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Hydrobiological Studies of Vandiyur Lake, Madurai, Tamil Nadu, India

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Abstract: *Lakes are important aquatic systems as they act as a source of drinking water and a habitat for crustaceans, fish and other organisms. Their hydrobiology is impaired mainly through anthropogenic activities. Hence the present work has been designed to study the hydrobiology of Vandiyur Lake at Madurai. The water samples were collected during premonsoon, monsoon and postmonsoon periods and analysed for physical, chemical and biological parameters using standard methods. Many of the physical and chemical parameters and fecal coliforms were higher during premonsoon period. The Vandiyur Lake water exhibited higher values for many of the parameters during premonsoon.*

Keywords: *Vandiyur Lake, Hydrobiology, Fish, Hydrophytes, Monsoon.*

INTRODUCTION

Every organism occupies a specific niche in the environment. In the hydrosphere, ninety seven percent of the water is in ocean and in the remaining three percent, nearly two percent is in the form of polar ice caps while the balance one percent is available as surface water and ground water (Shiklomanov, 2000). The surface water is in the form of rivers, lakes and ponds. One out of six persons does not have regular access to safe drinking water. Fresh water demands are outstanding the supplies with pollution of rivers, lakes and streams. There is fierce competition and tension between nations for acquiring water, but it can also be a catalyst for co-operation. Alarmingly, the water for agriculture is decreasing while the water demand for industry and municipalities is increasing. Most civilizations, settled around river basin and presently the populations abuse the water bodies indiscriminately. Water is both the essential and the most abundant substance in protoplasm which is closely similar to sea water and slightly greater than that of freshwater (Wetzel, 2001). The most convenient and cheapest waste disposal system is the fresh water ecosystem. It is clear that a major effect to reduce their stress must come quickly. Otherwise water will become the limiting factor for man (Smith et al., 1999). Untreated or partially treated sewage, agricultural chemicals and industrial effluents affect the water quality. When, the government or private vendors sell domestic water for cash their men and women may be responsible for that household expenditure (Srivastava et al., 2003).

Ponds and lakes are divided vertically into littoral, limnetic and profundal zones. Waters of the ponds, Lakes and rivers are mainly polluted due to discharged waste water from residential areas, sewage outlets, solid wastes, detergents, automobile oil wastes, fishing facilities and pesticides from farm lands (Usha et al., 2006). Due to increasing urbanization, industrialization and other developmental activities, most of the Indian lentic water bodies have become polluted (Banakar et al., 2005). Ecological conditions viz. water, temperature, pH,

alkalinity, and stocking density of aquatic environment plays a significant role on the colonization of bacterial flora and incidence of diseases in culturable and wild species of fish (Sneiszko, 2008).

Variability of rainfall from season to season is very high. While India is considered rich in terms of annual rainfall and total water resources, uneven geographical distribution of rainfall causes severe regional and temporal shortages. Farmers are forced to dig deeper wells leading to falling water tables in most states. Urban people drilled more bore wells when they go for individual houses. India will be in the list of water stressed countries by the year 2025. Changing life styles have increased the need for fresh water. Intense competition among agriculture, industry and the domestic sector is pushing the ground water table deeper. Urban development is believed to reduce recharge due to high impermeable surfaces following reduced plant cover in cities (Prasad, 2009; WBWDRT, 1993).

Madurai city is situated on the southern banks of river Vaigai and 500 km south west of Chennai. It is the second largest city of Tamil Nadu, India and the district head quarters of Madurai District. Water bodies which acted as flood moderations have witnessed silting and discharge of sewage and the tanks are used for ground water recharge. The season in Madurai is divided into summer (April-June) and winter (November-January). The monsoon lasts from August to November and the city gets average rainfall of 840mm per year (PWD, 2008). The aim of the present work is to study the physical, chemical and biological parameters of the Vandiyur lake which could help in a sustainable restoration plan for the lake.

Materials and Methods

Study area – Vandiyur Lake

Vandiyur lake is situated on the left bank of Vaigai River near Vandiyur village in Madurai north taluk, Tamil Nadu, India and it has source supply from Sathaiyar channel and upper tanks. This lake is located at 9°56'N latitude, 78°98'E longitudes. The lake belongs to Vandiyur village in Madurai North taluk and Madurai East block.

