Effective Wetland Management Using GIS

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ABSTRACT

'Wetland' denotes a large body of water surrounded by land, whether natural or artificial, permanent or temporary with water that is lentic or lotic. Wetlands perform some useful functions in the maintenance of overall balance of nature. Due to economic growth,urbanization,population increase and industrialization, more and more waste materials were discharged in to it and make it unfit for any uses. Hence to maintain the ecological balance,it is imperative to preserve these wetlands to make it fit for various purposes. Study is being undertaken in Bangalore, to identify the qualitative and quantitative impact on wetlands due to urbanization. In this connection, apart from field investigation (to identify the status of wetlands), Geographic Information System(GIS) is used for spatial and temporal assessment. A detailed investigation covering physical, chemical, and biological investigations were carried out in two lakes namely Rachenahalli and Amruthalli. Socio-economic survey was done to find the level of dependency on these lakes. Spatial and temporal changes are analyzed using GIS, remote sensing data and Survey of India, topographical maps. Water qualities of lakes situated in various location of the city were compared, with the data collected during last three years. Integration of water quality information, topographical information, land use and population density has aided in arriving at the appropriate restoration and conservation strategies.

INTRODUCTION

Two third of this world is surrounded by waterbodies. Wetlands occupy an estimated amount of 6.4% of the earth's surface(IUCN Environmental Policy and Law paper No.38). Wetlands are among the earth's most diverse and productive ecosystems. Wetland sustains all life and performs some useful functions in the maintenance of overall balance of nature. As a result of rapid urbanization, increase in population, technical development, economic growth and various anthropogenic activities, more and more waste materials were discharged into the natural sources of water bodies apart from conversion of wetlands for anthropogenic activities. Due to this, declination of wetland quality and quantity takes place and the requirements for water have also increased along with greater demands for higher quality water. Hence it is imperative to conserve and preserve these wetlands to make it fit for local consumption and to maintain the ecological balance.

Definition

'Wetland' denotes any area covered with water, which includes all rivers, lakes, paddy fields and periodically flooded lands. As per the definition given at Ramsar Convention (Ramsar, 1996),

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'Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing; fresh, brackish, or salty, including areas of marine water the depth of which at low tide does not exceed 6m'.

Importance of Wetlands: Funtions and Values

Wetlands are amongst the Earth's most productive ecosystems. Wetland systems directly or indirectly support millions of people and provide goods and services to them. The growth and development of all the organisms that require wetlands for life. Wetlands may benefit directly as components / products such as fish, timber, wild life, fertile land for agriculture, water transport, recreation and water supply or indirect benefits which arise from the functions occurring with in the ecosystem such as flood control, ground water recharge, storm protection, shore line stabilization, water quality improvement, sediment and nutrient retention. The mere existence of wetlands may be of a great significance to some people because it is a part of their cultural heritage. Apart from these, some socio-economic values through water supply, fisheries, fuel wood, medicinal plants, livestock grazing, agriculture, energy resource, wildlife resource, transport, recreation and tourism etc., is significant,and in maintaining the ecological balance of the ecosystem.

Wetland Loss and Degradation

Wetland constitutes important features of the landscape and subjected to constant change due to urbanisation and in some cases has led to disappearance. The impact on wetlands may be grouped in to five main categories: loss of wetland area, changes in water quality, changes to water regime, overexploitation of wetland products and introductions of endangered or alien species.

Wetlands are facing problems due to major proportion of the population in the catchment area, urbanization and industrialization; and various human activities, which has accounted for the over exploitation and leads to degradation of wetlands.

Wetlands are threatened by excessive loading of silt and nutrients from various sources(point and non-point sources)due to removal of vegetation cover in the cacthment area. Vast areas of wetlands have been encroached for various purposes such as for agricultural purposes, for settlements etc., due to rapid urbanization. These threats are resulted in shrinkage of area. Weed infestation and colonization by water hyacinth causes further degradation of most of the wetland ecosystem.

Effluent from industries, uncontrolled use of fertilizers in the agricultural lands, discharge of domestic wastes and sewerage from human settlements, all contribute to the water quality deterioration to these systems. Wetland waters are diverted for farming, public water supply, hydroelectricity and navigation, which can change its water regime.

Apart from these quality and quantity declinations,it has also decreased the Biological diversity of flora and fauna, migratory birds and also the productivity of the system. Simultaneously

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several thousand species are now endangered and many other sustainable species, products like fish, timber, medicinal plants, water transport and water supply are over exploited.

