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Original Research Paper

Monitoring the Pollution Intensity of Wetlands of Coimbatore, Tamil Nadu, India

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ABSTRACT

In the semiarid region in India, rainfall cannot be relied on for irrigation of crops due to its irregularities in availability as well as quantity. Tank irrigation is the best alternate solution for crops; but due to unscientific anthropogenic practices, the water quality of wetlands has degraded. Coimbatore city is currently facing acute water crisis because of degradation of the quality of water. The wetlands, which recharge the groundwater aquifers, have degraded in quality due to the discharge of domestic and industrial sewage. Continuous monitoring of surface water is essential for ensuring groundwater quality. The seven major tanks of the city were selected for the present study. The Water Quality Index of the wetlands during the premonsoon ranged from 41.23 for Perur lake to 82.03 for Ukkadam lake. The water type of the wetlands of the study area predominantly is of $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $NaHCO_3$ and NaCl type. The suitability of water for irrigation purposes was analysed using USSL (US Salinity Laboratory) classification system, and it was found that the water from three of the wetlands fall under S1C1 class, which indicate low salinity hazard. The Kurichi lake comes under S1C2 class and the other wetlands fall under S1C2 and S1C3 class. The study showed that the water from Singanallur wetland, Ukkadam wetland and Selvachinthamani wetland is unsuitable for irrigation due to high SAR (Sodium Adsorption Ratio) and electrical conductivity. The seasonal variation study showed that the wetland water quality parameters during premonsoon were higher than that of post monsoon. Ukkadam wetland and Singanallur wetland showed a degraded water quality due to continuous discharge of domestic and industrial sewage.

INTRODUCTION

Coimbatore, the textile capital of south India, is a highly populated industrial city, situated in the western Tamil Nadu, near the State of Kerala. It is located between 10°55'-11°10'N latitude and 77°10'-76°50'E longitude at an altitude of 470 m. It is surrounded by mountains on the west, with reserve forests and the Nilgiri Biosphere Reserve on the northern side. It is situated on the banks of River Noyyal, which forms a sub-basin of Cauvery river. The Noyyal is a seasonal river having good flow only for short periods during the north-east and south-west monsoon (Paul & Prakash Nelliyat 2007). The Noyyal river emerges in the Vellingiri hills of Western Ghats and flows over a distance of 180 km in an area of 3510 sq. km to join the River Cauvery at Karur district (Priya et al. 2008). There are many industries like textile mills, foundries and manufacturing industries in the city. But the city lacks proper drainage system and the facilities for treatment of industrial, municipal, domestic and hospital wastes are poor. Till now there is no integrated sewerage system. The existing drainage and sewerage systems are of open type, discharging wastes into lakes, wetlands and the Noyyal river without appropriate treatment. The city is rich with 28 wetlands, mostly fed by the River Noyyal. The river and the river-fed wetlands support a large number of plants (Chandra Bose & Nair 1988). The Noyyal's canals feed the lakes, most of them are interconnected and fill one after the other by natural gradient. These lakes cover an area of 2000 acres, thousands of which are within the city limit itself. The lakes are connected in chain link manner, well planned by the ancient rulers. Presently, the system has been disrupted and deteriorated due to mismanagement and overall negligence. Most of these wetlands get dried in summer and serve as dumping yard for garbage and industrial wastes (Mohanraj et al. 2000). Wetlands situated in the vicinity of cities undergo rapid degradation due to various factors related with city development like waste dumping, deforestation, industries and large scale reclamation for other uses. Inflows of wastewater carrying loads in due course of time overwhelm natural assimilation and carrying capacity of receiving water bodies (Prusty 2008). The bund of many wetlands is unscientifically used for open defecation by humans as well as animals. The quality of wetlands is so degraded that they are not suitable for drinking purposes. Water from some of the wetlands is used for agricultural purposes. Many of these wetlands support rich flora and fauna, which are reported in earlier studies (Chandra Bose & Nair 1988, Lalitha Vijayan et al. 2007). The flora and fauna will be greatly affected by degradation of water quality. As the environment of bottom-dwelling organisms is the final deposition of pollutants, they are subjected to greater pressures (Gupta & Sharma 2005). In addition to this, the degradation of surface water poses more stress on groundwater and results in overexploitation of groundwater for domestic and agricultural purposes. In 1970's Coimbatore district was declared as a drought prone district. In 1980's UNDP warned that Coimbatore district had the record of fastest depleting groundwater level in the world. This happened due to degradation of surface water quality. It becomes mandatory to minimize the surface water pollution to safeguard the water resources of the city. Government and other NGOs have taken some steps to prevent further pollution of surface water. To ascertain the extent of pollution of the water bodies in the current situation, seven wetlands which fall in the city limits, were selected for the study.

