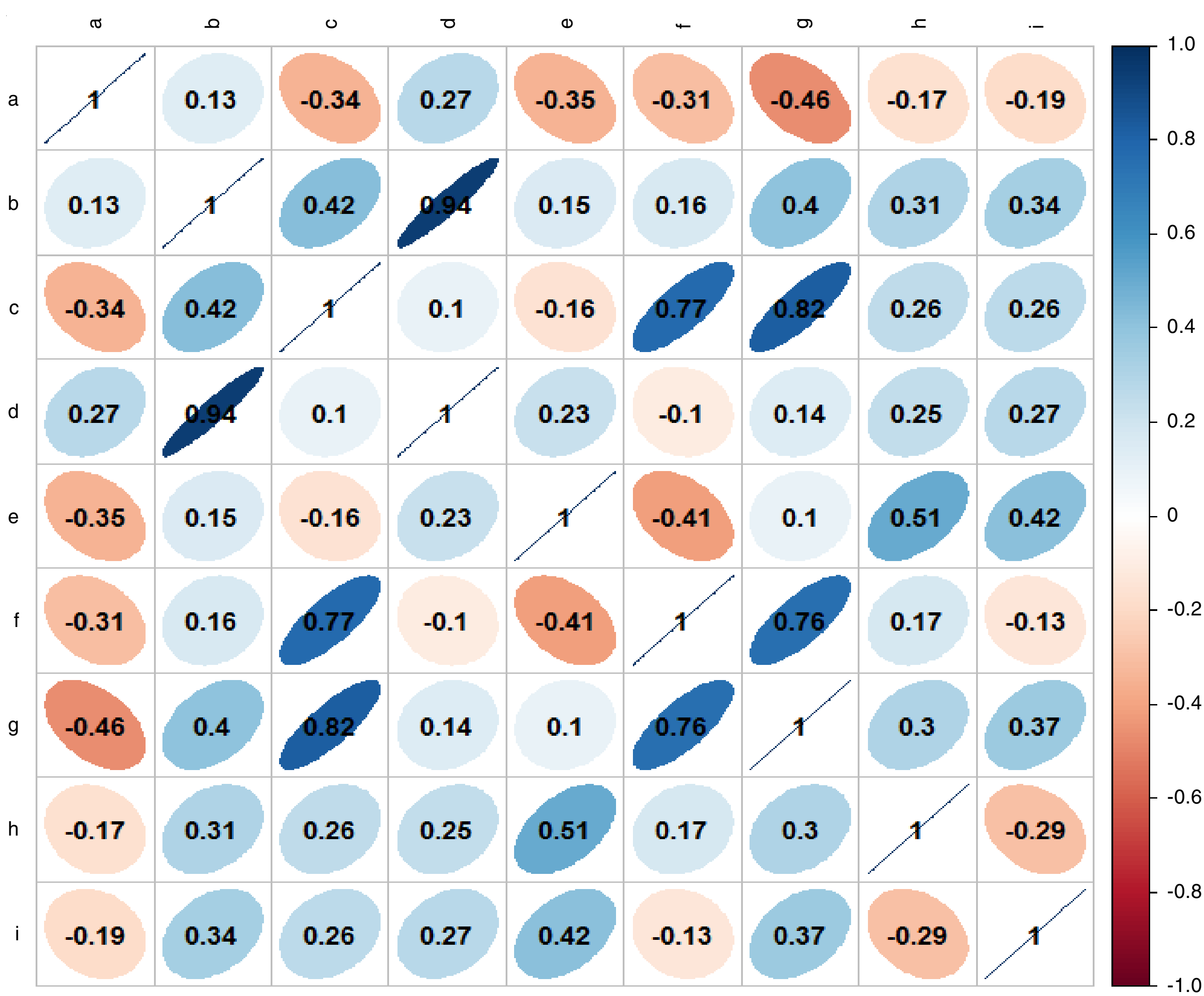

Fig. 6. Corr-plot showing correlations among all physico-chemical parameters of soil with color gradient (a) chloride, (b) TH, (c) CaH, (d) MgH, (E) flouride, (f) sulphate, (g) alkalinity, (h) phosphate, (i) nitrate

