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Water Quality Aspects of a Temporary Water Body in Palakkad District, Kerala

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Abstract: Contamination of drinking water mainly through anthropogenic activities has become a major challenge to the environmentalist in the developing countries. Solid wastes from industrial units is being dumped without any proper treatment near the factories, which is subjected to reaction with percolating rain water and reaching the ground water level. The soft drink beverage factory in Plachimada meets their water requirement by the tapping ground water and due to this ground water has undergone drastic fluctuations. Despite the fact that several studies have been conducted taking Plachimada and Perumatty panchayath as focal points, little attention has been given to the nearby Pattenchery area and Pudussery Panchayath. Thus, an attempt was contributed to invest the water quality parameters of temporary water bodies, mainly ponds of Pattenchery and Pudussery panchayaths in Palakkad district, Kerala. The phsyico-chemical parameters of eight ponds in the two stations were studied and its correlation pattern was recorded. Standard deviation and confidence limit of each parameter were also evaluated.

Key words: Water quality, temporary water body, pond water, correlation coefficient.

Introduction

The environment is suspected to be at risk from several thousands of toxic chemicals, of both anthropogenic and natural origin. There are more than 12,000 different toxic chemical compounds in industrial use today, and nearly 500 new chemicals are developed each year. The major issues associated with direct biological effects include the differential sensitivity of target organisms, the relative importance of the directly affected species, influences of the physico-chemical environment and the interactions with other chemical stresses on the organisms, including the potential for additive, synergistic or antagonistic responses.

Water is essential to our existence as breathing air. The overall amount of water on our planet has remained the same for two billion years. Only 1% of all water on earth is readily accessible for use. Of this amount, about 73% goes to agriculture, 20% to industry and balance is used for domestic purpose. Although water is a renewable source, supplies are limited and finite. Surface water in the form of rivers, reservoirs, lakes etc. account for 0.26% of fresh water, which alone is renewable (Shiklomanov, 1998).

Water in nature is available in the form of ground and surface water. The water that falls on earth in the form of rain, percolates through the soil and occupies subterranean permeable layers known as ground water. The water from rainfall collected in lakes, ponds, rivers, etc., is called surface water. Surface water has unique quality of self-purification, which means the exchange of gases like CO_2, O_2 in the environment. This property causes the oxidation of natural or foreign organic pollutants by oxygen dissolved in waters. In oxygen rich zones, degradable organic substances are broken down into simpler unobjectionable products by the action of aerobic organisms (Tomar, 1999).

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Water bodies can be classified into two types—fresh water and marine water. Fresh water bodies are then classified into two series—Lentic (lake, pond, and swamp etc.) and Lotic (spring, stream, and river) (Odum, 1980). A natural large sized depression formed within the surface of earth, when is filled up with water is known as pond or lake. If the size of the depression is comparatively small, it is termed as a pond and if it is large enough then it is called a lake. Ponds are nothing more than shallow holes where water collects and are shallow enough to support rooted plants having little wave action. The amount of dissolved oxygen varies gradually during a day and water temperature is fairly even from top to bottom which changes with air temperature.

A natural pond consists of three zones—littoral, limnetic and profoundal zone. The littoral zones are peripheral shallow region where light penetrates to bottom and water plants such as pondweeds, water lilies and so on are found, whereas limnetic zone are the inner open water zone to the depth of light penetration effective for photosynthesis. The littoral together with limnetic zone make up the autotrophic zone of the pond. The profoundal zones are the rest of the system including deep water and bottom that is beyond light penetration, which comprises the heterotrophic part. Pond ecosystem is a specific type of freshwater ecosystem that is largely based on the autotroph algae which provides the base trophic level for all life in the area.

Ponds are temporary water bodies and can be perennial or non-perennial depending on the source of water. In natural ponds, littoral zone is relatively large and profoundal zones are small or sometimes absent. Ponds may be found in most of the regions of adequate rainfall. As a stream shifts position, leaving the former bed isolated as a body of standing water, the water bodies formed are very productive. A pond has a distinct boundary and is thus a recognizable unit in terms of both structure and functions, even though it is not a closed system. In the Pond ecosystem, anthropogenic activities are greater and may cause eutrophication and deterioration of water quality that may ultimately affect the organisms. In assessing the quality of surface water, it should be considered that still or stationary water is more susceptible to pollutants than flowing water because of eutrophication, which makes water rich in phosphorus and nitrogen. If the concentration goes beyond the limit, excessive growth of algae takes place. Development within water bodies has increased greatly in recent years and many ponds have been subjected to an ever-increasing load of nutrients and sediments, resulting in decreased pond water quality. Increased nutrient loadings are most commonly due to excessive use of fertilizers, malfunctioning septic systems, poor aeration system and improper waste disposal within the watershed. As development continues to increase, the amount of total hard-surfaced area also increases and the volume and velocity of the water moving through the watershed into surface water increases. This run-off erodes soils and transports organic materials and nutrients from surface soils. Inorganic materials, in the form of sand, silt, and clay are also transported to receiving water, resulting in decreased pond water quality.

Healthy ponds have a natural capacity to cleanse themselves. Each pond is an individual ecosystem with a food chain of organisms that incorporate the incoming nutrients. This natural system works very well without any pond aeration system to improve pond water quality, keeping the ecosystem in balance until excessive nutrient inflow overwhelms the ability of the ecosystem to assimilate the nutrients. Once this occurs, the excessive nutrient levels adversely affect the aesthetic qualities of the pond by stimulating the growth of nuisance algae and plant life. Pond algae (algae blooms) can quickly turn a pond "pea soup" green or cause the formation of "smelly" floating algae mats.

If oxygen is present, the accumulated organic sediments begin to decompose aerobically. This organic material serves as food for bacteria and organisms that live in the substrate (bacteria, insect larvae, worms, etc.). These organisms require and consume dissolved oxygen as they digest the organic sediments. As sediments and biological activity increase, dissolved oxygen levels are depleted and become limiting. Low or no dissolved oxygen conditions can occur quickly, eliminating aerobic organisms and slowing the breakdown of the organic sediments. Then the growth of anaerobic bacteria, the bacteria that thrives in an environment of low or no dissolved oxygen, increases. Anaerobic digestion of the organic sediments begin, releasing toxic gases into the water that kill beneficial aerobic bacteria and insects. Anaerobic digestion of pond sediments is a much slower process than with aerobic digestion. Where aerobic digestion can result in the control or reduction of organic sediment levels, anaerobic digestion usually allows organic sediments levels to increase. During anaerobic digestion, bacterial enzymes and lack of oxygen make the nutrients in the bottom sediments soluble. Then the nutrients return to the water column and are available to support new weed and algae growth. Anaerobic conditions at the pond bottom have a damaging effect on the food chain that support fish population as well as reducing or eliminating fish habitat, ultimately resulting in a reduction of the fish quality, size and quantity.

