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Original Research Article

A Study on Remediation of Polluted Water Using Canna Indica

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ABSTRACT

Background: Bangalore, a nerve center for various economical activities, exhibits a radial pattern of drainage, distributing from the apex and ramifying to the lower plains with dentric and reticulate drainage pattern. Through this fresh water resources formed supply water for the population in the localized body called lentic water bodies. A *lake* is a sizable water body surrounded by land and fed by rivers, springs, or local precipitation. Lentic ecosystems (still waters) can be considered to have three zones – littoral, limnetic and benthic.

Aims and objectives:

- To contribute for sustainable water resource management
- To quantify the polluted water (lake water quality) in Bangalore south
- To Check economically viable methods to its remediation

Methodology: The Surface Water samples (5-10 cm below the water surface) for chemical analysis were collected from Bellandur Lake and brought to the laboratory in 5 liters cans. 6 months triplicate samples were collected (N=18) .The composite sampling method was used to collect the water sample. The sample was collected between 8am and 10am.

Results: The water quality of Bellandur lake was analyzed for the Surface Water samples from 3 sampling points. The descriptive statistics on the lake data reveals that the mean value for 6 months in Bellandur Lake shows that the conductivity, turbidity, TDS, DO, hardness, alkalinity, phosphate, nitrate and BOD is above the ISI standard. Other parameters such as pH, potassium, chloride, sulphate and COD are below the permissible limit. Bellandur Lake showed high Lead content beyond the permissible limit.

The Correlation analysis between the variables of water quality parameters of Bellandur Lake showed a positive significant correlation between conductivity and turbidity; TDS and Hardness; Turbidity and Hardness ; Potassium and Chloride, Sulphate; BOD and COD; Alkalinity and COD.

Conclusion: The present study indicates that *Canna indica* has a higher potential uptake of toxic metal lead. When properly designed and applied, the wetland system with and *Canna indica* as the ornamental plant would play a key role in minimizing the impact of imminent global clean fresh water resource. *Canna indica* which is harvestable and represents economic products, thus ensuring sustainability to the ecosystem.

Key words: Remediation, Polluted water, *Canna indica.*

INTRODUCTION

Back ground of the study

Bangalore, capital city of Karnataka is the sixth largest metropolis in the country and a nerve center for various economical activities, contributing to the growth of the city. Bangalore city is spread between Bangalore North and South taluks.

Bangalore, being a part of the Deccan Plateau is represented by plains, hills, valleys and undulating terrain, which is unique to this metro. The topography of Bangalore exhibits a radial pattern of drainage, distributing from the apex and ramifying to the lower plains with dentric and reticulate drainage pattern. The drainage pattern of the city is governed mainly by three drainage systems namely, the Vrishabhavati system that drains most of the Central and South Western parts of the city, the Kormangala and Challagata, Bellandur system that drains the southern and the South Eastern waters and the Hebbal system which drains the North Eastern parts of the city. Thus through this fresh water resources formed supply water for the population in the localized body called lentic water bodies (Chapman and Reiss 1995).

Bangalore Scenario

The absence of any kind of perennial surface waters led to construction of several water tanks. These tanks were constructed after identifying the natural valleys .The lake stored runoff during monsoon and this water was used during the lean period .The lakes in Bangalore are situated in the same catchment area. Hence the lakes form the chain, here the lakes on upper drainage basin feed the lower lakes that are present in lower catchment area. Evolution of lakes in Bangalore can be traced to pre colonial, colonial, and post independence period. During the pre colonial period water tanks were created by Kempagowda I& II (1537) for agricultural and domestic needs ,the lakes that were created were Kempambuddhi tank (Basavanagudi) Dharmambuddhi tank (Gandhinagar) Halsoor tank (Ulsoor tank ,Shivajinagar), Sampangi tank (Corporation) & Siddikatte tank (Kalasipalyam). Lal-bagh and its tank, was developed by Haider Ali and Tipu Sultan (1759). (Mahalakshmi, 2002)

Phytoremediation or vegetation method is becoming increasingly popular worldwide for removing contaminants from wastewater. Phytoextraction is a multidisciplinary approach to the cleanup of contaminated integrated soils using accumulator plants. Phytoextraction requires that the target metal must be available for plant root which is absorbed by the roots and translocated from the root to the shoot Phytoextraction (Chaney *et al.*, 1997).

Canna indica an ornamental plant has very recently researched for achieving the relatively high nutrient removal efficiency. it has shown vigorous and healthy growth, and a relatively high potential of rooting-zone aeration and nutrient removal efficiency in the wetland microcosms. (Kathy, 2007) Hence, the purpose of the study is to develop bioremediation technique which is cost effective sustainable & aesthetic in developing Water bodies.

Need of the study

The rapid urbanization has resulted in increase in population and consequent pressure on infrastructure. There has been a growth of 632% in urban areas, there is increase in local climate (an increase of 2.5% degree during last decade) 76% decline in vegetation cover and 79% decline in water bodies). (Ramachandra and Uttam Kumar,2009) The Bangalore district that supported about 461 tanks (Karnataka Gazettee, 1982). The number of tanks has reduced from 262 in 1960 to around 81 at present to cater to a population of 5.8 million in 2009 as compared to 0.4 million in 1941 (1991 census).The loss in wetland interconnectivity in Bangalore district is attributed to the enormous increase in population and the reclamation of tanks for various developmental activities. (Deepa *et al*, 1997).