MATERIALS AND METHODS

Seven wetlands falling within the city limit namely Kuruchi Kulam, Perur lake, Selvapuram (Selvachinthamani) lake, Kumaraswami lake, Ukkadam lake, Narasampathi lake and Singanallur lake were selected for the study. Of these, the pollution intensity of Kumaraswami lake and Narasampathi lake are poorly known from earlier studies. The study area showing the location of wetlands is shown in Fig. 1.

Kurichikulam lake has a registered ayacut of 452 acres in the catchment area, 6.272 sq. km of free and 12.162 sq. km of combined area. The full lake level is 10.75m. Perur lake is located in the village Perur. It has a registered ayacut of 866 acres in the catchment area, 2.227sq. km of free and 5.888 sq. km of combined area. The full lake level is 14.8m. The lake is surrounded by small villages and agricultural lands. Selvachinthamani lake is located in the village Selvapuram in Kumarapalayam. The capacity of the lake is 3.02 MCft. Its registered ayacut is 72 acres with a water spread area of 37.07 acres. The catchment area is 16 sq. km. There is only one sluice present in this lake. The full lake level is 6m. Kumaraswamy lake is located in the village Kumarapalayam. The capacity of the tank is 19.89 MCft. Its registered ayacut is 190 acres with a water spread area of 93.67 acres. The catchment area is 16 sq. km. There are two sluices present in this lake. The full lake level is 10.5m. Ukkadam lake is located in the village Ukkadam. It has a registered ayacut of 231 acres in the catchment area of 1.90 sq. km. The full lake level is 14.8m. It is situated near the municipal bus stand. The area is highly urbanized and receives both municipal and industrial sewage. The dumping of solid waste was practiced here earlier, but now the lake is protected by a boundary wall, and dumping of solid waste is almost stopped. But still near the road side, on the bunds, open defecation was noticed during the sample collection. The Narasimpathy lake is situated in village Veerapatti. The capacity of the lake is 59.8 MCft. The lake has 560.65 acres of registered ayacut with water spread area of 122.51 acres. The catchment area is 16 sq. km. There are two sluices present in the lake and its full level is 11m. Singanallur lake has a water spread area of 1.153 sq. km. The capacity of the lake is 1.48 Mm^3. The registered irrigated area is 337.1 ha. The lake is partly affected with eutrophication on the northern side during sample collection. This lake was earlier used for recreational boating, but due to the discharge of domestic waste, it was affected with eutrophication, and now the boathouse has shut off its working. Efforts have been made by NGOs and the Government to remove the water hyacinth. The earlier studies by Mohanraj et al. (2000) pointed out the status of Singanallur wetland as affected fully by eutrophication.

Samples were collected from each lake at three different locations in pre-cleaned bottles of 2 L capacity to get a representative sample. The samples were transferred to the laboratory in a time duration of 8 hours and analysed for various physico-chemical parameters by standard methods (Greenberg et al. 1992). The parameters analysed include pH, total dissolved solids (TDS), dissolved oxygen (DO), total alkalinity (TA), chlorides (Cl), total hardness (TH), sulphates (Sulp), nitrates (Nit), sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) during the postmonsoon (August 2009) and premonsoon season (February 2010).

The Water Quality Index (WQI) for the samples was calculated from the physico-chemical parameters using the following expression.

$$WQI = \text{antilog} \sum_{i=1} W_i \log_{10} q_i \quad ...(1)$$

Where W_i is the weightage for each parameter. It is calculated as,

$$W_i = K/S_i \quad ...(2)$$

K is the proportionality constant and S_i is the standard value for water quality parameter as per BIS/ICMR for each parameter.

K is calculated as,

$$K = 1/ \sum (1/S_i) \quad ...(3)$$

The standard values for water quality parameters and their weightage are given in Table 2. The quality rating, q_i is calculated as,

$$q_i = 100 * \{(V_{actual} - V_{ideal})/(V_{standard} - V_{ideal})\} \quad ...(4)$$

Where V_{actual} is the observed value for each parameter, V_{ideal} is the ideal value for each parameter and $V_{standard}$ is the standard value for each parameter as per BIS/ICMR standards. V_{ideal} for pH is taken as 7 and that for DO is taken as 14.6 mg/L and for all other parameters, value is 0.