To restore a pond to a healthy condition, nutrient inputs should be reduced or eliminated wherever possible. By maintaining aerobic conditions at the bottom of a pond, fish, the top consumer will also improve in quantity and quality. Maintaining the aerobic environment will also reduce or prevent the accumulation of organic sediments. Aerobic conditions at the bottom of the pond benefit all aspects of the aquatic environment and hence ponds can be treated by aeration process rather than by chemical treatment (Shilton, 2005).

Paper mills, distilleries, textiles and electroplating industries have caused an increase in concentration of nitrates, metals and cyanide in various water bodies. The public water supply polluted by naturally occurring arsenic compounds were reported from Bangladesh (Nickson et al., 1998). Assessment of water resources of Neyyatinkara municipal area showed a high level of metals (Suvarna Kumari, 2003). Studies on different tropic levels of Kuttanad wetland ecosystem and studies on metal distribution indicated presence of various metals beyond limit (George et al., 1999). Water quality status and sediment characteristics in the Trippallur—Kudallur areas of Palakkad district were also studied (Kamalakshan et al., 1994).

The heavy metal distribution in suspended sediments, bed sediments and ground water of Krishna delta was found to be significantly polluted (Saxena and Singh, 1999). In 2003 limnological features of temple pond in Kollam district was studied (Sulaba and Prakasam, 2003). Industrial, urban and agricultural sectors imposed severe impairments to fresh water source in Chelur and Sasthamkotta lakes due to excessive discharge of solid and liquid wastes (Sreejith and Arun, 1998). High hardness and alkalinity present in water in Connolly canal in Calicut resulted in the heavy pollution of the canal (Nirmala et al., 1994).

Many studies have been conducted regarding water contamination in Palakkad district of Kerala. Nevertheless, most of the studies were confined to water quality of rivers, lakes and wells and very few studies were carried on the ponds. The main objective of this study was to determine the physico–chemical parameters of these water bodies situated at Pattanchery and Pudussery Panchayath of Palakkad District, Kerala, there by to deduce the correlation between various water quality parameters.

Materials and Methods

Study Area

Water bodies situated in two rural areas of Palakkad district – Pattenchery panchayat and Pudussery panchayat were selected for this study. Both Pattenchery and Pudussery Panchayats are situated in remote interiors of eastern Palakkad where main occupation of inhabitants is agriculture (Figure 1). There are numerous ponds and other water bodies in both the areas. Most of them are perennial while some are non-perennial. Several factories situated in Palakkad have direct and indirect effects on water bodies. Water requirements of thousands of inhabitants have been threatened, besides putting paddy cultivation into danger. The deterioration of water quality parameters in the Perumatty panchayat of same district has entered into headlines of mainstream newspapers. The soft drink beverage factory in Plachimada resulted in tapping of ground water and due to this ground water table has undergone drastic fluctuation. Various reports were published on analysis of the effluent and sludge from this soft drink factory that reported high value of

Figure 1: Map showing two stations—Pattenchery and Pudussery.

cadmium and lead. The pesticides were also many times greater than the permissible limit. Despite the fact that several studies have been conducted taking Plachimada and Perumatty panchayat as focal points, little attention has been given to the near by Pattenchery area. Pudussery is another similar area, which suffers from water quality problems. Several industrial units situated here have direct and indirect effects on these water bodies. Even though numerous reports have been found regarding water quality standards in areas mentioned, main field of studies were centred on wells and rivers and little attention were focussed on ponds. In the present attempt, water samples from four different ponds of each station were chosen during January 2005 and their qualities in terms of physical and chemical parameters were studied.

Station I—Pattenchery Panchayath

The first area selected for study was Pattenchery panchayath (Station I), located southeast to the chitoor taluk of Palakkad District. It covers an area of 3030 sq. kms and belongs to midland region. There are about 11 wards in this panchayath. It is a medium rainfall area, average rainfall obtained in the period of June to September comes to about 120 to 150 cm and during the period of September to November, its about 60 to 80 cm. Major source of water in this area is rainfall, and this area gets an average rainfall of about 200 to 220 cm. The soil generally consists of sand and in some places clay contributes a major part. There are numerous ponds and other water bodies in this area. Most of the ponds are perennial, while some are non-perennial. Four water bodies were selected randomly from this area and the photograph of two ponds belonging to this site is shown in (Figures 2a and b).

Station II—Pudussery Panchayath

The second area chosen for the study was Pudussery panchayat (Station II); having a total area of 122.84 sq. kms. in the eastern part of Palakkad belonging to midland region. There are about 13 wards in this region and is a medium rainfall area and average rainfall in a year is about 170 to 200 cm, and the major source of water is from rain. Four different ponds were selected and water samples from these ponds were analysed (Figures 3a and 3b).

Figure 2a and 2b: Photographs of pond 1 and 3 of Station I.

Figure 3a and 3b: Photographs of pond 5 and 6 of Station II.

Sampling and Storage

Sample collection, preservation and analysis were done as per standard methods. (APHA, 1998). About two litres of water samples from seven different ponds of two stations were collected in plastic cans with tight fitting plugs. These containers were acid washed and thoroughly rinsed with distilled water and Milli-Q grade water in the laboratory prior to collection and rinsed with sample before filling (Murdoch and Azcue, 1995). Water for the determination of DO was collected from the sampling sites itself. After the collection of sample into DO bottles, the oxygen was fixed using Winkler A and B solutions on site. The parameters like pH and temperature were analysed in situ and the water samples were then carried to the laboratory, and refrigerated to prevent the alteration of result.

Analytical Method

The methodologies for the present pond water quality evaluation were selected according to the recommendations given by "Standard methods for the examination of Water and Waste Waters" by APHA (1998). The hydrographical parameters considered for this study are temperature, pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), hardness, alkalinity, chloride free carbon dioxide, nitrite and phosphate.

Statistical Evaluation

The strong correlation always exists among the water quality parameters, systematic calculation and interpretation of correlation coefficient gives an idea of water quality parameter. Therefore, systematic statistical studies of correlation and regression coefficients of the quality parameters not only helps to assess the overall water quality but also show relative concentration of various pollutants in water and provide necessary information for implementation of water quality programmes. Many studies were carried out in the statistical analysis and assessed the water quality in different parts of the country. Aravinda (1991); Singanan and Rao (1995); Srivastava and Sinha (1994); Biswal et al. (2001); Mishra et al. (2003); Mahajan et al. (2005) have undertaken statistical evaluation on ground water quality. The correlation is one of the most common and useful statistical approaches and is a single number that describes the degree of relationship between two variables. A correlation coefficient is a number between –1 and 1 that measures the degree to which two variables are linearly related. The quantity *r*, called the linear correlation coefficient, measures the strength and the direction of a linear relationship between two variables. The linear correlation coefficient is sometimes referred to as the Pearson product moment correlation coefficient. The mathematical formula for computing '*r*' is

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

where *n* is the number of pairs of data.