The current status of lakes catchment, which is succumbing to urbanization due to unplanned developmental activities devoid of ecosystem approach in regional planning, has lead to land change The lakes created due to natural topography was neglected, which otherwise could have been a boon since the city is dependent on Cauvery water, as Bangalore is on a ridge and does not have any perennial river as its sources of water. Drinking water is pumped from the river Cauvery, from a distance of about 100 Km over an elevation of 500 M. The need to conserve and provide effective restoration is essential. To understand the characteristics of lakes and to remediate the lakes through phyto-remediation techniques the researcher felt the need to undertake the present study

Aim and objectives:

- To contribute for sustainable water resource management
- To quantify the polluted water (lake water quality) in Bangalore south
- To Check economically viable methods to its remediation.

METHODOLOGY

The Flow chart presented in Figure 1 summarises the entire study.

Bellandur Lake

Bellandur Lake, the largest lake in Bangalore has the highest water pollution index. Physical, Chemical, and Biological parameters are used to assess the water quality of the lakes.

The catchment covers the eastern part of Bangalore, an area of about 148 sq. Km. The terrain of the region is relatively flat and sloping towards south of Bangalore city. Three main streams join the tank, which form the entire watershed. One of the streams originates at the northern part of the region, Jayamahal and covers the eastern portion and is referred to as the eastern stream. Another stream originates from the central part of the city, Krishna Raja Market and covers the central part of the region before joining the tank and is called the central stream. Further another stream from southwestern part of the region called the western stream joins the central stream. The lake feeds the Varthur lake which in turn feeds the Pinakini River in Tamilnadu. (Table 1)

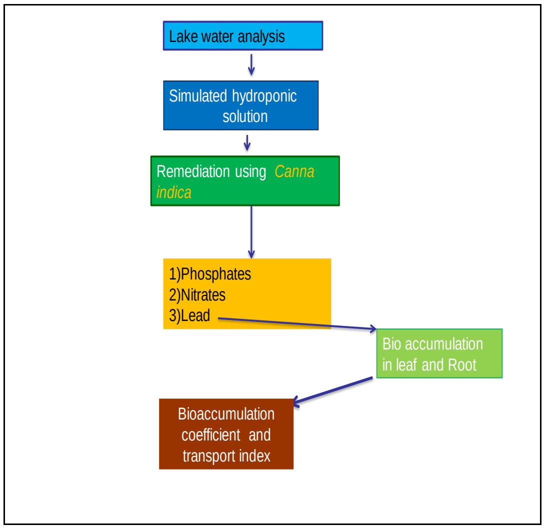

Figure 1: Research design of the study.

Bellandur lake catchment area falls into almost 41 wards of the Bruhat Bangalore Mahanagara Palike With the natural topography of the catchment sloping towards the lake, the storm water runoff eventually and makes its way into the lake. (Sreekantha and Narayana, 2000) the network of tanks was well connected with each other, the vegetation prevailed along the drainage linking these tanks, the entire catchment almost succumbed to the urban sprawl. This is evident from the disappearance of the water bodies, Challghatta Lake into a golf course, Shuleh tank into a football stadium and Koramangala tank into a sports complex.

Further, with the increased presence of urban areas in the catchment, the lake is also receiving wastewater generated in these areas that flow along the natural drainage. The wastewater is collected by the drainage basins Koramangala and Challghatta valley (K and C valley). The sewage treatment plant (STP) set up by the Bangalore Water Supply and Sewerage Board (BWSSB), is not functional to its installed capacity .The STP plant has a capacity of 248 MLD for treatment but and 218 is under renovation .Only 30 MLD is treated at primary and secondary levels and not by tertiary treatment . The remaining untreated sewage gains entry into the lake. (Figure 2,4)

Table 1. Bellandur Lake: Characteristics	
Among the largest wetlands of Bangalore is the Bellandur Lake. This Lake has been subjected to more than one-third of the domestic sewage (about 400+ MLD) generated in Bangalore city. It is on the verge of an imminent ecological disaster. Geographically, the study area is located between 77° 35´ west and 77° 45´ East and latitude 12° 50´ South and 13° 00´ North . Location	South eastern part of Bangalore
Valley	Challghatta
Surface area	328.87 Hectares
Area engulfed with slush and weed (ha)	174.33
Average depth	2.0 m
Catchment area	148 sq Km
Surface elevation	930m above mean sea level

Figure 3. Water sampling in Bellandur Lake.

