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Assessment of Physicochemical Characteristics and the Level of Nutrient Contents as Well as Heavy Metal Ions in Waters of Three Lakes at Coimbatore, Tamil Nadu, India

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Abstract
Lake water quality degradation and heavy metals pollution have been serious environmental threats for last decades, especially in those fresh water lakes situated in the vicinity of the cities and human habitations. The present study aimed to investigate the physicochemical parameters, level of nutrient contents and heavy metals to determine the water quality of Ukkadam, Kuruchi and Singanallur Lakes. All the physicochemical parameters except dissolved oxygen, sulphate, silicate and nitrate values were found above the prescribed limit as recommended by WHO (2011) and BIS (2003) drinking water quality. The concentrations of Ca, Cr, Cu, Fe, Ni and Pb in waters of the selected three lakes ranged from 0.014 – 0.038, 0.145 – 0.063, 0.025 – 0.552, 0.100 – 3.460, 0.028 – 0.117 and 0.463 – 2.172 mg/L respectively. The concentrations of heavy metals except Cu were found to be higher than the permeable dose. This investigation revealed that the water in these lakes is partially contaminated with high level of heavy metals. It is recommended that proper implementation of new wetland waste management system and constant monitoring is urgently required to maintain good water quality in these lakes for future generation.

Keywords: Physicochemical parameters; Nutrient; Heavy metals; Coimbatore

1. Introduction
Lakes are important natural resources for freshwater, replenishing of ground water and also habitats for wide variety of flora and fauna. Worldwide lakes act as a key factor for climatic changes and are considered as one of the most versatile ecosystems [1]. They are facing variety of pressures such as eutrophication and heavy metal pollutions due to anthropogenic activities. In recent years, rapid growth of human population, intensive development of industrial, agricultural based sectors have resulted in surplus discharge of these toxic wastes along with the municipal waste materials into the wetland lakes. This in turn has increased the level of nutrient inputs against the safe level of their natural occurrence, resulting in accelerated eutrophication [2].

In worldwide more than one billion people do not have suitable drinking water, and two to three billions lack access to basic sanitation services. About three to five millions peoples are dying annually from water related diseases [3, 4]. Surface waters (fresh water lakes, rivers, streams) are the principal natural water resources [5]. Nowadays heavy metals have become common pollutants throughout the world due to their toxic nature towards all living organisms. Heavy metals are being discharged into the aquatic ecosystems through natural and anthropogenic sources [6]. These pollutants are playing a major role in the degradation of wetlands and directly affect biotic inhabitants [5].

Coimbatore is referred popularly to as Southern Manchester of India, an important industrial city in Tamilnadu. There are around 28 wetlands in and around the city limits which are mostly fed by Noyyal river. The lake water has been used for agricultural land irrigation purposes and fish culturing by local farmers. These wetlands serve as a common reservoir of untreated industrial effluents, dumping of agricultural as well as municipal wastes bring more concern for the aquatic environment. Ukkadam lake has the largest water spread area with urbanized level. Hence water irrigation from this wetland is low but, the lake is being used for regular fishing. A number of migratory birds are encountered in the lake during winter. The Kuruchi wetland has a water spread area of 343.96 acres and holds the least water storage capacity because of its shallowness. Singanallur Lake is highly affected by eutrophication and is almost filled with *Eichhornia crassipes,* weeds. Although *Eichhornia crassipes*is praised for its ability to sequester nutrients and other chemicals from water, it is considered undesirable for wetlands. However, no detailed study has been reported so far in the selected three wetlands viz., Ukkadam, Kuruchi and Singanallur Lakes of Coimbatore city regarding the ecological risk assessment factor due to heavy metal contamination of their water quality. Therefore, the present investigation was aimed to assess the physicochemical parameters, level of nutrient contents and heavy metals present in the water samples from the selected three lakes.