Statistical evaluations—standard deviation and confidence limit (CL) of each parameter were also computed. Instead of a single estimate for the mean, a confidence interval generates a lower and upper limit for the mean. The interval estimate gives an indication of uncertainty. The narrower the interval, the more precise is our estimate. Confidence limits are the lower and upper boundaries/values of a confidence interval, that is, the values which define the range of a confidence interval. The upper and lower bounds of a 95% confidence interval are the 95% confidence limits. These limits may be taken for other confidence levels, for example, 90%, 99%, and 99.9%. In the present study, standard deviation and CL of all parameters in each pond were evaluated (Neyman, 1937). The standard deviation is expressed mathematically as

$$\sigma = \sqrt{\frac{1}{N}\sum_{i-1}^{N}(x_i - \bar{x})^2}$$

where *N* is the number of items and the mean is calculated first as

$$\bar{x} = \frac{1}{N}\sum_{i-1}^{N} x_i$$

Confidence limits (CL) are defined as

$$\bar{Y} \pm t_{(\alpha/2,\, N-1)^s} \Big/ \sqrt{N}$$

where $\bar{Y}$ is the sample mean, *s* is the sample standard deviation, *N* is the sample size, α is the desired significance level, and $t_{(\alpha/2,\, N-1)}$ is the upper critical value of the *t* distribution with $N - 1$ degree of freedom. Note that the confidence coefficient is $1 - \alpha$.

Results and Discussions

The physico–chemical parameters of water samples from ponds of Station I and Station II are summarised in Tables 1 and 4. The distribution of water quality parameters and their variation is depicted in Figure 4. Statistical

Table 1: Physico-chemical analysis of pond water samples of Station I

Sample	*Temp (C)*	*pH*	*Turbidity (NTU)*	*E.C. (µS/cm)*	*TDS (mgpl)*	*DO (mgpl)*	*Cl^- (mgpl)*	*Alkalinity (mgpl)*	*Hardness (mgpl)*	*Free CO_2 (mgpl)*	*NO_2^- (mgpl)*	*PO_4^{3-} (mgpl)*
1	27	5.65	3.8	213.9	124.6	4.9	10.65	250	205.1	17.60	0.008	0.002
2	30	6.61	2.2	194.9	112.9	3.5	14.20	270	120.1	11.80	0.003	0.001
3	28	5.20	3.2	255.5	139.9	6.3	19.52	230	105.1	12.76	0.030	0.002
4	28	7.10	2.5	267.2	156.2	3.5	10.65	315	95.05	7.92	0.007	0.001

Table 2: Statistical evaluations of water quality parameters of pond water samples from Station I

Parameter	*Min*	*Max*	*Avg*	*SD*	*95% CL*
Temperature	27	30	28.3	1.258	28.3 ± (1.23)
pH	5.65	7.1	6.1	0.869	6.1 ± (0.85)
Turbidity	2.2	3.8	2.9	0.718	2.9 ± (0.70)
EC	194.9	267.2	232.9	34.119	232.9 ± (33.44)
TDS	112.9	156.2	133.4	18.795	133.4 ± (18.42)
DO	3.5	6.3	4.6	1.340	4.6 ± (1.32)
Cl	10.65	19.52	13.8	4.192	13.8 ± (4.1)
Alkalinity	230	315	266.3	36.372	266.3 ± (35.64)
Hardness	95.05	205.1	131.3	50.241	131.3 ± (49.23)
CO_2	7.92	17.6	12.5	3.981	12.5 ± (3.90)
NO_2	0.003	0.03	0.012	0.012	0.012 ± (0.01)
PO_4	0.001	0.002	0.0015	0.001	0.0015 ± (0.0006)

Avg - average value; SD - standard deviation; CL - confidence limit.

Table 3: Correlation coefficient (*r*) among various water quality parameters of Station I

	pH	*Turbidity*	*EC*	*TDS*	*DO*	*Cl^-*	*Alkalinity*	*Hardness*	*Free CO_2*	*NO_2^-*	*PO_4^{3-}*
pH	1	-0.767	0.035	0.213	-0.949	-0.610	0.955	-0.394	-0.720	-0.755	-0.950
Turbidity		1	0.035	-0.018	0.691	-0.015	-0.608	0.747	0.815	0.384	0.924
EC			1	0.975	0.268	0.154	0.274	-0.547	-0.544	0.523	0.062
TDS				1	0.078	-0.064	0.459	-0.500	-0.594	0.324	-0.071
DO					1	0.700	-0.850	0.148	0.486	0.914	0.905
Cl-						1	-0.674	-0.431	-0.009	0.833	0.366
Alkalinity							1	-0.376	-0.733	-0.650	-0.833
Hardness								1	0.906	-0.264	0.546
Free CO_2									1	0.093	0.772
NO_2^-										1	0.663
PO_4^{3-}											1

Table 4: Physico-chemical analysis of pond water samples of Station II

Sample	*Temp (C)*	*pH*	*Turbidity (NTU)*	*EC (µS/cm)*	*TDS (mgpl)*	*DO (mgpl)*	*Cl^- (mgpl)*	*Alkalinity (mgpl)*	*Hardness (mgpl)*	*Free CO_2 (mgpl)*	*NO_2^- (mgpl)*	*PO_4^{3-} (mgpl)*
5	27	6.72	4.2	776	489.1	2.8	78.10	265	335.70	13.2	0.28	0.082
6	28	6.38	7.5	810	508.1	4.9	81.65	290	295.23	ND	1.60	0.015
7	28	7.09	5.0	758	484.4	2.1	69.20	295	260.21	ND	0.40	0.105
8	31	8.16	7.5	788	503.9	4.2	63.90	255	245.19	ND	3.20	0.088