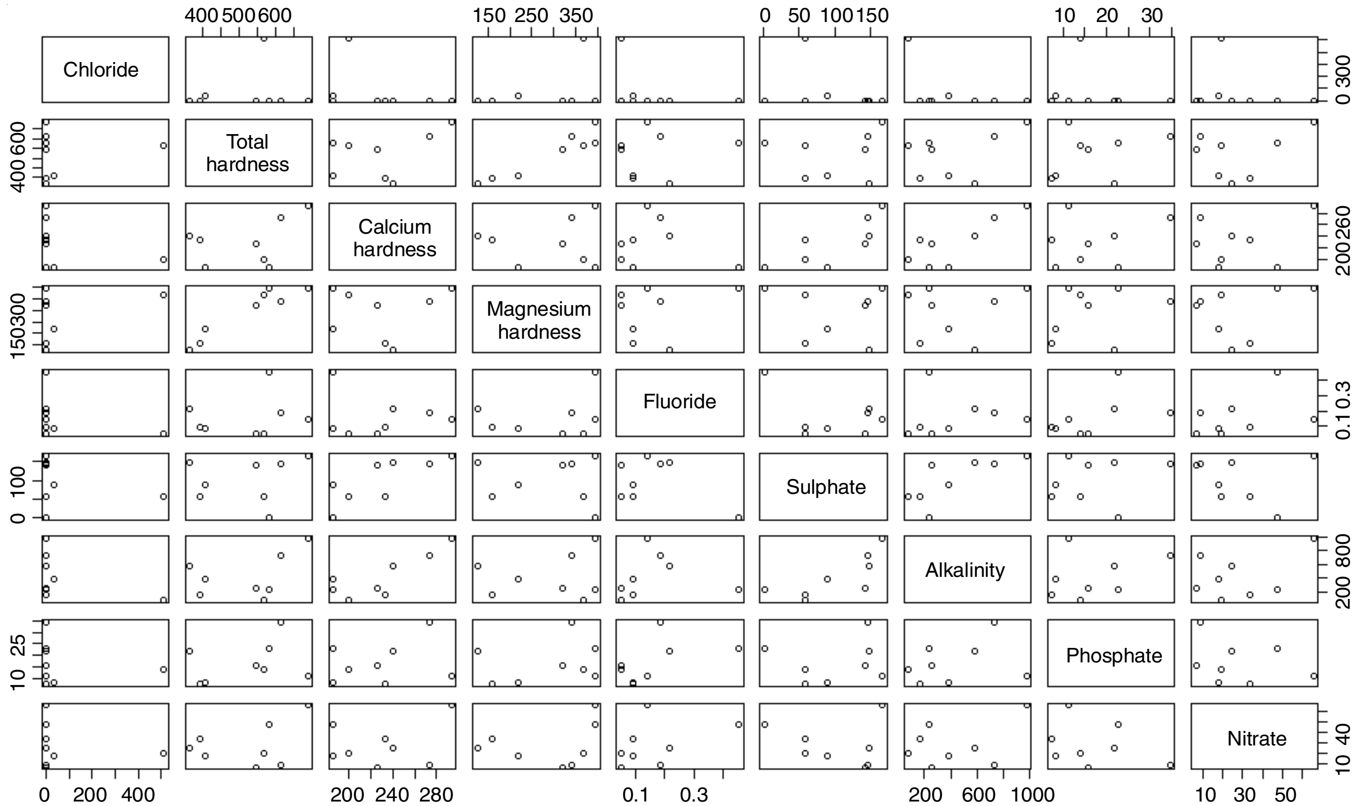

Fig. 7. Cluster analysis in the form of Scatter plot matrices showing concentrations of physico-chemical parameters of soil

alkaline pH is an indicator of higher macro invertebrates and overall productivity of wetland ecosystem which also support the avifaunal diversity in those regions [10] but this study revealed that the pH was slightly acidic (6.13-7.08) and this leads to the negative correlation with avian diversity. Phosphate concentration fluctuations of water bodies affect the waterfowl abundance [26]. Some group of birds like ducks were significantly negatively correlated with the DO but for other species there was a positive correlation between DO and bird diversity. Earlier studies [10,17,27] described that chloride, conductivity, ORP, DO, salinity and TDS were positively correlated with the abundance and diversity of birds. So for biomonitoring, every component of the ecosystem is important and should be taken into consideration.

Conclusion

In any habitat, physico-chemical parameters of soil and water play an important role for the plant and animal composition. These parameters of one ecosystem influence the floral diversity of that region, which ultimately leads to support the faunal diversity. In aquatic ecosystem, the physico-chemical parameters control the weed diversity and water quality which influences the wetland birds. These parameters of water are also correlated among themselves. Physico-chemical parameters of water and soil also interlinked and correlated among each other. It goes from the soil to water with the rainwater and deposited on the sediment from the water. Sometimes these parameters work as a cycle to maintain the equilibrium in the ecosystem. Many activities by congregation of birds were always influenced by the physical and chemical compositions of habitat. One single factor can not be the reason for the composition of species. With these factors, water depth also plays an important role for bird congregation [28]. Flock size of waterbirds also affected by the habitat selection with many biotic and abiotic factors [1]. There were instances where some egrets changed their feeding habit according to water management in agricultural fields [29]. Higher level of research work is needed to control the source of pollution to wetlands. By controlling the physico-chemical parameters of habitat, the diversity, density and richness of residential and migratory birds and other wetland dependent organisms can be controlled.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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