2. Materials and Methods

2.1 Description of study area

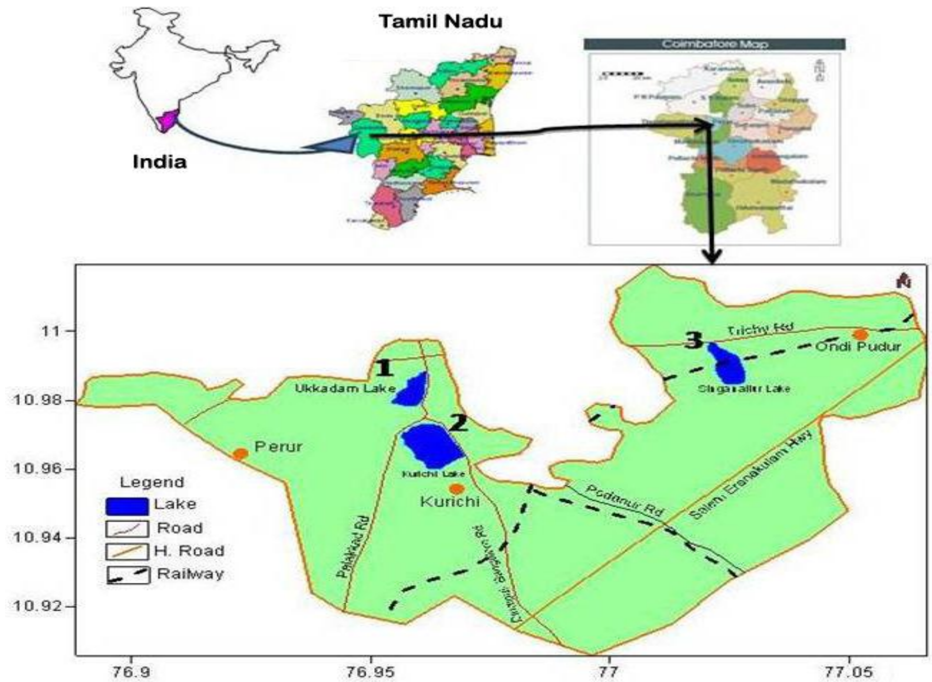
Figure 1 represents the three Lakes chosen for study. Ukkadam Lake is an urban lake situated close to a municipal market and bus stand which has the largest water area spread amongst the Coimbatore wetlands. This Lake lies between 10°59’ 40” and 76°46’ 18” longitude. Kuruchi Lake, a shallow basin lake, is situated in Kuruchi at latitude of 10°58’ 38’’ and longtitude of 76° 55’ 44’’. This lake is a point for the inflow of received municipal sewage and a famous site for dumping garbage inhabitations around its vicinity [7]. Singanallur Lake is an urban lake situated towards, the Southwest of Coimbatore, Tamil Nadu, India. It is located within the geographical coordinates of 10° 56’46’’ latitude and 77°01’ 11’’ longtitude. The lake is divided into two equal halves, but connected by a railway line running through it. The southern part of the lake receives freshwater only during the rainy season from the Noyyal river and the northern part of the lake receives industrial wastewater, domestic sewage and urban solid wastes [8]. The present study focuses only on northern part of lake due to the enhanced pollution by various industrial, urban wastes and domestic sewage.

2.2 Sample collection, physicochemical and nutrient content analysis

Surface water samples were collected during the periods from September 2012 to August 2013 from the three sampling stations at a distance of 500 m for each lake. Samples were collected in pre cleaned plastic bottles and labeled. The water samples were taken to the laboratory and filtered through Whatmann No.1 filter paper and kept in a refrigerator at 4°C with addition of HNO_3 in order to preserve samples until analysis [9]. The pH values were measured using a digital pH meter. Various physicochemical parameters viz., Total Dissolved Solids (TDS), Total Solids (TS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Chloride $(Cl)^{-}$, Sulphate (SO_4^{2-}), Nitrates (NO_3^{-}), Silicates (Si^{2+}) were analyzed using the standard methods [9, 10]. Calcium (Ca^{+}) and Magnesium (Mg^{2+}) concentrations were determined by using the method of Katz and Navone [11]. Phosphate (PO_4^{3-}) was determined by molybdate method [12]. Sodium (Na^{+}) and Potassium (K^{+}) content was analyzed using Flame Photometer [13].

2.3 Heavy metal analysis

Surface water samples were digested with 10 ml of diacid mixture (HNO_3: HCl, 7:3) on a hot plate for 10 min, the digested samples were filtered using Whatman No.1 filter paper and made up to 25ml using distilled water. These samples were used for analysis to detect the presence of six heavy metals namely Cd, Cr, Cu, Fe, Ni and Pb using Atomic Absorption Flame Emission Spectrophotometer (AAFES – 6200 (Shimadzu).



1. Ukkadam lake, 2. Kuruchi lake and 3. Singanallur lake

Figure 1: Study area map.

2.4 Statistical analysis

Mean metal concentrations were evaluated according to site and season by analysis of variance (ANOVA) and Duncan's multiple range tests [14]. The statistical analyses were performed according to the methods described by Gomez and Gomez [15], using SPSS-11 computer software.