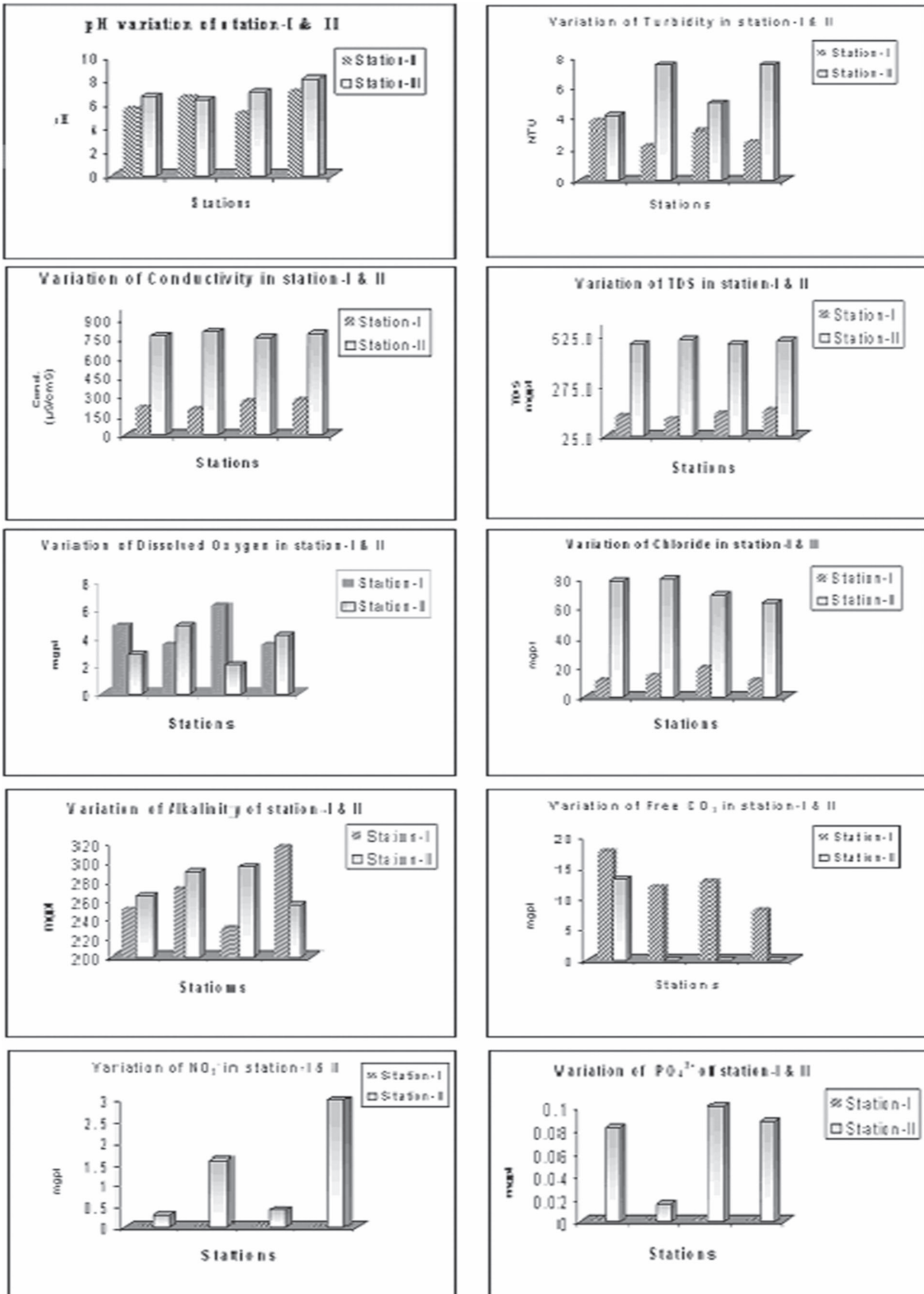

Figure 4: Distribution of water quality parameters of Stations I and II.

evaluations from physico–chemical data of pond water are appended in Tables 2 and 5. The numerical values of correlation coefficient (*r*) for 11 parameters are tabulated in Tables 3 and 6. In Station I, the significantly correlated values were found between parameters, EC and TDS ($r = 0.975$), pH and alkalinity ($r = 0.955$), hardness and free CO_2 ($r = 0.906$), DO and nitrite ($r = 0.914$), turbidity and phosphate ($r = 0.924$), DO and phosphate ($r = 0.905$), respectively. In Station II, strong correlations were found between turbidity and TDS ($r = 0.924$), EC and TDS ($r = 0.944$), EC and DO ($r = 0.971$), TDS and DO ($r = 0.995$), hardness and chloride ($r = 0.819$), respectively.

The linear regression analysis was carried out in a few pairs of significantly correlated parameters of both stations and is represented in Figures 5 and 6. The results of the analysis are summarised in Table 8, representing the value of correlation coefficient (*r*); empirical parameters '*a*' and '*b*', best fit linear regression equations ($Y = aX + b$), observed and predicted values of some significantly correlated parameters.

Temperature

Temperature is an important factor that can modify both physical and ecological properties of aquatic environment. The ideal temperature range is 20°C – 25°C and acceptable values is between 2°C–30°C. The temperature of the pond normally follows that of its surroundings even though with a delay related to the size of the pond. Direct exposure of the pond to open sky can cause larger swings in temperature. Direct sunlight during the day can cause the temperature to rise higher and heat loss on clear nights can affect the temperature to drop lower than shaded ponds. On most occasions, temperature will be lowest in the morning just before sunrise and the highest at sunset. Temperature is influenced by the amount of sun, the intensity of the sun the pond receives and other factors such as the wind speed during the day or night. A clear night sky can absorb a large amount of heat from a small pond and actually drive the pond temperature below air temperature. Over normal temperature ranges, biological activity doubles for each ten-degree rise in temperature. In Station I, the average surface temperature varied between 27°C and 30°C and in Station II temperature varied between 27°C and 31°C.

pH

Generally, the relative concentration of hydrogen ion in water decides whether the water will behave like a weak acid or an alkali. The pH of the samples collected from Station I varied from 5.20 to 7.1 and the average value with 95% CL was found to be in the range 6.1 ± (0.85). The pH value of samples from site 1, 2 and 3 were below 7. The pH of samples from Station II varied between 6.72 and 8.16 and the average value with 95% CL was found to be 7.09 ± (0.756). Samples 5 and 6 were slightly acidic while sample 8 was rather alkaline. A pH greater than 8 shows the presence of carbonate, bicarbonate and pH less than 5 shows the presence of any organic acid. The pH range of 6 to 8.5 is acceptable for most pond life. The primary concern with pH is its direct relationship to the toxicity of ammonia and nitrite. The pH levels in a given pond can fluctuate daily and is determined by complex relationships between carbon dioxide, hardness, alkalinity, photosynthesis, and respiration. If pH levels are not maintained, there could be negative effects in the pond.

In Station I, pH showed a significantly negative correlation coefficient on turbidity, DO, chloride, hardness, free CO_2, nitrite, phosphate, and positive values for alkalinity, EC and TDS. Contradictory to Station I,

Table 5: Statistical evaluations of water quality parameters of pond water samples from Station II

Parameter	*Min*	*Max*	*Avg*	*SD*	*95% CL*
Temperature	27	31	29	1.732	29 ± (1.697)
pH	6.38	8.16	7.09	0.772	7.09 ± (0.756)
Turbidity	4.2	7.5	6.1	1.706	6.1 ± (1.672)
EC	758	810	783	21.817	783 ± (21.38)
TDS	484.4	508.1	496.4	11.408	496.4 ± (11.18)
DO	2.1	4.9	3.5	1.278	3.5 ± (1.25)
Cl	63.9	81.65	73.2	8.122	73.2 ± (7.96)
Alkalinity	255	295	276.3	19.311	276.3 ± (18.92)
Hardness	245.19	335.7	284.1	40.295	284.1 ± (39.49)
CO_2	0	13.2	13.2	6.600	13.2 ± (6.47)
NO_2^-	0.28	3.2	1.3725	1.355	1.37 ± (1.33)
PO_4^{3-}	0.015	0.105	0.073	0.040	0.073 ± (0.38)

Avg - average value; SD - standard deviation; CL - confidence limit.