Determination of Physico-Chemical parameters

The physico-chemical parameters such as appearance, colour, odour, turbidity, conductivity (EC Meter method), total dissolved solids, pH, alkalinity/acidity, total hardness, calcium, magnesium, sodium, potassium, iron (Ammonium thiocyanate method), manganese, ammonia, nitrites, nitrates (Brucine sulphate method), chlorides, fluorides (By Alizarin method), sulphates, phosphates, Tidy's test (4 hrs Permanganate test), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were analysed based on standard procedures (APHA, 2002).

Determination of biological parameters

Membrane filter technique for total coliforms

Using sterile forceps a sterile filter was placed over the porous plate of the apparatus, grid side up. The matched funnel unit was carefully placed over the receptacle and locked. Filtration was accomplished by passing the water sample through the filter under partial vacuum. The funnel was rinsed by filtering three 20 to 30ml portions of sterile dilution water, while the filter was still in place. The funnel was unlocked and removed. The filter was removed with sterile forceps and placed on the sterile pad or agar. Filtration unit was sterilized before each filtration. When less than 20ml of sample was to be filtered a small amount of sterile dilution water was added to the funnel before filtration for uniform dispersion. A fresh sterile pad was placed in the bottom half of the dish and saturated with 1.8 to 2ml of nutrient before the transfer of membrane filter from the unit. Either agar or the liquid medium was used. The dish was inverted and incubated for 20 to 22 hours at 35 $\pm$ 0.5°C. The colonies were counted using colony counter.

Total coliform colonies/100ml = colonies counted X 100ml sample filtered

Faecal coliforms (7 hours F.C. test)

An appropriate sample volume was filtered through a membrane filter, the filter was placed on the surface of a plate containing M-7hr F.C. agar medium (Proteose peptone No.3 or polypeptone-5g; Yeast extract-3g;

Lactose-10g; d-Mannitol-5g; Sodium chloride -7.5g; Sodium lauryl sulphate -0.2g; Sodium desoxy cholate-0.1g; Bromo cresol purple-0.35g; Phenol red-0.3g; Agar-15g; Distilled water-1 litre; pH-7.3 $\pm$ 0.1) and incubated at 41.5°C for 7 hours. F.C. colonies were yellow in colour which indicates lactose fermentation.

Hydrophytes Analysis

The aquatic plants collected were identified based on their morphology (Tiner, 1991; Das et al., 2009).

Results

The Vandiyur Lake was assessed for physical, chemical and biological parameters during the months of July and November in 2010 and January in 2011. Rainfall data for the premonsoon, monsoon and post monsoon periods respectively are given in Table 1, 2 and 3. The physical parameters of Vandiyur lake water samples are shown in Table 4. The chemical parameters of water samples are recorded in Table 5. The faecal coliform parameter of Vandiyur lake water is given in Figure1. Fish species found in Vandiyur Lake water is given in Table 6. Hydrophytes found in Vandiyur lake water is given in Table 7. The minimum rainfall for the premonsoon period in Madurai was recorded in April and Sathiyar Dam in June and was maximum in May for Madurai and Sathiyar Dam. The minimum rainfall for the monsoon period in Madurai and Sathiyar Dam was in August and maximum in November. The minimum rainfall for the postmonsoon period in Sathiyar Dam was in March (Madurai recorded nil) and the maximum in Madurai and Sathiyar Dam was recorded during December.

During premonsoon period, turbidity, electrical conductivity, pH, total dissolved solids, total alkalinity, calcium, sodium, potassium, ammonia, nitrite, chloride, sulphate and number of faecal coliforms were high. Fluoride level was low during that period. During monsoon period, total hardness, magnesium, iron, nitrate, fluoride, oxygen and COD levels were high. At the same time, low levels of total alkalinity, calcium, ammonia, sulphates and phosphates were observed. During postmonsoon period, phosphate was high where as turbidity, electrical conductivity, pH, total dissolved solids, total hardness, magnesium, sodium, potassium, iron, nitrate, chlorides, fluorides, oxygen, COD and number of faecal coliforms were low.