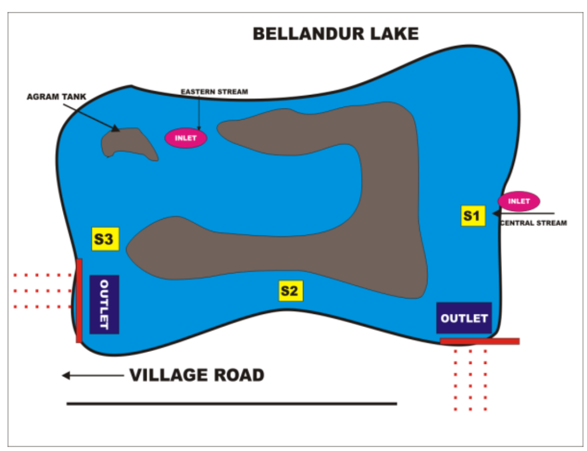

Figure 2. Different study station in Bellandur Lake.

Figure 4. Outlet, frothing of lake water.

LAKE WATER ANALYSIS: The Surface Water samples (5-10 cm below the water surface) for chemical analysis were collected from Bellandur Lake and brought to the laboratory in 5 liters cans. 6 months triplicate samples were collected (N=18) .The composite sampling method was used to collect the water sample. The sample was collected between 8am and 10am. While collecting the sample, care was taken that it is not exposed to heat or direct solar radiation. (Figure 3)

Electrical conductivity. (APHA 1992, p p: 2-43).

Conductivity is the capacity of water to conduct electric current and varies both with number and types of ions in the solution. The values of conductivity and TDS are interrelated.

Conductivity meter, was used to measure conductivity and expressed as m mhos or µ mhos/cm or as µS/cm.

pH (APHA 1992, pp: 4-65)

pH was determined at the site by the potable water analyzer (systronics) and was confirmed by electrometric pH meter. The probe was immersed directly in the water collected in a wide mouthed sampling bottle at the sampling site immediately after collection for a period of time sufficient to permit constant reading.

Total dissolved solids (TDS) (APHA, 1992, pp:2-55)

An electronic probe, which measures TDS was used. The values are expressed as mg/L of water. The probe was immersed directly in the water collected in a wide mouthed sampling bottle at the sampling site immediately after collection for a period of time sufficient to permit constant reading.

Turbidity. (APHA 1992, pp:2-130 **)**

Turbidity is an expression of optical property; wherein light is scattered by suspended particles present in water (Tyndall effect) and is measured using a nephelometer. Nephelometric measurement is based on comparison of the intensity of scattered light of the sample with the intensity of light scattered by a standard reference suspension (Formazin polymer) under similar conditions.

The nephelometer is calibrated using distilled water (Zero NTU) and a standard turbidity suspension of 40NTU. The thoroughly shaken sample is taken in the nephelometric tube and the value is recorded.

Turbidity (NTU) = (Nephelometer readings) (Dilution factor*)

Alkalinity (APHA.,1992. ,pp:2-26)

Alkalnity was measured by *Sulphuric* acid titrimetric method. The alkalinity of water is a measure of its capacity to neutralize acids. The alkalnity of water sample is recorded as follows**:**

P (phenolphthalein alkalinity), mg/L= A * 1000 / ml of sample

T (total alkalinity), mg/L= B * 1000 / ml of sample

In case H_2 SO_4 is not 0.02 N, then the following formula is applied

Alkalinity, mg/L = A / B * N * 50000 / ml of sample

Where,

A = ml of required to change from pink to colourless with phenolphthalein indicator

B = ml of $H_2 SO_4$ required to change from yellow to pinkish orange with methyl orange indicator

N = normality of $H_2 SO_4$ used

Chloride by Argentometric Method, (APHA, 1992, pp.4-49)

In a neutral or slightly alkaline solution, potassium chromate can indicate the en point of the silver nitrate titration of chloride. Silver chloride is precipitated quantitatively before red silver chromate is formed. Chloride is calculated as follows:

$$\text{mg Cl / L} = \frac{(A-B) \times N \times 35.450}{\text{mL sample}}$$

Where:

A = mL titration for sample,

B = mL titration for blank, and

N = normality of $AgNO_3$

$$\text{mg NaCl/L} = (\text{mg Cl}^-\text{/L}) \times 1.65$$

Total hardness by EDTA titrimetric method,(APHA, 1992, pp.2-36)

Hardness is generally caused by the calcium and magnesium ions (bivalent cations) present in water. The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/L. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and Chlorides cause permanent hardness

In alkaline conditions EDTA (Ethylene-diamine tetra acetic acid) and its sodium salts react with cations forming a soluble chelated complex when added to a solution. If a small amount of dye such as Eriochrome black-T is added to an aqueous solution containing calcium and magnesium ions at alkaline pH of 10.0 ± 0.1, it forms wine red colour. When EDTA is added as a titrant, all the calcium and magnesium ions in the solution get complexed resulting in a sharp colour change from wine red to blue, marking the end point of the titration.. At higher pH>12.0, Mg++ ion precipitates with only Ca++ in solution. At this pH, Patton and Reeders indicator forms a pink color with Ca++ ion. When EDTA is added, Ca++ gets complexed resulting in a change from pink to purple indicating the end point of the reaction. When EDTA (Ethylene-diamine tetra acetic acid) is added to the water containing calcium and magnesium, it combines first with calcium. Calcium can be determined directly with EDTA when pH is made sufficiently high such that the magnesium is largely precipitated as hydroxyl compound (by adding NaOH and iso-propyl alcohol). When Patton and Reeders indicator is added to the solution containing calcium, all the calcium gets complexed by the EDTA at pH 12-13. The end point is indicated from a colour change from pink to purple. The difference between total hardness and calcium