Table 6: Correlation coefficient (*r*) among various water quality parameters of Station II

	pH	*Turbidity*	*EC*	*TDS*	*DO*	*Cl^-*	*Alkalinity*	*Hardness*	*Free CO_2*	*NO_2^-*	*PO_4^{3-}*
pH	1	0.335	-0.222	0.092	0.005	-0.945	-0.634	-0.736	-0.318	0.699	0.589
Turbidity		1	0.547	0.744	0.693	-0.286	0.139	-0.738	-0.918	0.766	-0.400
EC			1	0.944	0.971	0.465	-0.099	0.130	-0.214	0.532	-0.909
TDS				1	0.995	0.149	-0.214	-0.182	-0.425	0.775	-0.750
DO					1	0.241	-0.189	-0.093	-0.365	0.715	-0.803
Cl^-						1	0.390	0.819	0.401	-0.500	-0.740
Alkalinity							1	-0.021	-0.388	-0.529	-0.269
Hardness								1	0.854	-0.620	-0.320
Free CO_2									1	-0.535	0.160
NO_2^-										1	-0.166
PO_4^{3-}											1

Table 7: Indian Standard Drinking Water - Specification (BIS 10500 : 1991)

Sl. No.	*Substance or characteristic*	*Requirement (desirable limit)*	*Permissible limit in the absence of alternative source*
1	Colour (Hazen units, max)	5	25
2	Odour	Unobjectionable	Unobjectionable
3	Taste	Agreeable	Agreeable
4	Turbidity (NTU, max)	5	5
5	pH Value	6.5 to 8.5	No Relaxation
6	DO, mgpl	5	10
7	Total hardness (as $CaCO_3$) mgpl, max	300	600
8	Chlorides (as Cl) mgpl, max	250	1000
9	Dissolved solids mgpl, max	500	2000
10	Nitrate (as NO_3) mgpl, max	45	100
11	Alkalinity mgpl, max	200	600

BIS 2003, Bureau of Indian Standards, New Delhi, IS 10500:1991 Edn 2.2(2003).

Table 8: Linear correlation and regression equation for some pairs of strongly correlated parameters Station I and Station II and their predicted values

Sample	*Parameters*	*a*	*b*	*r*	*Regression Equation*	*Predicted value*	*Observed value*	*% Deviation*
Station I	EC, TDS	0.537	8.36	0.975	TDS = 0.537 EC + 8.36	151.8	156.2	2.82
	Hardness(H), Free CO_2	0.072	3.09	0.906	CO_2 = 0.072 H + 3.09	17.9	17.6	-1.70
	DO, NO_2^-	100.5	3.34	0.914	DO = 100.5 NO2- + 3.34	6.4	6.3	-1.59
	Turbidity (Tb), PO_4^{3-}	1150	1.20	0.924	Tb = 1150 PO43- + 1.20	3.5	3.8	7.89
	DO, PO_4^{3-}	2100	1.40	0.905	DO = 2100 PO43- + 1.40	3.51	3.5	-0.29
Station II	EC, TDS	0.493	110.1	0.944	TDS = 0.493 EC + 110.1	509.4	508.1	-0.26
	Turbidity (Tb),TDS	6.179	458.9	0.924	TDS = 6.18 Tb + 458.9	505.3	508.1	0.55
	EC, DO	16.57	725.0	0.971	EC = 16.57 DO + 725.0	806	810	0.49
	TDS, DO	8.886	465.3	0.995	TDS = 8.886DO + 465.3	508.8	508.1	-0.14
	Hardness (H), Chloride	0.165	26.31	0.819	Cl^- = 0.165 H + 26.31	75.0	81.65	8.14

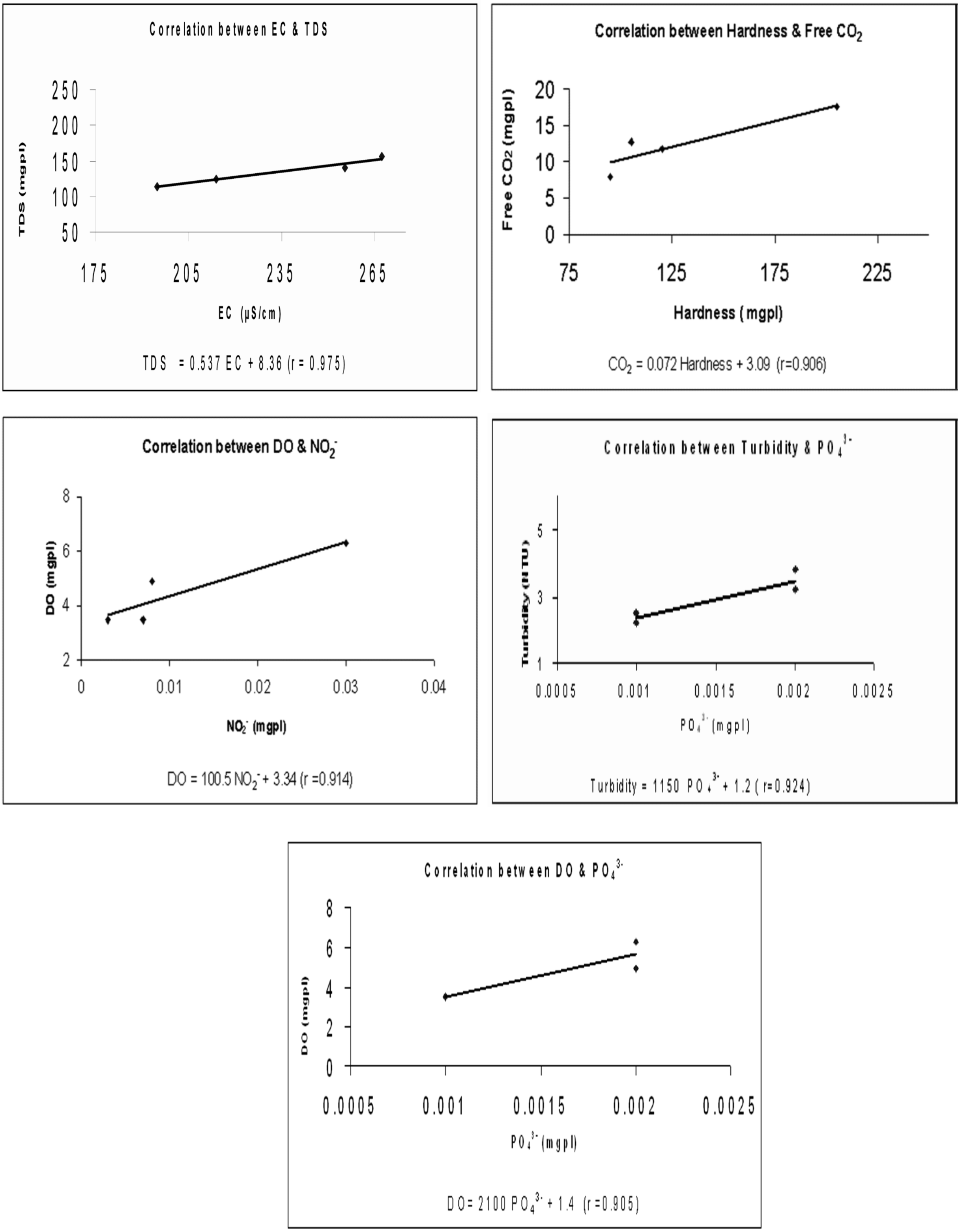

Figure 5: Correlation graphs of significantly correlated parameters of Station I.