Discussion

Water Parameters

Water resources found in the earth are under tremendous pressure and they should be managed properly for the survival of human beings and aquatic organisms. Quality of an aquatic ecosystem is dependent on the physico-chemical qualities of water and biological diversity of the ecosystem. In Tamil Nadu, monsoon period prevails between August and November. The monsoon period in 2010 registered the maximum rainfall. Sathiyar Dam is the catchment area and the source of water for the Vandiyur Lake. Rainfall was the minimum during the post monsoon in 2011.

Turbidity

Turbidity may be due to algal population and sewage disposal. Urbanization has increased sewage load in Vandiyur Lake. Algae are used for assessing the degree of pollution or as an indicator of water pollution of different water bodies. If the primary source of turbidity in ponds is plankton as is often the case, planktonic abundance may be estimated by turbidometry. Cyanophyceae and Euglinophyceae are generally seen to appear near sewage outfall. Not only algae, but also wind caused resuspension of sediment particles which decreases the transparency. Plankton appeared to be the primary source of turbidity in most ponds (Tas and Gonulol, 2007). In Vandiyur Lake, high turbidity was found in the premonsoon probably due to high planktonic and algal growth. Due to less rain in the summer, the concentration of plankton and algae might have been very high. It might have been also due to sewage disposal because of urbanization. The colour of the lake water was greenish and green in premonsoon and monsoon. It was yellow during postmonsoon. Plankton blooms impart yellow, red, brown or black colouration to water. Less turbidity in the post monsoon

might be due to the dilution of lake water by the incessant rain during late winter (Tiwari and Chauhan, 2006).

Total dissolved solids

Studies of dissolved organic matter (DOM) usually focus on dissolved organic carbon (DOC). DOM is assimilated by bacteria which are consumed by heterotrophic grazers, thereby forming a heterotrophic food chain. Dissolved organic nitrogen (DON) concentration in freshwater is usually much higher than dissolved inorganic nitrogen concentration. The accepted limit of TDS in surface water or stream water is 1000 mg/l (Stevenson and Pan, 1999). In Vandiyur Lake, high TDS was noted during premonsoon period (2310 mg/l) followed by monsoon period (1224 mg/l) and postmonsoon period (528 mg/l). During premonsoon, Vandiyur Lake exhibited high dissolved solids and the rain during monsoon and postmonsoon diluted the lake and hence there was less TDS.

pH and Electrical conductivity

The lowest dissolved oxygen value in pond was associated with highest level of conductivity, total dissolved solids and pH as well as high free carbon-di-oxide and iron values which is in agreement with the studies conducted in different aquatic systems (Dwivedi and Pandey, 2002). The chlorophytic algal bloom in turn led to the release of the nutrients which enhanced the alkalinity and conductivity of pond water. Pond with high pH had more phytoplankton bloom. Algal metabolism increases the concentration of CO_2 and HCO_3 which will increase the pH. pH also increases with increase in photosynthesis and gross primary production. During premonsoon, Vandiyur Lake exhibited high dissolved solids and consequently high electrical conductivity. The rain during monsoon period and post monsoon diluted the Lake and hence there were less total dissolved solids and low electrical conductivity (Pandit, 2002; Torremorell, 2007). In Vandiyur Lake, during premonsoon summer the water exhibited high pH (8.64) while during monsoon the pH was slightly acidic (pH 6.91). It hints that there might be acid precipitation.

Calcium and Magnesium

As hydrogen ion increases pH declines as expected and calcium and magnesium also declined markedly while sodium and potassium declined moderately. Calcium increases the availability of other ions and magnesium acts as carrier of phosphorus. Lake Manasbal of Kashmir Valley of India which is infested by *Euglena peduncalata* also had calcium rich water. Again magnesium acts as a micronutrient in enzymatic transphosphorylation by algae. Both Calcium and magnesium significantly contribute to the hardness of water. Further they play an important role in neutralizing the excess acid produced in the system (Bhuiyan and Gupta, 2007). In Vandiyur lake more calcium was found in the premonsoon (68mg/l) than in monsoon (43mg/l). Premonsoon period had high pH with correspondingly high calcium. Thus, there is positive correlation between pH and calcium concentration. As pH decreases (pH 6.91) the calcium concentration also decreases.