The Total hardness is calculated as mg/L = ml EDTA used * 1000 / ml sample

$Ca_{\text{(Hardness)}} = \mathbf{V}_{\text{EDTA (Ca)}} \times M_{\text{EDTA}} \times 1000 \times 100$ / volume of sample

$Mg_{\text{(Hardness)}} = \mathbf{V}_{\text{EDTA (Total)}} - \mathbf{V}_{\text{EDTA (Ca)}} \times \mathbf{M}_{\text{EDTA}} \times 1000 \times 84.3$ / volume of sample

Where,

$\mathbf{V}_{\text{EDTA (Ca)}}$) = Volume of EDTA consumed in the estimation of Ca hardness.

$\mathbf{V}_{\text{EDTA (Total)}}$) = Volume of EDTA consumed in the estimation of total hardness.

$\mathbf{M}_{\text{EDTA}}$ = Molarity of EDTA

Sulphates by Turbidimetric method, (APHA, 1992, pp.4-134)

Sulphates are found appreciably in all natural waters, particularly those with high salt content. Besides industrial pollution and domestic sewage, biological oxidation of reduced sulphur species also adds to sulphate content. Soluble in water, it imparts hardness with other cations. Sulphate causes scaling in industrial water supplies, and odour and corrosion problems due to its reduction to hydrogen sulphide. It can be calculated by turbidometric method. Sulphate ions are precipitated in acetic acid medium with barium chloride to form barium sulphate crystals of uniform size.

The scattering of light by the precipitated suspension (barium sulphate) is measured by a Nephelometer and the concentration is recorded.

Sulphate is Calculated as mg SO_4^{-2} / L= mg $SO4^{-2}$ * 1000/ mL Sample

Nitrates by Phenol disulphonic acid method, (Gautham *et al*, 2002).

Nitrates are the most oxidized forms of nitrogen and the end product of the aerobic decomposition of organic nitrogenous matter. Nitrogen along with phosphorus is termed as a bio stimulant. Nitrate reacts with phenol disulphonic acid to form a nitro derivative, which in an alkaline medium (liquid ammonia) develops a yellow colour. The concentration of NO_3 can be determined colorimetrically, since the colour so formed obeys the Beer's law. (The concentration of the colour is directly proportional to the concentration of nitrates in the sample).

Nitrates is Calculated as (mg/L) = mg NO_3 * 1000/mL Sample

Phosphates by Stannous chloride method, (APHA, 1992, pp:4-114.)

Phosphorus is essential for the growth of organisms and can be the nutrient that limits the primary productivity in water. The phosphates in water react with ammonium molybdate and forms the complex molybdophosphoric acid, which gets reduced to a complex of blue colour in the presence of stannous chloride. The absorption of light by this blue colour can be measured at 690 nm to calculate the concentration of phosphates.

Phosphates is calculated as (mg/L) = mg PO_4 * 1000/mL Sample

Potassium by Flame photometric method , (APHA, 1992, pp:3-80)

Potassium ranks seventh among the elements in order of abundance. Potassium can be determined accurately by flame photometer. The characteristic radiation for Potassium is 768 nm, the intensity of which can be read on a scale by using a filter for this wavelength.The concentration of Potassium is Calculated as (mg/L) = (mg K /L in portion)* D, Where D = mL sample + mL distilled water / mL sample

Dissolved oxygen by Azide modification,(APHA, 1992, pp: 4-100)

DO is a very important parameter for the survival of fishes and other aquatic organisms. DO is estimated by Winkler's method. Oxygen present in the sample oxidises the dispersed divalent manganous hydroxide to the higher valency to precipitate as a brown hydrated oxide after addition of potassium iodide and sodium hydroxide. Upon acidification, manganese reverts to its divalent state and liberates iodine from potassium iodide, equivalent to the original dissolved oxygen content of the sample. The liberated iodine is titrated against 0.025N sodium thiosulphate using fresh starch as an indicator.

DO is calculated as (mg/L) = Volume of titrant * 8 * 1000 / ml of sample taken

Where, N = normalcy of sodium thiosulphate

BIOCHEMICAL OXYGEN DEMAND (BOD) 5 day BOD test.(APHA, 1992, pp-5-3)

The biochemical oxygen demand (BOD) determination is an empirical test in which standard lab procedures are used to determine the relative oxygen requirements of waste waters, effluents and polluted waters. This test measures the oxygen required for the biochemical degradation of organic matter. The method consists of placing a sample in a full, air-tight bottle and incubating the bottle under specified conditions for a specific period – 5 days at 20^o C or 3 days at 27^o C. Dissolved oxygen (D.O.) is measured before and after incubation, the difference between the two being the BOD value. A reagent blank is also carried out in the same manner.