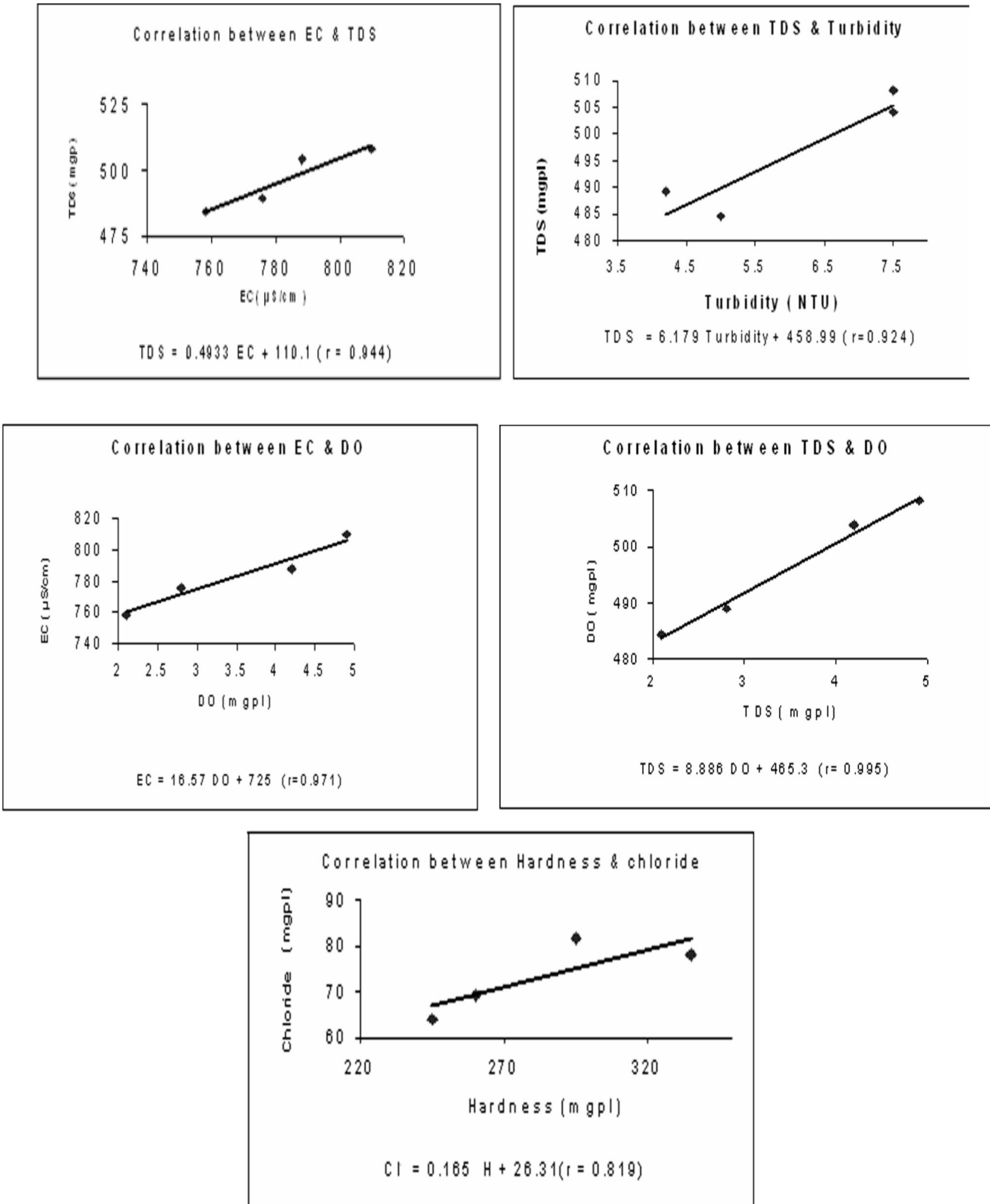

Figure 6: Correlation graphs of significantly correlated parameters of Station II.

Station II shows a negative correlation coefficient for alkalinity, EC, and positive correlation coefficient for turbidity, EC, DO, nitrite and phosphate.

Electrical Cconductivity

Electrical conductivity (EC) is a measure of how well solution conducts electricity and is correlated with salt content. EC is typically reported in units of µS/cm (micro siemens per centimetre). Freshwater fish generally thrive over a wide range of electrically conductive aquatic phase. Some minimum salt content is desirable for fish to maintain their osmotic balance. The highest range varies between different fish species (Stone and Thomforde, 2004).

EC of Station I samples varied between 195 and 267 µS/cm. In Station II, the values were within the range 758–810 µS/cm. The permissible limit of EC is between 50–500 µS/cm. In Station I, correlation coefficient of EC on TDS, DO, chloride, alkalinity, nitrites and phosphates were positive while for hardness and free carbon dioxide were negative. In Station II, positive correlation coefficient was shown with TDS, DO, chloride, hardness and nitrite while alkalinity, free carbon dioxide and phosphate showed negative correlation coefficient.

The EC of samples from Station I varied between 194.9 and 267.2 and the average value with 95% CL was found to be 232.9 ± (33.44). In Station II the value ranges between 758 and 810 and the average value with 95% CL was found to be 783 ± (21.38).

Total Dissolved Solids

Total Dissolved Solids is one of the most important physico–chemical parameter of fresh water system that directly or indirectly affects the ecology of biota living there. The standard limit of total dissolved solids is 500 mgpl. The TDS of samples from Station I was found to be between 112 and 156 mgpl and was within the tolerance limits. The TDS of samples from Station II varied between 484–508 mgpl. Samples 6 and 7 of Station II showed a slight increase while all the other samples were well within the limits.

In Station I, a strong correlation was observed between TDS and EC (r = 0.975) whereas in Station II TDS showed a strong positive correlation with turbidity (r = 0.924), DO (r = 0.971) in addition to EC (r = 0.944). In Station I, the average value with 95% CL was found to be 133.4 ± 8.42 and in Station II, it was found to be 496.4 ± (11.18).

Turbidity

Penetration of light is checked by suspended particles and when the aquatic bodies have considerable depth; this may restrict the photosynthetic zone. Turbidity is caused by clay, silt and other fine matter entering into the water body and by the oxidation of dissolved ferrous and manganese in insoluble forms. In Station I, the turbidity was within the tolerance limit and value ranged between 2.2 and 3.8 NTU, showing a less amount of suspended matter. Besides the samples from Station II was in the range 4.2 to 7.5 NTU. The presence of turbidity may be due to some suspended particles or impurities. Earlier studies were conducted in wells of these areas and turbidity had an average value of 5 NTU.