The Hill Piper diagram is a trilinear diagram having two triangles, one of which shows the cations and the other shows the anions. The cation and anion fields are combined to show

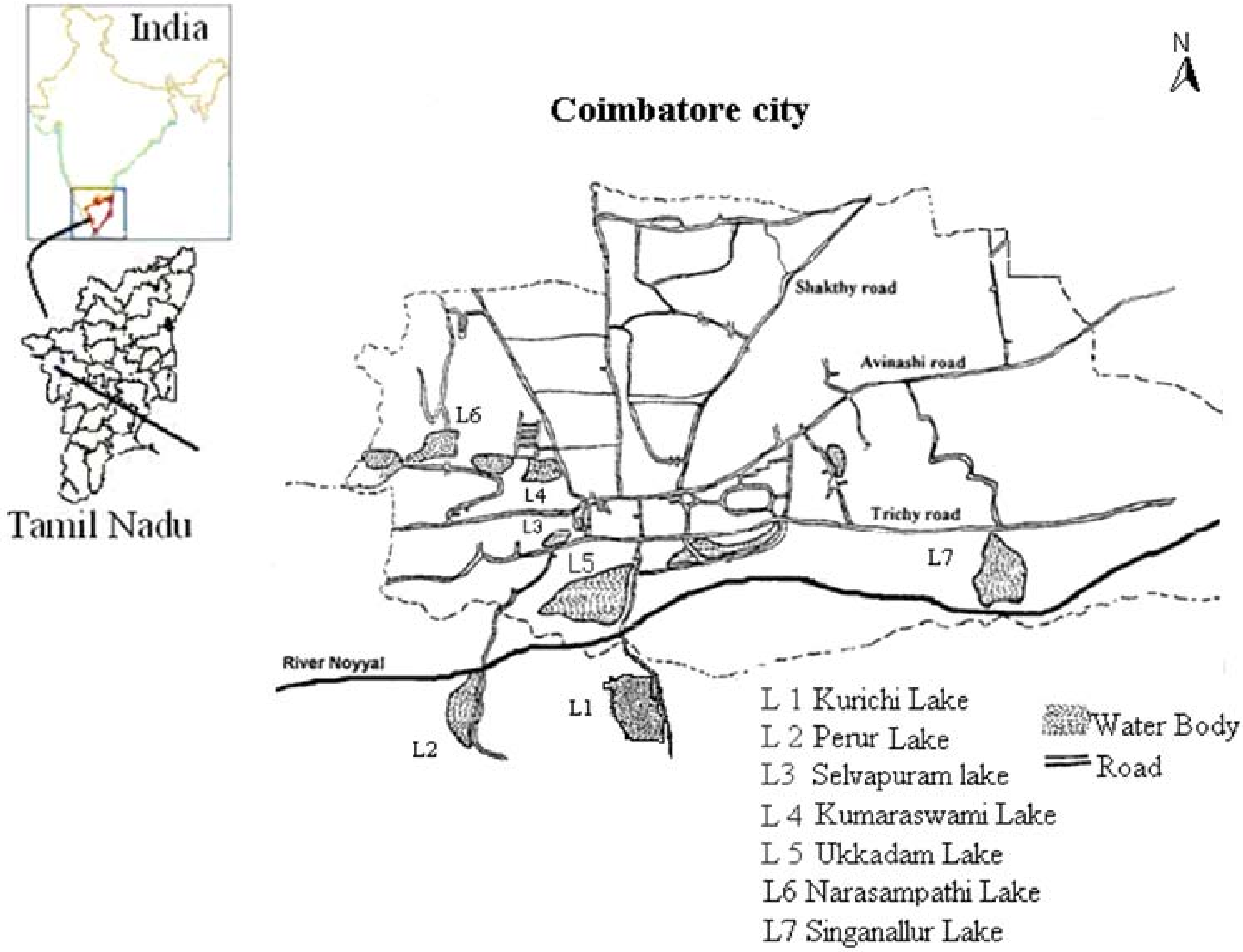

Fig. 1: Study area showing the location of lakes.

a single point in a diamond-shaped field, from which the characteristics of the water samples are drawn.