The bottle size, incubation temperature and period are all critical. Most waste waters contain more O_2-demanding materials than the amount of DO available in the sample. Thus, it is necessary to dilute the sample before incubation, with special 'aerated water', that has been aerated with O_2 for 3-4 hours. This water is also buffered with phosphate buffer, $MgSO_4$, $CaCl_2$ and $FeCl_3$ buffers to maintain the pH between 6.5 – 7.5.

CALCULATIONS:

When dilution water is not seeded

BOD (mg/l)= $DO_0 - DO_5$ / P

When dilution water is seeded,

BOD (mg/l) = $(DO_0 - DO_5) - (B_0 - B_5)$ f / p

where, DO_0 = initial DO of sample

DO_5 = final DO of sample

B_0 = initial DO of blank

B_5 = final DO of blank

f = ratio of seed in sample to seed in control

(% seed in DO_0) / (% seed in B_5)

p = decimal volumetric fraction of sample used

CHEMICAL OXYGEN DEMAND (COD) Open Reflux method, using potassium dichromate. (APHA, 1992, pp.5-7)

COD is the oxygen required by the organic substances in water to oxidize them by a strong chemical oxidant. This shows the oxygen equivalent of the organic substances in water that can be oxidized by a strong chemical oxidant such as potassium dichromate in acidic solution. COD is the measure of oxygen consumed during the oxidation of the oxidisable organic matter by a strong oxidising agent. Potassium dichromate ($K_2Cr_2O_7$) in the presence of sulphuric acid is generally used as an oxidisng agent in the determination of COD. The sample is treated with potassium dichromate and sulphuric acid and titrated against ferrous ammonium sulphate (FAS) using ferroin as an indicator. The amount of ($K_2Cr_2O_7$) used is proportional to the oxidisable organic matter present in the sample.

COD value is calculated as COD (mg/L)=(Volume of titrant used in blank – volume of titrant used in sample) * N of FAS * 8 * 1000 / volume of sample taken.

Bioremediation(Phytoremediation)

A Filter system was designed to check the Phytoremediation properties of *Canna indica* (Figure 5) on Heavy metals such as Lead , Nutrients such as Phosphates and Nitrates were also added for phytoremediation study. The filtering system was designed by taking 20 liters capacity water-can be collected with a tap at the base.

FILTERING SYSTEM: (Figure 6)

Large Pebbles 30%

Small Pebble 30%

Sand 30% *3 shoots of Canna indica*

The containers were washed with distilled water. A small piece of tile was placed on the inside of the tap to prevent blockage. The filter was layered in the following order-large pebbles, small pebbles, sand, *Canna indica*.

Figure 5. Canna indica taken from the college premises.

Filtering System (Figure 7)

Large pebbles 30%, Small pebbles 30%,Sand 30%.

Figure 6. Filter system to check the Phytoremediation properties of *Canna indica*.

Figure 7. Filter system (Control) to check the Phytoremediation properties.

The four filter systems were rinsed thoroughly with distilled water repeatedly to remove any traces of unwanted substances. The filter systems were left as such for 3 weeks for the proper growth of the *Canna indica*. This was done to enhance the root System of the *Canna indica*. 1 liter of 100mg/l lead solution was poured into each of the 4 filtering systems (1 control + 3 replicates). The filter systems were left for a week. After a week, the solutions from each of the filtering systems were collected at the bottom via the tap. To each of the collected samples, 4ml of HNO_3 was added in order to prevent precipitation. These samples were then filtered using Whatmann's filter paper and stored in 50ml standard flasks. These samples were estimated for Lead by AAS method. (Figure 8)

Figure 8. Simulated Hydroponic technique for phytoaccumulation study.

RESULTS AND DISCUSSION

After the data were obtained, it was processed using Microsoft Excel-2000 software and the data was analyzed using SPSS 10.0 Statistical software .The results obtained thereby have been interpreted. The chapter is organized under following sections:

Descriptive Statistics of lake water

Correlation analysis between the variables

Phytoremediation

Lake Water analysis

The water quality of Bellandur lake was analyzed for The Surface Water samples from 3 sampling points.

The descriptive statistics on the lake data reveals that the mean value for 6 months in Bellandur Lake shows that the conductivity, turbidity, TDS, DO, hardness, alkalinity, phosphate, nitrate and BOD is above the ISI standard. Other parameters such as pH, potassium, chloride, sulphate and COD are below the permissible limit.

pH explains certain significant biotic and abiotic ecological characteristics of aquatic systems in general. pH balance in an ecosystem is maintained when it is within the range of 5.5 to 8.5 (Chandrasekhar *et al.*, 2003), Kaul and Handoo (1980)observed that increased surface pH in water bodies is due to increased metabolic activities of autotrophs. The Environment Protection Agency of United State's criterion for pH of fresh water aquatic life is 6.5 to 6.9. According to ICMR (1975) and WHO (1985) safe pH limit is 7 to 8.5.But ISI (1991) range is 6.5 to 8.5. A pH range of 6 to 8.5 is normal according to the United States Public Health Association. When compared to all these Standards pH observed in both the lakes are within the permissible limit.