Iron

Khan and Bhatt (2000) have recorded much higher concentration of iron in Lake and pond water and emphasized its role in inducing Chrysophyte and euglenoid blooms regularly. Chrysophytes and euglenoids are absent in the ponds where iron level is quite high. Lower iron is associated with moderate abundance of Euglenophyceae. In Vandiyur Lake, low iron was found in the postmonsoon probably indicating the moderate growth of Euglenophyceae species.

Ammonia

Ammonia present in winter is more and is quickly used by primary producers in the spring. During summer stratification, the ammonia concentration decreases in the epilimnion and ammonium accumulates in the deeper water strata. The general tendency of ammonia to accumulate after the onset of anaerobic condition near the bottom is explained by the loss of absorptive capacity when the oxidized microzone of the upper sediment layer is reduced. During the winter period, the total nitrogen content of the lake generally increases due to an increase in ammonia obviously coming from the sediment followed by nitrification (Das, 2002). Organisms capable of fixing molecular nitrogen e.g. blue green algae and photosynthetic bacteria are present

in the lake. Their quantitative role in the nitrogen cycle is probably of minor importance. Generally there is a net loss of nitrogen in spring by sedimentation and denitrification followed by nitrogen gain in summer due to ammonification and ammonia release from the bottom deposit and in winter caused by ammonia and nitrate supply from the sediments. More NH_4^+ is released per unit of carbon decomposed by anaerobic bacteria than by aerobic bacteria (Verma, 2002).

Nitrates

Nitrate uptake by macrophytes in the littoral zone can also contribute to a loss of nitrogen from the water, but is probably of minor importance. Nitrate decreases in spring and early summer whereas after the autumn overturn it reappears. Nitrification is responsible for the regeneration of nitrate in the circulation period. Nitrate is assimilated by primary producers in the upper water strata and in the littoral zone (Tranvik et al., 2009). In Lake Ecosystem, besides the input of nitrate through run off, decomposition of nitrogenous matter and its further oxidation plays a significant role. Ponds have been found to be favourable for fish productivity as nitrate value of the ponds ranged between 0.1 to 3mgl. The moderate nitrate concentration enhances the growth of phytoplankton which in turn produces more dissolved oxygen (Bhuiyan and Gupta, 2007). In Vandiyur Lake, nitrate concentration is low during post monsoon (3mg/l). This is the ideal level for fish productivity as obviously more fishing was done during this period.

Chlorides

Chloride concentration usually varied depending upon the seasons such as summer, and decreased during autumn, winter and spring (Mudryk et al., 2003). Vandiyur Lake exhibited high chloride content during the premonsoon period with 530mg/l. The chlorosity might be probably due to the disposal of domestic sewage. The chlorides are least during winter (monsoon) and very least in the postmonsoon period. The incessant rain during winter and spring might have probably diluted the chlorides in the lake water.

Sulphates

Sulphate concentration in lake water is influenced by several factors including oxygen concentration, temperature, availability of organic matter and so on (Holmer and Storkholm, 2001). Vandiyur Lake had correspondingly high calcium and sulphates during the premonsoon period and correspondingly low calcium and sulphate during the postmonsoon period.

Phosphates

Many algal species are able to utilize organic phosphorus after enzymatic hydrolysis by their alkaline phosphatases. Eutrophication of several lakes has been reversed by reducing external supplies of phosphorus (Sondergaard et al., 2001). Turnover time of phytoplanktonic carbon was estimated to be about five days in winter and five hours in summer. In comparison phosphorus turnover of cells was roughly five times faster. The low range of phosphate value in the ponds is due to the fact that at high temperature phosphate is rapidly assimilated by plankton and microorganisms (Vymazal, 2007; Assemany et al., 2015). In Vandiyur Lake more phosphates were found in the postmonsoon period (spring) and lesser in the premonsoon (summer) and monsoon periods.