RESULTS AND DISCUSSION

The results of physio-chemical analysis of water are given in Tables 1a and 1b. The pH of water samples from all the wetlands lie within the permissible limit as per BIS standards of 6.5 to 8.5 during both postmonsoon and premonsoon. The highest pH was found to be for Ukkadam lake during both the seasons. A pH of 7.49 was reported in earlier studies on Ukkadam lake during the month of March 2009 by the same author (Priya et al. 2010). The rise in pH of Ukkadam wetland indicates increased pollution. The chlorides varied from 10.6 mg/L for Perur lake to 540 mg/L for Singanallur lake during the postmonsoon, and from 23.34 mg/L for Perur lake to 575 mg/L for Ukkadam lake during the premonsoon. The human as well as animal defecation is the main cause for high chlorides in Ukkadam wetland. The chlorides during postmonsoon were found to be less as compared to premonsoon due to the fact that during premonsoon, the water level falls and as a result, there is an increase in concentration of pollutants. The high chlorides in Singanallur wetland during postmonsoon compared to pre monsoon is due to land leachate along with runoff water during monsoon. The high chlorides in Ukkadam wetland are probably due to the joining of effluents form bleaching industries. Higher chlorides greater than the permissible limit prescribed by BIS standards was found for water samples from Selvachinthamani lake and Singanallur lake. Dissolved oxygen was found to vary from 2.65 mg/L to 6.26 mg/L during the postmonsoon. During the premonsoon, dissolved oxygen varied from 2.95 mg/L to 6.5 mg/L, the lowest for Narasampathy lake, and highest for Kumaraswami lake. The DO for all the samples except for Narasampathy wetland was found to be appreciable for aquatic life during the premonsoon. A slight increase in DO during the premonsoon

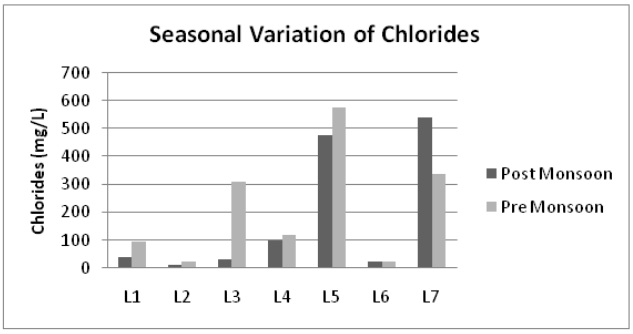

Fig. 2a: Seasonal variation of chlorides.

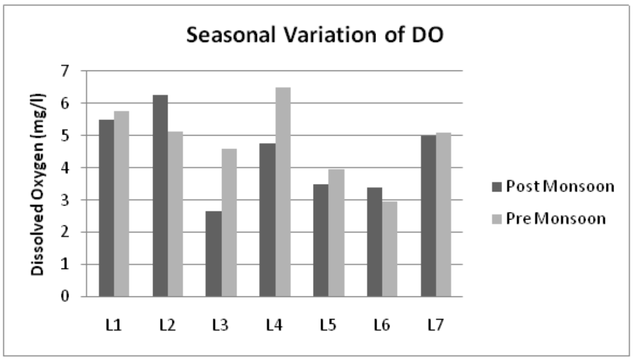

Fig. 2b: Seasonal variation of dissolved oxygen.

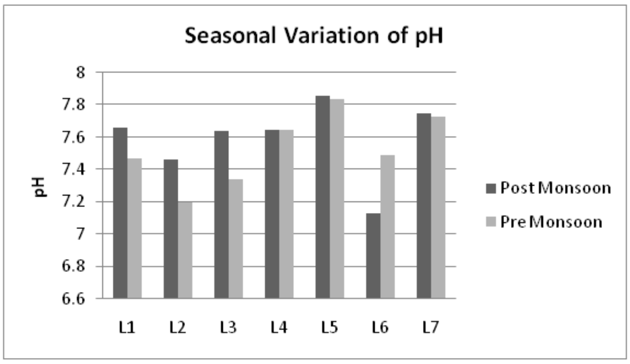

Fig. 2c: Seasonal variation of pH.

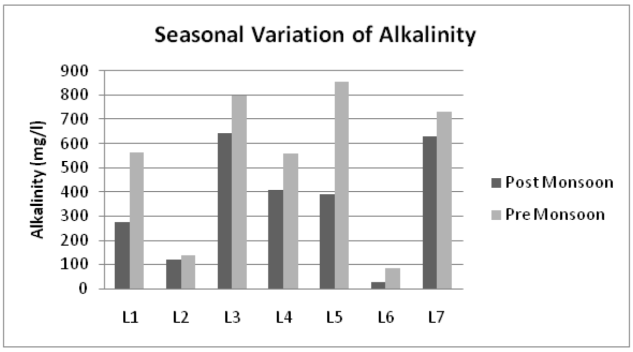

Fig. 2d: Seasonal variation of alkalinity.