3. Results and Discussion

The variations in the physicochemical parameters of the surface water samples collected from the three lakes during the monsoon, pre and post monsoons and summer seasons are summarized in Table 1. These parameters were compared with International [16] and National [17] standards. The temperatures obviously recorded higher during summer season (30.0 to 31.3°C) and lower in the monsoon season (27°C). The pH values were observed to be in the range of 8.03 – 8.60, 7.20 – 7.94 and 7.80 – 8.10 for Ukkadam Lake, Kuruchi Lake and Singanallur Lake respectively, during the study periods. Among the three lakes, the pH values were found to be high in Ukkadam Lake during the summer season, which exceeds the WHO [16] permissible limits (6.5 – 8.5). This can be possibly related to anthropogenic activities as well as natural processes. Similar results have been reported by Mohanraj et al. [18] and Chandra et al. [7]. In Kuruchi and Singanallur Lakes the pH levels recorded were found to be within the WHO [16] recommendations. Sankand and Patil [19] have documented that the higher levels of pH has enhanced the photosynthetic activity during summer and pre monsoon seasons in aquatic ecosystems.

Total suspended solids (TSS) and Total Solids (TS) in surface waters of three lakes ranged from 1.23 – 7.82 mg/L and from 603 – 1953 mg/L during the study periods, respectively. These parameters registered higher in Ukkadam Lake during the summer season, compared to the other two lakes. This may be attributed to the fact of dumping lot of suspended solid wastes containing effluents received from textile and dyeing industries [20]. The TDS values in Ukkadam Lake, Kuruchi Lake and in Singanallur Lake varied between 1219 – 2171 mg/L, 599 – 5033 mg/L and 1228 – 4669 mg/L respectively. The observations reveal that the TDS values in Kuruchi Lake are much higher than that of Ukkadam and Singanallur Lakes. However, all the TDS values exceed the WHO [16] permissible limit (1000 mg/L). The present values of TDS in all the water samples from the three lakes were found to be higher than the previous results reported by Mohanraj et al. [18] and Chandra et al. [7]. Rahman et al. [20] have discussed that, the dissolution of low molecular weight organic bases originating from dye industries may result in the higher TDS value of the samples.

The Total Alkalinity (TA) and Total Hardness (TH) values in all the water samples ranged from 251 – 562 mg/L and from 202 – 450 mg/L respectively. Among the three lakes, Singanallur Lake registered greater TA and TH values. The highest TA value (562 mg/L) was noticed in Singanallur Lake at the summer season. This is considerably higher than the WHO [16] guidelines limits and the previous report by Chandra et al. [7], who have documented that higher level of TA in wetlands is likely due to the accumulation of domestic wastes and open defecation. The maximum level of TH (450 mg/L) was recorded in Singanallur Lake during the summer season. Against the WHO [16] recommitted limits of 300 mg/L. Almost, similar kind of results was reported in Ukkadam and Singanallur Lake by Mohanraj et al. [18]. High levels of TH in lake water may be attributed to the mechanical engineering wastes, hospital and sewage wastes [21].

Dissolved Oxygen (DO) is mainly involved in maintaining the oxygen balance of aquatic ecosystems based on the tropical and pollution levels. DO acts as a good indicator of healthy status of freshwater systems and this value above 5 mg/L is a support for all the living organisms. However, this value if observed to be less than 3 mg/L shall cause health risk to human [22]. As evident from Table 1, the DO levels varied from 0.48 – 5.54 mg/L, 0.68 – 6.19 mg/L and 0.19 – 1.15 mg/L in Ukkadam Lake, Kuruchi Lake and Singanallur Lake respectively. However, the highest DO level was noticed in pre monsoon while lower level was recorded in monsoon season in all the three Lakes. Reports of Iqbal et al. [23] indicate that the DO contents were found to be high during winter season (5.20 mg/L) than summer (4.09 mg/L) in Rawal Lake, Pakistan. The present DO results may be attributed due to the temperature changes as well as increased anthropogenic activities in and around these lakes during the study periods.

BOD values ranged between 20.6 – 60.0 mg/L, 19.0 – 48.7 mg/L and 20.3 – 42.0 mg/L in Ukkadam, Kuruchi and SinganallurlLakes respectively. The BOD values recorded were above the WHO [16] tolerance level in all the three lakes. Highest BOD value (60.0 mg/L) was observed in Ukkadam Lake. The highest value of BOD has been reported by Mohanraj et al. [18] and Chandra et al. [7]. The COD levels varied from 103 – 220 mg/, 82.0 – 197 mg/L and 104 – 187 mg/L L in Ukkadam, Kuruchi, and Singanallur Lakes, respectively with Ukkadam Lake, being the maximum. The highest levels of BOD and COD are associated with the increased concentrations of organic and inorganic wastes being released into these lakes.