Electrical conductivity is a basic index to select the suitability of water for agricultural purposes (Kataria *et al.*, 1995). EC in water is due to ionization of dissolved inorganic solids and is a measure of total dissolved solids and salinity. (Bhatt *et al.*, 1999) Salts that dissolve in water break in to positive charge and negative charge ions. Dissolved solids affect the quality of water used for irrigation or drinking. They also have a critical influence on aquatic biota, and every kind of organism has a typical salinity range that it can tolerate. Moreover, the ionic composition of the water can be critical. These observations pointed out that EC is a highly variable factor in freshwaters. Conductivity is highly dependant on temperature.

Table 2. Summary statistics of different variables in Belandur Lake

Variables	*Standard	Minimum	Maximum	Range	Mean	Median	Std.Dev.	SE
pH	5.5-8.5	7.00	7.90	0.90	7.30	7.25	0.30	0.09
cond		92.00	106.00	14.00	97.23	95.50	4.59	1.32
turb	5 NTU	13.00	21.00	8.00	17.50	17.00	2.65	0.76
Tds	500mg/L	770.00	1150.00	380.00	929.00	915.00	123.45	35.64
DO	>5mg/L	--	--	--	--	--	--	--
hardness	300mg/l	360.00	470.00	110.00	417.58	423.50	36.67	10.59
K		43.00	150.00	107.00	82.67	66.00	36.68	10.59
Alk	<200	300.00	448.00	148.00	370.83	375.00	51.25	14.79
Cl	250mg/L	89.00	258.00	169.00	147.00	135.00	51.00	14.72
So	150mg/L	76.00	219.00	143.00	134.83	125.00	44.78	12.93
No	10mg/L	15.00	25.00	10.00	20.01	20.50	3.04	0.88
Phosphate	0.1mg/L	9.40	31.00	21.60	20.48	21.75	8.72	2.52
Bod	30mg/L	19.00	200.00	181.00	52.42	27.50	53.83	15.54
Cod	150mg/L	54.00	300.00	246.00	125.92	112.00	71.21	20.56

* ISI Standard
N=18

Suspension of particles in water interfering with passage of light causes turbidity. Turbidity of water is responsible for the light to be scattered or absorbed rather than its straight transmission through the sample, it is the size, shape, and refractive index of suspended particulates rather than the total concentration of the latter present in the water samples that are responsible for turbidity in natural waters restricts light penetration thus limiting photosynthesis, which consequently leads to depletion of oxygen content. Turbidity in water is caused by a wide variety of suspended matter, which range in size from colloidal to coarse dispersions and also ranges from pure organic substances to those that are highly organic in nature. Clay, silt, organic matter, phytoplankton and other microscopic organisms cause turbidity in natural waters.

Sources of oxygen in water are by diffusion of oxygen from the air into the water, photosynthetic activity of aquatic autotrophs and inflowing streams. DO is a very important parameter for the survival of fishes and other aquatic organisms. DO is the sole source of oxygen for all the aerobic aquatic life and hence it is considered as an important measure of purity for all waters. Oxygen content is important for direct need of many organisms and affects the solubility and availability of many nutrients and therefore the most significant parameter affecting the productivity of aquatic systems (Wetzel, 1983). DO reflect the water quality status and physical and biological processes in waters and show the metabolic balance of a lake. DO is an important water quality parameter in assessing water pollution (Laluraj *et al.*, 2002). The factors affecting oxygen content in natural waters include input due to atmosphere and photosynthesis and output from respiration, decomposition and mineralization of organic matter as well as losses to atmosphere. Hence, the oxygen balances in water bodies become poorer as the input of oxygen at the surface and photosynthetic activity decreases and as the metabolic activities of heterotrophs are enhanced. Fluctuation in DO is also due to fluctuation in water temperature and addition of sewage waste demanding oxygen (Koshy and Nayar, 2000).

Correlation Analysis (Table 3)

Table 3. Correlation among different variables in Belandur Lake by Karl Pearson's correlation coefficient procedure.

Variables	pH	Cond	Turb	TDS	DO	Hardness	K	Alk	Chloride	So	No	Phosphate	B.O.D	COD
pH	1.0000													
Cond	0.2217	1.0000												
Turb	0.1151	0.714*	1.0000											
TDS	0.2013	0.938*	0.847*	1.0000										
DO	-	-	-	-	-									
Hardness	0.4709	0.641*	0.5982	0.751*	-	1.0000								
K	0.4691	0.4361	0.0169	0.2982	-	0.3447	1.0000							
Alk	0.4243	0.2264	0.4090	0.4422	-	0.4952	-0.186	1.0000						
Chloride	0.1875	0.4675	-0.060	0.2549	-	0.2064	0.850*	-0.483	1.0000					
So	0.1367	0.4325	-0.138	0.2043	-	0.1673	0.836*	-0.495	0.985*	1.0000				
No	0.0401	-0.272	-0.516	-0.430	-	-0.116	0.2522	-0.484	0.4066	0.4904	1.0000			
Phosphate	-0.126	-0.219	-0.254	-0.126	-	0.1506	-0.103	0.2025	-0.157	-0.134	0.0389	1.0000		
B.O.D	0.0085	0.3950	0.3654	0.5004	-	0.4517	-0.256	0.5586	-0.314	-0.315	-0.327	0.4187	1.000	
COD	0.3879	0.3370	0.3114	0.4308	-	0.5234	-0.165	0.749*	-0.395	-0.379	-0.321	0.0825	0.788*	1.000

*Significant at 5% level of significance ($p<0.05$).