Dissolved Oxygen, BOD and COD

Oxygen is depleted in the hypolimnion and circulation in epilimnion supplies oxygen to the metalimnion. Dissolved oxygen is mainly regulated by photosynthetic activity of algal flora when free carbon-di-oxide is utilized. Water with high temperature had low oxygen. Dissolved oxygen increases with decrease in temperature. So, DO is generally higher in the winter (Jennings et al., 2012; Jiang et al., 2008). In Vandiyur Lake during hot premonsoon the water had high pH which may result in less DO consequently and there will be less fish population and more phytoplankton bloom. The Vandiyur Lake is dumped with sewage, drainage and other wastes which increase eutrophication, BOD and COD.

Fishes

The bulk of the food of the fishes was blue green algae, diatoms and green algae. Detritus that is present in the food but not quantified also provide substantial nutrition to the fishes. Food source for zooplanktivorous fishes are mostly cladocerans and copepods. Large copepods are better observed by particulate feeder fishes

and hence are more intensively preyed (Balirwa et al., 2003; Stiassny, 1996). The fish species found in Vandiyur L ake are *Channa striatus* (snake head), *Pterycoplichthys pardalis* (Tank cleaner), *Channa punctatus* (Spotted murrell), *Oreochromis mossambicus* (Tilapia), *Parambassis* sp. (Glass fish), *Puntius terio* (one spot barb), *Labeo rohita* (Roghu), *Cirrhinus mrigala* (Mirghal), *Ctenopharyngodon idella* (Grass carp) and *Catla catla*. Among these *Pterycoplichthys pardalis, O. mossambicus, Parambassis, P. terio* and *C. punctatus* originally exist in the water body and were not introduced. *Pterycoplichthys pardalis* feeds in the ditchy areas and damages the net while fishing. It is a poor table food. While the remainders are introduced species and are good table foods.

Faecal coliforms

In Vandiyur Lake, Faecal coliform count was higher in the premonsoon period (1000/100ml) than in the monsoon period (150/100ml). People in the surroundings also use the lake for cleaning after defecation. Besides, sewage is also dumped. The less water during summer had more concentrated population of coliforms. During winter the monsoon rain floods the lake water and dilutes it, so the count of coliform was less in the monsoon and postmonsoon periods.

Macrophytes

The aquatic macrophytes may contribute by primary production and detritus formation. They serve as substrate for other organisms such as periphyte algae, bacteria and macro fauna. The decrease in water transparency appears to be a major factor causing the disappearance of submerged plants (Mnaya et al., 2007). The macrophytes observed in Vandiyur Lake are *Ceratophyllum demersum, Hydrilla verticellata, Otellia alismoides, Eicchornia crassipes* and *Valisneria natans*. The aquatic macrophytes contribute to the primary production, detritus formation and serve as substrate for periphyte algae, bacteria and macrofauna. *Ceratophyllum* also harboured macrofauna like *Oligochaeta* and *Chironomids* and mayflies.

Conclusion

In Vandiyur Lake water parameters like Fecal coliforms, Turbidity, TDS, EC, pH, alkalinity, total hardness, Ca, Na, K, free ammonia, nitrates, chlorides and sulphates were high during premonsoon. Totally ten fresh water fish species and five species of aquatic plants were noticed.

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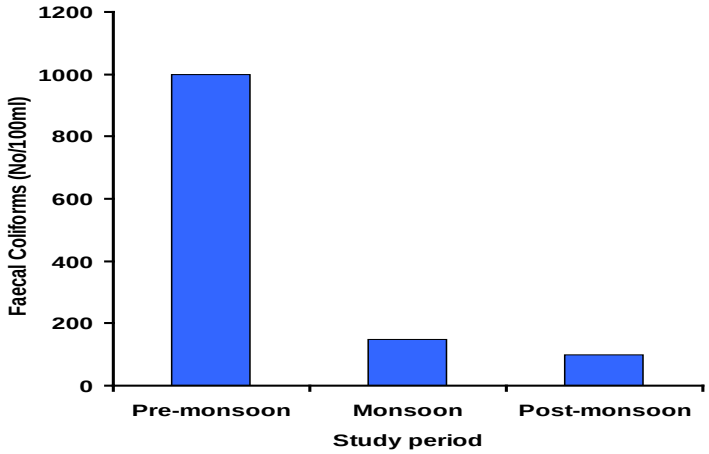

Figure 1. Faecal coliforms in Vandiyur Lake water samples collected during the study period (2010-2011).