3.1 Nutrient properties of water

Seasonal variations of some nutrients in surface waters of three lakes are depicted as bar charts in Fig. 2. From the bar diagram it is obvious that Na^+ and K^+ values varied between 14.08–55.26 mg/L and 0.27–12.17 mg/L respectively, during the monitoring period (Fig.2 a, b). The maximum concentrations of Na^+ (55.26 mg/L) and K^+ (12.17 mg/L) ions were observed in Ukkadam Lake during the pre monsoon and minimum level was noticed in Kuruchi Lake during the post monsoon season. The levels of Ca^{2+} and Mg^{2+} ions ranged from 14.0 mg/L to 60.0 mg/L and 7.7 mg/L to 17.8 mg/L, respectively (Fig. 2 c & d). The highest Ca^{2+} and Mg^{2+} concentrations were observed during the summer season. In this study, the mean values of Cl^- ion range between 291–1038 mg/L (Fig. 2g). Seasonal variation data imply that during the monitoring period, the chloride ion concentrations were found to be high in the monsoon season at Ukkadam Lake which may be probably due to the accumulation of more municipal wastes. Similar results were reported by Chaturvedi and Pandey [24]. The chloride levels in all the lakes were observed to be higher than the permissible limits recommended by WHO[16]. Sulphate, Silicate and Nitrate values did not vary significantly (Fig. 2 e, f & h). but within the permissible limits (Sulphates 200 mg/L and nitrates 45 mg/L) prescribed by WHO [16].

3.2 Heavy metals concentration in water of three lakes

Seasonal variations of heavy metal concentrations (Cd, Cr, Cu, Fe, Ni and Pb) in the surface waters of the three lakes in comparison with National/ International guidelines are presented in Table 2. The concentrations of Cd ranged between 0.015-0.038 mg/L, 0.014 – 0.038 mg/L and 0.014 – 0.037 mg/L for Ukkadam, Kuruchi and Singanallur lakes respectively. The maximum concentrations of Cd recorded was 0.038 mg/L, 0.038 mg/L and 0.037 mg/L) for Ukkadam, Kuruchi and Singanallur lakes respectively during the post monsoon season exceeding WHO [16] and BIS [17] recommended standards (0.003 mg/L) for drinking water.

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Table 1. Physicochemical parameters of the surface waters in three lakes and comparison with National and International Guidelines

Sampling Sites	Seasons	Temp.(°C)	pH	SS (mg/L)	DS (mg/L)	TS (mg/L)	TA (mg/L)	TH (mg/L)	BOD (mg/L)	COD (mg/L)	DO (mg/L)
Ukkadam Lake	Monsoon	27.0±0.0	8.35±0.3	6.52±1.1	1789±33	1790±33	390±73	342±52	60.0±8.1	220±35	0.48±0.1
	Postmonsoon	27.0±0.0	8.05±0.1	5.43±0.4	1604±35	1609±34	425±75	314±46	31.0±9.0	140±40	0.72±0.2
	Summer	31.3±0.6	8.60±0.3	7.82±0.2	2171±15	1953±22	456±46	365±19	44.3±6.8	218±20	1.15±0.2
	Pre monsoon	30.6±1.3	8.03±0.2	2.86±1.2	1219±54	1223±54	329±10	299±11	20.6±19	103±79	5.54±1.8
Kuruchi Lake	Monsoon	27.0±0.0	7.85±0.2	1.77±0.5	5033±21	7244±19	249±34	202±10	48.7±10	197±37	0.68±0.2
	Postmonsoon	27.0±0.0	7.2±0.2	1.59±0.7	4557±34	4559±34	337±62	248±10	19.0±1.0	100±20	1.00±0.1
	Summer	30.6±1.3	7.94±0.0	6.05±0.4	1352±15	1646±30	391±4.9	374±4.2	42.6±9.3	194±2.9	1.23±0.1
	Pre monsoon	30.6±1.3	7.50±0.0	1.23±1.2	599.1±27	603.1±27	251±73	292±11	19.3±19	82.0±82	6.19±2.2
Singanallur Lake	Monsoon	27.0±0.0	8.01±0.1	2.55±1.0	4669±17	1196±26	376±46	367±14	42.0±8.9	147±25	1.35±0.1
	Postmonsoon	27.0±0.0	7.80±0.2	1.26±0.7	4542±34	934±13	562±12	288±16	20.3±6.0	104±16	0.92±0.3
	Summer	30.6±1.3	7.78±0.1	5.29±0.2	1228±86	1598±43	465±55	450±58	38.6±9.8	187±15	1.11±0.0
	Premonsoon	30.6±1.3	8.10±0.1	5.06±0.5	1294±81	1428±13	503±61	376±57	25.3±13	171±28	1.15±0.1
WHO Permissible limit (mg/L) (2011)		__	6.5 – 8.5	__	500	__	__	300			
BIS Permissible limit (mg/L) (2003)		__	6.5 – 8.5	__	500	__	__	300	2.0		6.0