The total hardness is defined as the sum of Ca and Mg concentrations, both expressed as $CaCO_3$ in mg/L. Carbonates and bicarbonates of Ca and Mg cause temporary hardness. Sulphates and chlorides cause permanent hardness. Water with total hardness 0-60 mg/Lis considered soft; 60-120 mgL^{-1} is considered medium and above 120 mg/L is considered very hard. According to Durfer and Baker's classification when hardness is less than 75 mgL^{-1} of $CaCO_3$, water is soft (Adak *et al.*, 2002). According to Moyle (1949) Total alkalinity is caused by bicarbonates, carbonates, OH ions, borates, silicates and phosphates (Kataria *et al.*, 1995). Alkalinity is a measure of buffering capacity ofwater and is important for aquatic life in a freshwater system because it equilibrates the pH changes that occur naturally as a result of photosynthetic activity of phytoplankton (Kaushik and Saksena, 1989) Alkalinity is used as criteria for determining thenutrient status of waters (Sorgensen, 1948; and Moyle, 1949).

Excess Chloride ions in water indicate degree of pollution and in natural waters the Chloride ions are usually found associated with Na, K, and Ca, and Cl ions produce salty taste when concentration is 100 mg/L (Kataria *et al.*, 1995). Gowd *et al.* (1998) observed that a high concentration of Chloride imparts a salty taste to water. According to Chandrasekhar *et al.* (2003) the presence of Chloride concentration in a water source is used as an indicator of organic pollution by domestic sewage

Phosphorus occurs almost solely as phosphates in natural waters. All forms of phosphates such as orthophosphates, condensed phosphates, and organically bound phosphates are found in waters. Phosphate is added to land through different ways; P containing fertilizers, animal manures, and waste products from animals supplemented with P enriched feed. In natural waters P exists as soluble phosphates. P is the nutrient considered to be the critical limiting nutrient, causing eutrophications of fresh water systems

Organic matters of natural as well as anthropogenic inputs were the main contributory factors for the high COD values in natural waters.

The Karl Pearson Correlation between the variables indicated the following in Bellandur Lake:

Increase in Electrical conductance increases the turbidity of water. There is a positive significant correlation between Conductivity and turbidity.

Total hardness of water found to have a positive significant correlation with Conductivitz Total Dissolved Solids and turbidity.

Potassium of water was found to have a positive significant correlation with Chloride and Sulphate .Chlorides are indicators of pollution due to organic wastes from animals or industrial origin

A positive significant correlation was seen between BOD and COD.

A positive significant correlation between alkalinity and COD was seen the alkalinity of water is due to the salt of carbonates ,bicarbonates ,borates, silicates and phosphates along with hydroxyl ions. The high value of alkalinity due to water softening agents such as washing soda and sodium carbonate, the use of these soaps mighty have increased the concentration of carbonates and hence alkalinity which in turn increases the Chemical oxygen demand.

Table 4. Heavy metal content in lake water sample.

Constituents (mg/L)	ISI Standards	Bellandur Lake
Lead	0.01mg/L	0.06*

Water Quality index of Bellandur Lake

Calculation of Overall Water Quality Index

Factor	Weight	Quality Index
Dissolved oxygen	0.17	2
Fecal coliform	0.16	17
pH	0.11	93
Biochemical oxygen demand	0.11	5
Temperature Change	0.10	11
Total phosphate	0.10	2
Nitrates	0.10	37
Turbidity	0.08	64

Based on the 8 factors entered,

the water quality index is 26.

The 100 point index can be divided into several ranges corresponding to the general descriptive terms shown in the table below.

Water Quality Index Legend

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Thus from the above online (calculated value) (source: WQI Index- Consumer Support Group Online Calculators http://www.csgnetwork.com/h2oqualindexcvttemponlycalc.html) Ulsoor lake which is restored has medium water quality index and Bellandur Lake has a bad water quality index.

Table 5. Efficiency of Canna in removing Phosphate from phosphate samples provided.

Growth time in days	0	1	3	7
Total phosphate in mg (Canna)	0.5 ±0.05	0.268 ± 0.02	0.141 ± 0.03	0.0217 ± 0.004
Removed (%)	0	46.4	71.8	95.6

Table 6. Efficiency of canna in removing Nitrate from simulated nitrates from hydroponic growth medium.

Growth time in days	0 (control)	1	3	7
Total Nitrate in mg (Canna)	1±0.05	0.87 ± 0.02	0.693 ± 0.052	0.433 ± 0.049
Removed (%)	0	13	30.7	56.7

Phytoaccumulation of Lead after 7 days with an initial concentration of 100mg/L being added to *Canna indica* placed in simulated hydroponics system.