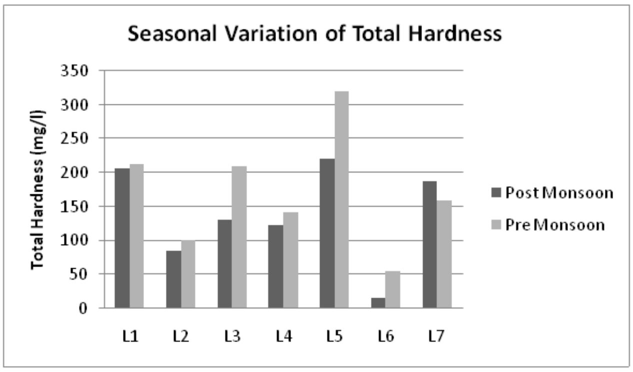

Fig. 2e: Seasonal variation of total hardness.

is due to the fact that the temperature was slightly low compared to the postmonsoon and that DO increases as temperature decreases. The total alkalinity ranged from 120.3 mg/L to 630 mg/L during the postmonsoon and from 82.5 mg/L to 855 mg/L during the premonsoon. The high alkalinity of water samples from Ukkadam and Singanallur lakes may be due to the carbonates which reach the lake from the domestic sewage. The alkalinity of Ukkadam lake was high compared to the reports of Rachna (2009) and Priya (2010). This shows the increase in pollution intensity in the Ukkadam wetland. The alkalinity of Singanallur lake and Kurichi lake also showed a hike compared to the reports of Priya (2010). Total hardness ranged from 55 mg/L to 320 mg/L, the highest being for Ukkadam lake during the postmonsoon as well as premonsoon. The total hardness for all the samples was within the permissible limit during the postmonsoon whereas for the premonsoon, it was slightly greater than the permissible limit for Ukkadam lake. High value for sodium ions was found for the samples from Selvapuram wetland, Ukkadam wetland and Singanallur wetland during the premonsoon. The chlorides of these wetlands were also found to be high that indicates the presence of sodium chloride in the samples collected from Selvapuram lake, Ukkadam lake and Singanallur lake. High sodium chloride in samples indicate pollution from human and animal waste, which enters the wetland through open defecation practices in the vicinity of these wetlands. Sulphates ranged from 1 mg/L to 90.75 mg/L and are within the permissible limit specified by BIS drinking water standards. Nitrates ranged from 1 mg/L to 16.2 mg/L, the highest value was found to be for Singanallur wetland. High value of nitrates more than 45 mg/L may lead to methaemoglobinaemia or blue baby syndrome in infants. The BOD ranged from 1.8 mg/L to 12.7 mg/L during the postmonsoon and from 1.2 mg/L to 11.66 mg/L, during the premonsoon. BOD values greater than 20mg/L indicate organic pollution.

The Figs, 2.a to 2.e show the seasonal variation of water quality characteristics of the wetlands.

The water quality characteristics are slightly higher during the premonsoon as compared to the postmonsoon sea-

Table 1.a: Physio-chemical characteristics of wetlands (postmonsoon).

	Parameters	BIS standards	Sampling lakes						
			L1	L2	L3	L4	L5	L6	L7
1	Chlorides (mg/L)	250	39.3	10.6	33.46	101.1	477.2	25.04	540
2	pH	6.5-8.5	7.66	7.46	7.64	7.65	7.86	7.13	7.75
3	Dissolved Oxygen (mg/L)	NA	5.48	6.26	2.65	4.75	3.47	3.38	5.0
4	Total Alkalinity (mg/L)	200	273	120.3	643	410	390	25.6	630
5	Total Hardness (mg/L)	300	206.7	85.67	131.33	123.33	220	15	188
6	Calcium (Ca^{2+}) (mg/L)	75	3.2	2.92	6.12	2.8	5.47	2.53	56
7	Magnesium (Mg^{2+}) (mg/L)	30	3.06	2.034	3.895	3.96	2.017	2.104	11.664
8	BOD (mg/L)	NA	7.11	1.8	12.7	8.63	10.3	10.82	5.9

Table 1.b Physio-chemical characteristics of wetlands (premonsoon).