Table1. Rainfall data for the premonsoon period 2010

Months	Rainfall (mm)	
	Madurai	Sathiyar Dam (Catchment area)
April	42.60	49.50
May	103.00	101.00
June	81.30	15.00
July	55.60	68.00
Average	70.63	58.38

Table2. Rainfall data for the monsoon period 2010

Months	Rainfall (mm)	
	Madurai	Sathiyar Dam (Catchment area)
August	49.00	49.00
September	338.00	159.23
October	218.00	173.60
November	393.40	181.20
Average	249.63	140.76

Table 3. Rainfall data for the postmonsoon period 2010-2011

Months	Rainfall (mm)	
	Madurai	Sathiyar Dam (Catchment area)
December	135.60	86.00
January	15.00	3.00
February	69.00	12.20
March	0.00	2.00
Average	54.9	25.8

Table 4. Physical parameters of Vandiyur Lake water samples collected during the study period (2010-2011)

Sl. No.	Parameter (unit)	Study period		
		Pre-monsoon	Monsoon	Post-monsoon
1	Appearance	Turbid	Turbid	Turbid
2	Colour (Pt. Co. Scale)	Greenish	Green	Pale yellow
3	Odour	Foul	None	Foul

4	Turbidity (Nephelometric turbidity units)	120	60	30
5	Total dissolved solids (mg/l)	2310	1224	538
6	Electrical conductivity (micromho/cm)	3310	1748	768

Table 5. Chemical parameters of Vandiyur Lake water samples collected during the study period (2010-2011)

Sl. No.	Parameter	Study period		
		Pre monsoon	Monsoon	Post monsoon
1	pH	8.69	6.91	7.87
2	Phenolphthalein alkalinity	20	0	0
3	Total alkalinity (mg/l)	726	5.4	266
4	Total hardness (mg/l)	300	284	216
5	Calcium (mg/l)	68	43	52
6	Magnesium (mg/l)	31	42	21
7	Sodium (mg/l)	598	253	69
8	Potassium (mg/l)	22	10	5
9	Iron (mg/l)	1.2	953	0.26
10	Manganese (mg/l)	0	0	0
11	Free Ammonia (mg/l)	4.2	2.9	3.50
12	Nitrites (mg/l)	0.1	1.15	1.08
13	Nitrates (mg/l)	6	6	3
14	Chlorides (mg/l)	530	254	41
15	Fluorides (mg/l)	0.3	0.4	0.4
16	Sulphates (mg/l)	39	30	32
17	Phosphates (mg/l)	0.32	0.08	1.28
18	Tidy's test 4hrs for O_2 (mg/l)	2.16	7.36	1.2
19	BOD (mg/l)	5.2	18.4	3
20	COD (mg/l)	12.4	46	7

Table 6. Fish species found in Vandiyur Lake during the study period

Sl.No.	Scientific names	Common names
1	*Channa striatus*	Snake head
2	*Pterycoplichthys pardalis*	Tank cleaner
3	*Channa punctatus*	Spotted murrell
4	*Oreochromis mossambicus*	Tilapia
5	*Parambassis* sp.	Glass fish
6	*Puntius terio*	One spot barb
7	*Labeo rohita*	Roghu
8	*Cirrhinus mrigala*	Mirghal
9	*Ctenopharyngodon idella*	Grass carp
10	Catla catla	Catla

Table 7. Hydrophytes found in Vandiyur Lake during the study period

Sl.No.	Hydrophytes
1	*Ceratophyllum demersum*
2	*Hydrilla verticellata*
3	*Ottelia alismoides (L.F.) Royle*
4	*Eichhornia crassipes*
5	*Vallisneria natans* (Lour.) H.Hara