Data are mean ± SE (n=3), Water temperature (Temp.), Suspended Solid (SS), Dissolved Solids (DS), Total Solids (TS), Total Alkalinity (TA), Total Hardness (TH), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO).

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Table 2: Heavy metal concentrations of lake waters and comparison with National and International Guidelines

Sampling Sites	Seasons	Heavy metals content (mg/l) in lake water					
		Cd	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
Ukkadam Lake	Monsoon	0.0157±0.000	0.0310±0.001	0.3501±0.006	3.4600±3.060	ND	ND
	Postmonsoon	0.0389±0.000	0.0595±0.000	0.1810±0.005	0.3001±0.100	ND	0.6143±0.000
	Summer	0.0223±8.819	ND	0.5523±0.012	0.4333±0.145	0.0283±0.000	0.4635±0.005
	Premonsoon	0.0277±5.773	ND	ND	1.1000±0.458	0.1177±0.005	2.0921±5.775
Kurinchi Lake	Monsoon	0.0145±0.001	0.0145±5.773	0.3179±0.000	0.1000±0.000	ND	ND
	Postmonsoon	0.0380±3.333	0.0305±0.000	0.3390±0.003	0.1666±0.066	ND	0.5690±0.000
	Summer	0.0200±5.770	ND	0.0509±0.010	0.9001±0.400	0.0400±3.333	0.4810±0.000
	Premonsoon	0.0240±0.000	ND	ND	0.8333±0.523	0.1011±0.000	2.1728±0.005
Singanallur Lake	Monsoon	0.0140±0.001	0.0475±0.090	0.3240±0.005	0.2666±0.176	ND	ND
	Postmonsoon	0.0374±0.001	0.0633±0.000	0.1020±0.000	0.1000±0.057	ND	0.5310±0.000
	Summer	0.0220±0.001	ND	ND	1.4000±0.305	0.0429±3.333	0.4926±0.001
	Premonsoon	0.0263±0.002	ND	0.0254±0.000	1.5666±0.375	0.0944±0.000	2.1046±0.002
WHO Permissible limit (mg/L) (2011)		0.003	0.050	2.000	0.300	0.070	0.010
BIS Permissible limit (mg/L) (2003)		0.003	0.050	1.500	--	0.200	0.050

Data are mean ± SE (n=3), ND – Not Detected, Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb), World Health Organization (WHO) and Bureau of Indian - Standard (BIS).

Similar observations were also reported for the study of Bangshi River, Bangladesh by Rahman et al. [20]. The higher levels of Cd in lake water may be due to the discharging of wastewaters from electroplating and textile printing industries. The concentrations of Cr in Ukkadam and Singanallur lakes during the post monsoon season were 0.059 mg/L and 0.063 mg/L respectively exceeding the WHO [16] and BIS [17] standards as mentioned in the Table 2. Similar result was reported by Singh et al. [25] in Naukuchiatal Lake, India. The concentration of Ni in water samples ranged from 0.094 to 0.117 mg/L for pre monsoon and 0.023 to 0.042 mg/L for summer season. The maximum Ni concentration found in these lakes during the pre monsoon season is higher than the recommended WHO [16] value (0.070 mg/L). Virha et al. [21] has observed higher level of Ni in water samples of Upper Lake, Bhopal, India.