	Parameters	BIS Standards	Sampling lakes						
			L1	L2	L3	L4	L5	L6	L7
1	Chlorides (mg/l)	250	95	23.34	310	118.4	575	25.5	340
2	pH	6.5-8.5	7.47	7.2	7.34	7.65	7.84	7.49	7.73
3	Dissolved Oxygen (mg/L)	NA	5.75	5.13	4.6	6.5	3.95	2.95	5.1
4	Total Alkalinity (mg/L)	200	565	139.3	800	560	855	82.5	730
5	Total Hardness (mg/L)	300	212.5	101.6	210	141.98	320	55	159.55
6	Calcium (Ca^{2+}) (mg/L)	75	47	20.26	66	32	44	14.4	15.03
7	Magnesium (Mg^{2+}) (mg/L)	30	23.08	12.41	10.93	15.06	51.03	4.62	29.64
8	Sodium (Na^{2+}) (mg/L)	NA	30.1	12	264.8	17.4	292.6	15.5	191
9	Potassium (K^{+}) (mg/L)	NA	4.9	4.6	10	4.9	16.4	2	19
10	Sulphates (mg/L)	200	6.5	3	69	19	33.5	1	90.75
11	Nitrates (mg/L)	45	1	9.2	5	10	6	8.8	16.2
12	BOD (mg/L)	NA	6.21	5.7	8.8	1.2	9.8	11.66	5.7
	Water Quality Index		51.33	41.23	53.93	59.13	82.03	52.63	72.53

Note: NA-Not specified in BIS drinking water standards

Table 2: Irrigation characteristics of wetland water samples.

Samples	SAR	ESR	% Na	MH (%)	RSC	EC
L1	0.929	0.319	22.95	44.7	4.4	443.05
L2	0.518	0.518	19.46	50.2	0	217.43
L3	7.95	7.95	72.1	21.5	7.79	1992
L4	0.636	0.636	20.28	43.7	5.94	863.4
L5	7.12	7.12	64.99	65.7	7.28	1997
L6	0.91	0.91	36.87	34.6	0.162	215.4
L7	6.58	6.58	69.26	76.5	8.37	1445

Note: SAR-Sodium Adsorption Ratio, ESR-Exchangeable Sodium Ratio, % Na-% Sodium, MH-Magnesium Hazard, RSC-Residual Sodium Carbonate (meq/L), EC-Electrical Conductivity (micromho/cm)

son due to the fact that during postmonsoon the storm water adds to the dilution of concentration of pollutants. The dissolved oxygen was found to be slightly higher during the premonsoon because the water temperature was low during the month of premonsoon compared to postmonsoon. The Fig. 3 shows the Piper diagram for the water samples. The Piper diagram gives an idea of the type of water of the wetlands and indicates about the dominating pollutant in a particular wetland. Fig. 4 shows the Schoeller diagram showing the distribution of ions in the study area.

It was found that the water samples from Kurichi lake, Kumaraswami lake and Narasampathi lake exhibited a water type of $Ca(HCO_3)_2$ whereas Selvapuram lake and Singanallur lake exhibited a water type of $NaHCO_3$. The type of water found in Perur lake was of $Mg(HCO_3)_2$ type and that in Ukkadam lake was of NaCl type. As the region is not a coastal region, the chance of occurring NaCl water type in