In Station I, turbidity showed a strong positive correlation with phosphate (r = 0.924) while a negative correlation was observed in Station II. Turbidity in Station II was strongly correlated with TDS (r = 0.924) and to some extent nitrite (r = 0.867). In Station I, the average value with 95% CL was found to be 2.9 ± (0.70) and in Station II, it was found to be 496.4 ± (11.18).

Dissolved oxygen

Dissolved Oxygen is one of the most important water quality parameters specific to fish and other aquatic life in pond. It is a measure of the amount of oxygen dissolved in the water that is available for aquatic life and is typically measured in parts per million (ppm). Dissolved oxygen levels fluctuate within the daytime when the activities are in the peak. During night time, plants stop producing oxygen in the photosynthesis process and actually start using up oxygen. The life activity and feeding of fish and aquatic life uses up dissolved oxygen in the pond. Bacteria are also an encounter of DO during decomposition processes to breakdown organic material. During a plant or algae die off, decomposition rates greatly increase and so does the demand for oxygen. Eventually dissolved oxygen comes down drastically and ultimately results in the death of fishes. Dissolved oxygen is provided from plants during the process of photo-synthesis, diffusion of oxygen at the air–water interface, wind or wave action, and cascading or splashing water.

The DO level in Station I varied between 3.5 and 6.3 ppm. The desirable limit of DO is 4–6 ppm. For potable water, the dissolved oxygen should be between 5 and 10 ppm. The concentration of DO might have decreased due to the oxidation of some inorganic wastes or by some processes that consume organic matter.

In Station II, DO vary between 2.1 and 4.9 ppm. In this station, pond sample 7 showed lowest value indicating the intensity of pollution. DO substantially lower than its saturation concentration results in some undesirable processes, which affects the strength of water quality. In Station I, a strong positive correlation for DO was observed with nitrite ($r = 0.914$) and phosphate ($r = 0.905$) while a negative correlation was observed in Station II. Positive correlation was observed for DO with TDS ($r = 0.995$) and EC ($r = 0.971$).

The value of dissolved oxygen in the Vellayani Lake showed a range of 3.42 to 5.87 mgpl (Nair et al., 2000). Similarly in coastal areas of Cochin, several studies were conducted. Pillai et al. (1994) assessed water quality of coastal areas of Cochin and dissolved oxygen varied in the limit 2.68–3.70 mgpl. However, in the present study even though the average value of oxygen in Station I was in the limit, samples 2 and 4 showed a low value and in Station II, sample seven showed the least.

Chloride

Chloride concentration of all samples from both stations showed a lower value and supports geographical nature of the selected sites. Chloride concentration of samples from Station I varied between 10.65 and 19.2 mgpl and the average value with 95% CL was found to be 13.8 ± (4.1). In Station II the value ranges between 64 and 81.7 and the average value with 95% CL was found to be 73.2 ± (7.96). In both stations, there is not any significant correlation for chloride with other parameters.

Sulabha et al. (2003) conducted water analysis of Kottaram temple pond in Kollam district, Kerala, India. The chloride concentration had an average value of 30.06 mgpl, and was well within the tolerance limit. Water with a chloride concentration 150 mgpl is satisfactory for most uses and a higher concentration gives an undesirable taste to water. Infants and children may suffer more with high chloride as their delicate kidney tissues may be damaged by the higher osmotic pressure brought about by the presence of high concentration of salts. Therefore, care should be taken to keep the chloride content of water supply in the range of 250 mgpl.

Alkalinity

Alkalinity is most often measured in terms of mgpl of calcium carbonate equivalents and is the buffering capacity of a pond or lake. This buffering capacity is important to allow pH levels to remain constant even with the introduction of acids from non point source pollution and acid rainfall. Basic materials such as carbonates, hydroxides, phosphates, and bicarbonates are common in pond environments. Alkalinity below 20 mgpl limits primary productivity in water, and ponds with such water is treated with lime. Application rates of copper sulphate for algae control are based on the alkalinity of the water, and copper sulphate should not be used at all in waters with fish if the alkalinity is less than 50 mgpl. (Killian, 1999).

Alkalinity of samples from Station I was within the limits of 230–315 mgpl and the average value with 95% CL was found to be 266.3 ± (35.64). The highest limit of alkalinity is 100 mgpl. All the samples were beyond the limit. The alkalinity of samples from Station II ranged from 255 to 295 mgpl and the value with 95% CL was found to be 276.3 ± (18.92). Except pH no significant correlation with other parameters was noticed.

The alkalinity of natural water is due primarily to the salts of weak acids bicarbonates representing the major form of alkalinity. A few organic acid that are quite resistant to biological oxidation form salts, which contribute to alkalinity. Vasanthy et al. (2000) conducted water quality analysis in Ariyalur, Perambalur district of Tamilnadu. Out of 20 samples tested, 19 samples showed higher values and a maximum value of 440 mgpl.

Total Hardness

Hardness is mainly caused by bivalent cations of calcium and magnesium. Water having hardness below 50 mgpl is soft, 150–300 mgpl is hard and values greater than 300 mgpl are very hard. Surface water is found to be less hard compared to ground water. As the depth increases the dissolution of bicarbonate ion and DO which promote the solubility of calcite, gypsum and dolomite also increases.

The values of hardness of samples from Station I were within the limit. All the samples were found to be moderately hard which may be due to the influence of effluents. The value ranged between 95 and 205 mgpl and the average value with 95% CL was found to be 131.3 ± (49.23). Water samples from Station II showed a range between 245 and 335 mgpl. Water with hardness more than 150 mgpl is found to be objectionable for domestic purposes. Water samples 6, 7, 8 from Station II were moderately hard while sample 5 was rather harder. The average value with 95% CL was found to be 284.1 ± (39.49).

In Station I, a strong correlation was observed between hardness and free CO_2 ($r = 0.906$) whereas in Station II a comparatively less positive correlation was observed ($r = 0.854$). However, no such studies have been done in ponds. Studies conducted in Vellayani Lake by Nair et al. (2000) showed an average value of 20 mgpl, showing a very low percentage of hardness. However, in the present study the ponds were moderately hard.

Free Carbon dioxide

The total amount of carbon dioxide in simple solution and that in the form of H_2CO_3 is called free CO_2. The occurrence of carbon dioxide in water is more complex than that on the land. Since pond algae are plants, they both exhale and inhale oxygen in the photosynthesis process. Under dense conditions, algae can remove all oxygen from water. Therefore, a dense dark green pea soup like pond water is potentially disastrous for pond life.

The value of free carbon dioxide varied between 7.9 and 17.6 mgpl in Station I and the average value with 95% CL was found to be 12.5 ± (3.90). The values were very low and showed only very low percentage of pollution. In Station II, the percentage of free carbon dioxide was found to be nil in most of the samples and only sample 5 showed a threshold limit of 13.2 mgpl.