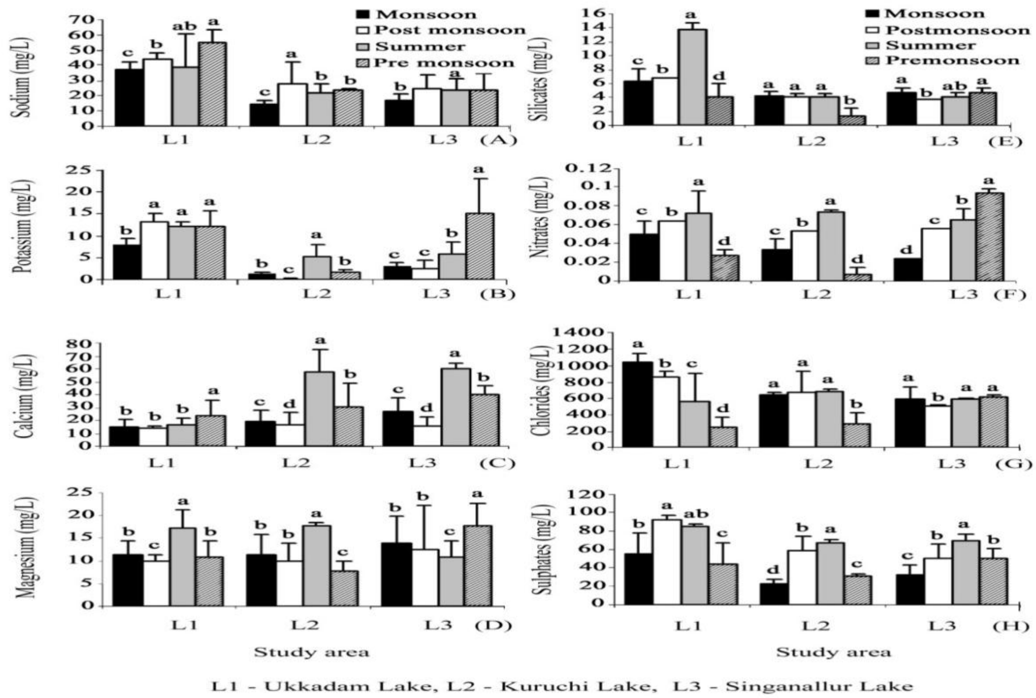

Figure 2. Nutrient properties of studied three lake waters,Data are means $\pm$ SE (n=4), bars with different letters indicate significant differences at $P \leq 0.05$. Sodium (A), Potassium (B), Calcium (C), Magnesium (D), Silicates (E), Nitrates (F), Chlorides (G) and Sulphates (H).

From this investigation, the occurrence of Cr and Ni ions is confirmed in all the three lakes. It was noticed that, some electroplating and textile industries have been established and are discharging their effluents into these lakes. However, the Cu concentration was found to be below the WHO [16] permissible dose (2 mg/L) in all the collected samples.

The concentrations of Fe ranged from 0.266 - 3.460 mg/L. The maximum Fe concentration was recorded in Ukkadam Lake (3.460 mg/L) during the monsoon season. Occurrence of ions in almost all the lakes at any one season or others seemed to be higher than the WHO's [16] recommendations (0.300 mg/L).

This may be attributed due to the direct discharge of mechanical engineering wastes, hospital and domestic wastes in and around these lake areas. The mean concentrations of Pb was ranged from 0.463 mg/L to 2.172 mg/L. Relatively maximum level of Pb was observed in Ukkadam lake (2.092 mg/L), Kuruchi lake (2.172 mg/L) and Singanallur lake (2.104 mg/L) during the pre monsoon season, against the WHO prescribed limit of 0.010 mg/L. This might be due to receiving of wastewaters from automobile and metal industries. Rahman et al. [20] have documented higher concentrations of Pb in freshwater ecosystems due to the long – term accumulation of Pb from motor vehicles emission being the major source for enhanced Pb contamination in the aquatic environments. From the heavy metal analysis, it is evident that the heavy metal concentrations (Cd, Cr, Cu, Fe, Ni and Pb) in Ukkadam and Singanallur lake waters much higher than that of previous report made by Mohanraj et al in 2000.

Conclusion

The present study of the selected lakes revealed that the observed values for most of the parameters seemed to be much higher than the recommended level. This may be due to the accumulation of heavy metals, climate change in the recent years, discharge of wastes in folds due to the population growth in and around the Coimbatore city. The modernization of industries leads to the accumulation of heavy metal contaminants in water stream by industrial effluents due to lack of proper waste water treatment procedures. Results clearly showed that the heavy metal level was found to be permissible limit and therefore, an urgent wetland phytoremdiation system could be adopted to clean the pollutants. The present study together suggested that there will be proper implementation of new waste management systems to provide better water quality in the urban areas and to ensure the availability of safety drinking water from natural water bodies to consumers in the years to come.

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