Table 7. Removal of lead by Canna.

Type of Filter	Conc. of Lead in the filtrate (mg/L) by AAS	Percentage of Removal (%)
Control	35.5	64.5
Canna	Nil	100

Table 8. Uptake of lead by Canna placed in hydroponic growth medium.

Type of remediating plant	Conc. Of Lead accumulated in Leaf (mg/dry wt)	Conc. Of Lead accumulated in Root (mg/dry wt)
Control	ND	ND
Canna	1.54	22.76

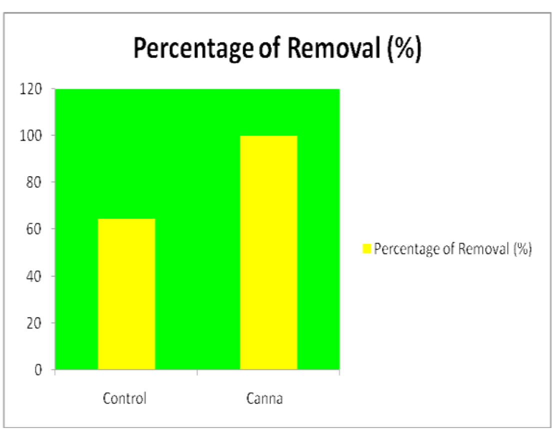

Figure 9. Percentage of removal of lead by Canna.

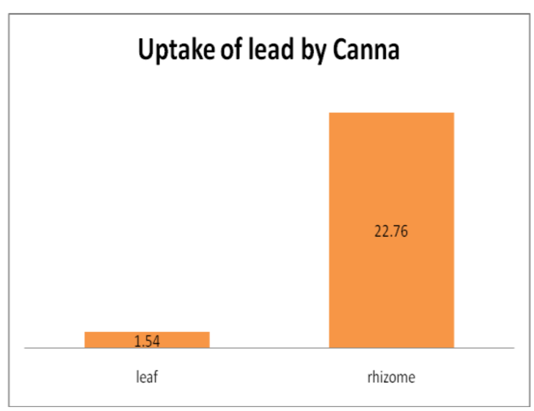

Figure 10. Uptake of lead by Canna.

Table 9. Bioaccumulation coefficient and transport index Canna indica.

Type of remediating plant	Bioaccumulation Coefficient	Transport index%
Canna	243	6.33

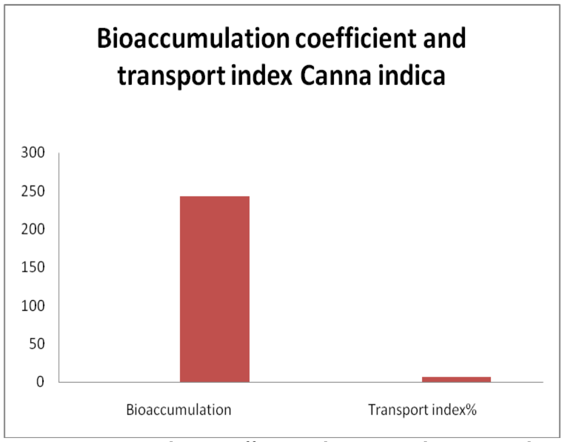

Figure 11. Bioaccumulation coefficient and transport index; Canna indica.

SUMMARY AND CONCLUSION

The descriptive statistics on the lake data reveals that the mean value for 6 months in Bellandur Lake shows that the conductivity, turbidity, TDS, DO, hardness, alkalinity, phosphate, nitrate and BOD is above the ISI standard. Other parameters such as pH, potassium, chloride, sulphate and COD are below the permissible limit. Bellandur Lake showed high Lead content beyond the permissible limit.

The Correlation analysis between the variables of water quality parameters of Bellandur Lake showed a positive significant correlation between conductivity and turbidity; TDS and Hardness; Turbidity and Hardness ; Potassium and Chloride, Sulphate; BOD and COD; Alkalinity and COD.

Considering the problem of deteriorated water quality, Phytoremediation was developed in the Environmental science Laboratory (Mount Carmel College, Bangalore, India) which could be easily implemented in lakes. The system is based on filterable wetland where *Canna indica* were grown in filtering system both horizontal (filtering system) and vertical (plants suspended in buckets).The uptake of lead was found high in root tissues compared to shoot tissues. The present study indicates that Canna indica has a higher potential uptake of toxic metal lead. *Canna indica*, which had a bioaccumulation coefficient of 243 and transport index is 6.33. *Canna indica* is a good potential macrophytes that could be used in bioremediation technique which is cost effective sustainable & aesthetic in developing lakes. This plant is used for ornamental purpose hence there is less chance of biomagnification of toxic elements in the ecosystem.

CONCLUSION

When properly designed and applied, the wetland system with and *Canna indica* as the ornamental plant would play a key role in minimizing the impact of imminent global clean fresh water resource. *Canna indica* which is harvestable and represents economic products, thus ensuring sustainability to the ecosystem.

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