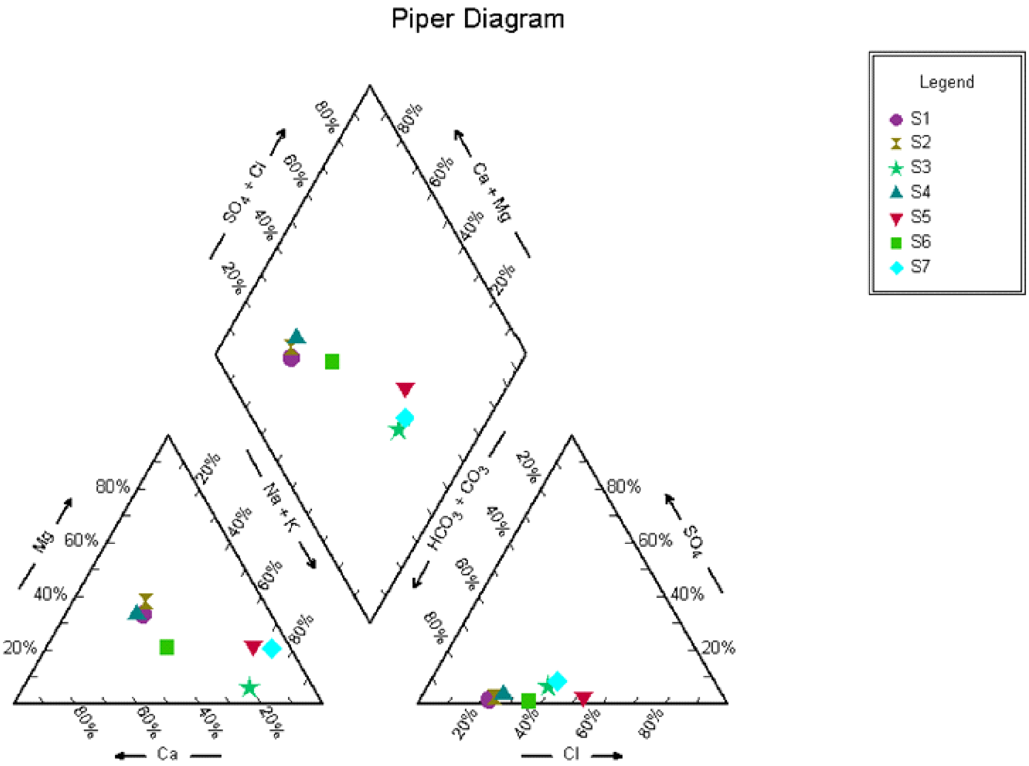

Fig. 3: Piper diagram for the wetland water samples.

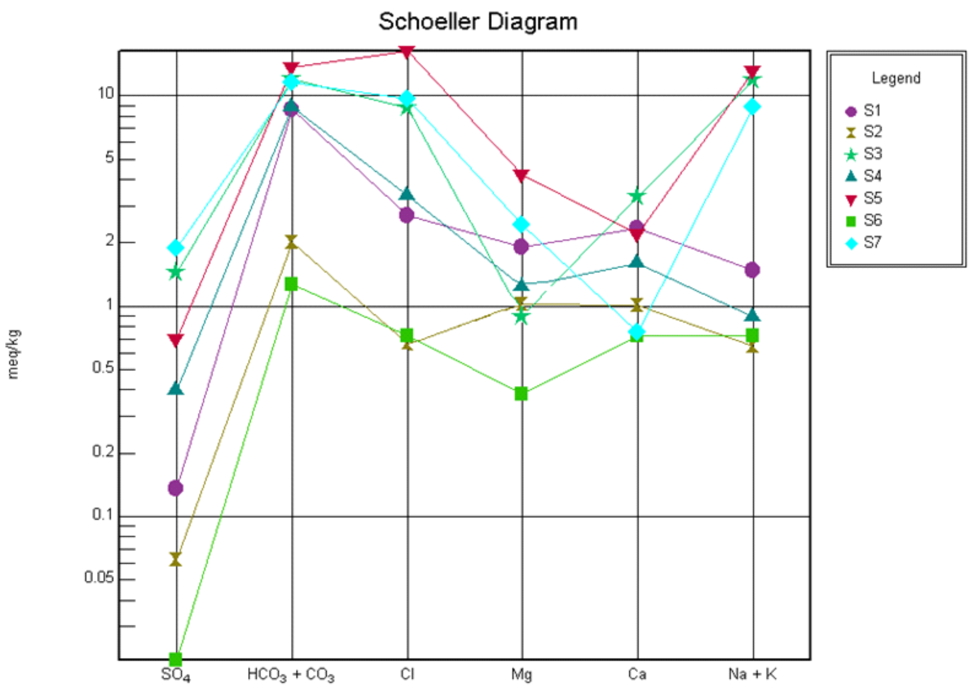

Fig. 4: Schoeller diagram for the study area.

Table 3a: Water class based on sodium adsorption ratio.

Sodium hazard class	SAR	Water class	Samples
S1	< 10	Excellent	All samples
S2	10-18	Good	Nil
S3	18-26	Poorly suitable	Nil
S4	> 26	Unsuitable	Nil

Table 3b: Water class based on % sodium.

% Sodium	Water Class	Samples
< 20	Excellent	L2
20-40	Good	L1, L4, L6
40-60	Permissible	Nil
60-80	Poorly suitable	L3, L5, L7
> 80	Unsuitable	Nil

Table 3c: Water class based on electrical conductivity.