Nitrite

The nitrite concentration of samples in Station I varied between 0.003 mgpl and 0.03 mgpl. Excretion by phytoplankton, oxidation of ammonia, reduction of nitrate etc. could contribute to the accumulation of nitrite in the aquatic environment. The nitrate concentrations were found to be very low in Station I. It may be due to oxidation of nitrate. In Station II, the concentration ranged between 0.28 mgpl to 3.2 mgpl and sample 8 showed the highest value (3.2 mgpl). In coastal areas of Cochin, the nitrite nitrogen showed value between 0.28 and 4.2 mgpl (Pillai et al., 1994). However, no studies have been conducted regarding nitrite concentration in Plachimada or near by places.

The average value of nitrite in Station I with 95% CL was found to be 0.012 ± (0.01) and in Station II the value obtained was 1.37 ± (1.33). In Station I a good correlation was observed with DO ($r = 0.914$) while in Station II the correlation is comparatively less ($r = 0.715$).

Phosphate

Phosphorous is necessary to all living organism as it is the constituent of ATP present in the nucleic acid as phosphate groups of nucleotides. The usual forms of phosphorus that are found in aqueous solution include orthophosphate, polyphosphate and organic phosphate. The orthophosphates are available for the biological metabolism without further breakdown. Polyphosphates undergo hydrolysis in aqueous solution and revert in to orthophosphate form. The phosphate concentration of samples from Station I varied between 0.001 mgpl to 0.002 mgpl, while that of samples from Station II were within the standard limits (0.015 and 0.105 mgpl). In Station I, Phosphate showed a strong correlation with turbidity ($r = 0.924$) and DO ($r = 0.905$), while in Station II a negative correlation was observed.

The main sources of phosphates are from excreta, food wastes and synthetic detergents. From these detergents contribute a major part. High value of phosphate causes eutrophication but in both stations the values were well within the limits. In Vellayani Lake, the phosphate value ranged between 3.08 and 45.53 mgpl, which was a value in the limit. In coastal areas of Cochin, the concentration was between 8.41 and 14.01 mgpl (Pillai et al., 1994). In Kottaram temple pond the average phosphate concentration was found to be 0.08 mgpl (Sulabha et al., 2003).

Conclusion

The presence of water makes the existence of life possible on earth. Water is a prime natural resource, a basic human need and a precious national asset and in fact, a true wealth in a dry land, without it, land is worthless. However, the most important resource, which is fundamental to life, is fresh water. In view of the vital importance of water for human and animal life, for maintaining ecological balance, for economic and developmental activities, and considering its escalating shortage, planning and management of this resource and its optimal, economical and equitable use has become a matter of utmost urgency. How to make best use of alternative water sources is a major focal point for any country, including using brackish water, reuse of wastewater, developing new desalinisation techniques, exploiting fresh water bodies that are available. As the world's freshwater supply is also deteriorating, more focus should be made on aquatic bodies like ponds, streams, etc. One of the problems complicating the delivery of clean drinking water is the excessive use of fertilizer. Indiscriminate use of nitrate-rich manure in agriculture, large quantities of nitrate have leached through the soil to the groundwater. Kerala, land of 44 rivers and backwaters and an annual rainfall of 3000 mm is now facing drought in every summer. In this scenario, the Palakkad district in the state is the most affected part facing water scarcity. Maintaining water quality standard of these water bodies like ponds, water shortage can be minimised to some extent.

The physico–chemical analysis of eight ponds showed that, some ponds could be used as a source of freshwater. With few exceptions, all hydrographical parameters were within the desirable standards. The desirable limit and permissible limit in the absence of alternative source of drinking water as per the BIS 10500: 1991 specification is given in Table 7. The ponds that belong to Pattenchery panchayath are slightly acidic and can be neutralised by the controlled addition of lime. The statistical study of 11 physico-chemical parameters of pond water reveals that all the parameters were more or less correlated with one another. Further microbiological studies have to be carried out on these ponds and if any problem exists, it may be tackled by water treatment methods like aeration; chlorination, etc., and these resources can be converted into even drinking water.

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Calendar of Events

2011 International Conference on Environment Science and Engineering – ICESE 2011
1 to 3 April 2011
Bali Island, Indonesia
Website: http://www.icese.org/
Contact name: Conferences Secretary
Sponsored by: CBEES, IEEE

Water & Environment 2011: CIWEM's Annual Conference
6 to 7 April 2011
London, United Kingdom
Website: http://www.ciwem.org/events/annual-conference.aspx
Contact name: Lauren Goozee
Organized by: CIWEM

Environmental International Forum SAVE the Planet – Waste & Water Management, Recycling
13 to 15 April 2011
Sofia, Bulgaria
Website: http://www.viaexpo.com/index.php?option=com_content&view=article&id=113&Itemid=138&lang=en
Contact name: Maya Kristeva
Organized by: Via Expo

International Summit on Water in Developing Countries
15 April 2011
Washington, DC, United States
Website: http://www.watersummit.org
Contact name: May Gwinn
Organized by: Rotary Clubs of Washington, DC and Paris Academies (France)

Global Water Summit 2011
18 to 19 April 2011
Berlin, Germany
Website: http://www.watermeetsmoney.com
Contact name: Emma Welsh
Organized by: Global Water Intelligence

Gulf Wastewater Treatment & Reuse Summit 2011
26 to 28 April 2011
Dubai, United Arab Emirates
Website: http://www.fleminggulf.com/utilities/middle-east/the-gulf-wastewater-summit-2011
Contact name: Lucia Kasanicka
Organized by: Fleming Gulf Conferences

World Environmental and Water Resources Congress
22 to 26 May 2011
Palm Springs, California, United States
Website: http://content.asce.org/conferences/ewri2011/index.html
Contact name: Lucy King
Organized by: ASCE/EWRI

Water Resources Management 2011
23 to 25 May 2011
Riverside, California, United States
Website: http://www.wessex.ac.uk/11-conferences/waterresourcesmanagement-2011.html
Contact name: Alice Jones
Organized by: Wessex Institute of Technology

International Seminar on River, Society and Sustainable Development
26 to 29 May 2011
Dibrugarh University, Dibrugarh, Assam, India, Assam, India
Website: http://dibru.ac.in/INSIDE/Inter%20seminar/Internationalseminar
Contact name: Dr. M. Hazarika
Organized by: Dibrugarh University, Assam, India

The 8th IWA Leading-Edge Conference on Water and Wastewater Technologies
6 to 10 June 2011
Amsterdam, North Holland, Netherlands
Website: http://www.let2011.org
Organized by: IWA

ACE11 The World's Water Event
12 to 16 June 2011
Washington, DC, United States
Website: http://www.awwa.org/ACE11/index.cfm
Contact name: American Water Works Assocation
Organized by: American Water Works Assocation

Climate Change and Water Management - Meeting the Challenges in the Barents Region
15 to 16 June 2011
Arkhangelsk, Russian Federation
Website: http://waterclimate2011.com/default_.aspx
Organized by: The Nordic Council of Ministers, Barents Euro-Arctic Council, Arkhangelsk Region Government