Salinity Hazard class	Salinity hazard	Conductivity (micro mho/cm)	Samples
C1	Low salinity, no detrimental effects expected	<250	L2, L6
C2	Medium salinity, detrimental effects to sensitive crops	250-750	L1
C3	High salinity, adverseeffects on many crops	750-2250	L3, L4. L5, L7
C4	Very high salinity suitable only for salt tolerant plants	> 2250	Nil

Ukkadam wetland is definitely due to the entry of human and animal waste into the wetland. These practices have led to the degradation of water quality, and it becomes evident that the water from these wetlands does not fulfil the requirements of drinking water. The water from these wetlands is being used for irrigation purposes in the nearby vicinity.

The suitability of water for irrigation purposes can be ascertained by certain parameters such as Sodium Adsorption Ratio (SAR), Exchangeable Sodium Ratio (ESR), % sodium (% Na), Magnesium Hazard (MH), Electrical Conductivity (EC) and Residual Sodium Carbonate (RSC).

$$SAR = Na^{+}/[(Ca^{2+} + Mg^{2+})\backslash 2]^{1/2}$$

$$ESR = Na^{+}/(Ca^{2+} + Mg^{2+})$$

$$\% Na = Na^{+} \times 100 / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})$$

$$MH = Mg^{2+}/(Ca^{2+} + Mg^{2+})$$

$$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

The irrigation characteristics of water samples of the wetlands are summarized in Table 2 and the classification of waters based on suitability for irrigation is given in Table 3a to Table 3c. From this classification, it becomes evident that the water from Kurichi wetland, Perur wetland and Narasampathi wetland fulfil the requirements for irrigation, while Selvapuram wetland, Ukkadam wetland and Singanallur wetland are degraded in quality and the water cannot be used for irrigation purposes. Based on USSL (United States Salinity Laboratory) classification system, Perur lake and Narasampathi lake falls under S1C1, Kurichi lake comes under S1C2 and the remaining lakes come under S1C3 group. The registered irrigated area for Ukkadam lake and Selvapuram lake is quite small, while that of Singanallur lake is as large as about 350 hectares. In order that crops do not get detrimental effects, suitable management measures to reduce the pollution of these wetlands become necessary. This should be made possible only by the combined efforts of Government, NGOs and the public participation.

At present, the water from the wetlands is not used by the public for drinking purposes, but it is being used for irrigation and livestock. The wetlands also help in recharging the groundwater which is another source for domestic and agricultural use. So if the quality of water in the wetlands is not controlled, the water crisis of the city will aggravate and a situation will arise when the entire surface water gets deteriorated. The polluted water percolates and recharges the groundwater, thus, resulting in the qualitative degradation of groundwater also. Steps need to be implemented to minimize the pollution of these wetlands.

CONCLUSIONS

Water quality of Coimbatore wetlands has shown a deterioration in the past few decades. The present study reveals that the water quality of the wetlands has degraded in past few years. The water quality characteristics during the premonsoon were found to be higher as compared to that of postmonsoon. The water types of the study area were $Ca(HCO_3)_2$, $NaHCO_3$, $Mg(HCO_3)_2$ and NaCl type. The Ukkadam wetland exhibited the water type of NaCl due to the fact that it continuously receives human waste as well as municipal sewage. Some of the wetlands such as Kurichi wetland, Perur wetland and Narasampathi wetland can be used for irrigation as they fulfil the requirements of irrigation water. The water quality of Singanallur wetland and Ukkadam wetland was so worse that it cannot be used for any purpose. Since the city do not have proper sewerage system and wastewater treatment plant, the sewage, both domestic and industrial, reaches the wetlands. Therefore, it is suggested to have a proper sewerage system for the city along with a combined sewage treatment plant which needs to be properly monitored and maintained regularly. There is a general tendency to dump solid wastes on the banks of the lakes. This will leach down into the wetland during rain and thereby polluting the water. This will not only pollute the lake waters, but the leachates also percolate into the groundwater to cause its pollution. So there is necessity for a well planned collection system of solid wastes from the city to reduce dumping of wastes on open land. The city is in dire need of a solid waste treatment plant along with its proper collection and transportation. The hygienic conditions of the city need to be uplifted by construction of comfort stations at different locations in order to prevent open defecation. These should be followed by continuous monitoring of the quality of water so that well planned hygiene city conditions can be attained.

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