Status of Wetlands in Bangalore

Bangalore has many man-made wetlands, that were artificially built for various hydrological purposes and mainly to serve the needs of irrigated agriculture. The number of man made lakes has fallen from 262 in 1960, to some 81 lakes at present (Lakshman Rao, N. et al 1986). The quality of water has reduced due to discharge of industrial effluent and domestic sewage (Shivshanker, T.V. et al, 1985). Many lakes have been lost by converting wetlands for residential, agricultural and industrial purposes (Venkataraman R.,1997). More than 28 % of lakes suffered from various degree of eutrophication and nearly 30% of vegetables were grown in untreated water(Krishna, M.B. et.al).Earlier investigations also revealed that,for nearly 40% of the lakes, sewage was the main source, 13% lakes surrounded by slums and loss of catchment for nearly 35% lakes surveyed between 1973 and 1996 (Deepa,R.S, et.al,1996).Now it has become necessary to preserve and conserve these vanishing ecosystems, which is important for various purposes and to achieve ecological sustainability.

OBJECTIVES

The main approach of the present study was

- To identify the qualitative and quantitative impact on wetlands (status of wetlands) due to urbanization; and
- To find the level of dependence on the lakes in Bangalore, inorder to explore suitable restoration conservation strategies.

STUDY AREA

Bangalore District is located in the heart of south Deccan of Peninsular India. It is situated in the south-eastern corner of Karnataka state ($12^{o}39'$ - $13^{o}18'$ N latitude and $77^{o}22'$ - $77^{o}52'$ E longitude) with a geographical area of about 2,191 sq. Km and at an average elevation of 900 m above the mean sea level. The climate of the district is having agreeable temperature ranges from the highest mean maximum of 36.2^{o} C in April to lowest mean maximum of 11.4^{o} C in January. It has two rainy seasons from June to September and from October to November coming one after the other but with opposite wind regime, corresponding to south- west and north-east monsoons. The mean value of the rainfall of about 900-mm with standard deviation of 18.7mm was recorded from the year 1875 to 1976(Srivastava et.al).The present study area is situated in Bangalore North and Bangalore South taluks.

METHODOLOGY

The proposed study to suggest suitable restoration techniques for the lakes in Bangalore based on the pollution level. Valuation of lakes is done to ascertain the economic dependency of the

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people living in the surrounding areas on these lakes. This entails sampling, analysing the lake water quality in the field and laboratory by using appropriate methods, socio-economic aspects of the lakes, depth analysis and volume computations of the lakes using GIS.

Sampling

For physico-Chemical characterisation of lakes, samples were collected at various inlets, outlets and middle part of Rachenahalli and Amruthalli lakes at 15 days interval. Totally four samples have been taken from each lake,every time of sampling using polyethylene containers.

Physico-chemical Analysis

The main objective of physico-chemical analysis is to assess the quality of water and to find out its pollution level.

 # Physical Parameters:
Various physical parameters that were analysed were color, temperature, transparency, conductivity, pH, total solids, dissolved solids and suspended solids.

 # Chemical Parameters:
Various chemical parameters analysed were alkalinity, acidity, dissolved oxygen, chlorides, sulphate, total hardness, calcium, magnesium, sodium, potassium, nitrates and phosphates. The analysis of these lake water qualities was done as per the standard methods prepared and published by NEERI and American public health association.

Color was measured using visual comparison method; temperature was determined using Mercury thermometer; pH was measured using a pH meter; electrical conductivity,using a conductivity meter; total solids,total suspended solids, and total dissolved solids, was determined using Gravimetric method;D.O was estimated using the Winkler's method. Sodium and Potassium were analysed by using flame-photometer. Alkalinity and acidity were determined by titration method provided by NEERI. Total hardness, calcium and magnesium, were determined using EDTA titration method; chlorides, using Argentometric method; sulphates, using turbidimetric method using Spectrophometer at 420 nms; nitrates, using Phenol Di sulfonic Acid method using Spectrophometer at 410 nm and phosphates , was determined using Ammonium Molybdate method using Spectrophometer at 690 nm.

Socio-economic Survey:

Socio-economy survey was conducted to quantify the values of wetland resources and to determine the economic dependency of the people living in the surrounding areas on these lakes. A random survey of the houses around the lake was carried out using a standard questionnaire format designed for this purpose. Totally five villages were selected in this regard.

Bathymetric Analysis

Bathymetric analyse is carried out to find out the depth profile of the lake. This is done by dividing the lake in to different segments using transects. The depth at various points is found by using plumb bob or by simply a rope tied with a stone at one end and a measuring tape. Volume of the lake can be computed using the depth and area data's that is obtained.

Appilication of GIS and Collateral Data

The Geographic Information System (GIS) is used for spatial and temporal assessment, which helps in identifying and monitoring the impacts, due to point and non-point source(NPS) of pollution. The patial and temporal changes in the surface water bodies are mapped using Survey of India 1:50,000 scale, topographical maps. The technology of remote sensing is used as a monitoring tool for basin management. The SOI 1:50,000 scale, toposheet number 57 G/12 are used for topographical informations, for placing ground truth sites in the field and for the preparation of base maps. Converting topographical information with field data in to digital format creates final maps and various layers of maps are prepared in this regard using Map info software. Integration of thematic layers of water quality and quantity along with socio-economic, land use and population informations are overlaid on the base map to know the Current Status and Socio-economic aspects of the wetlands.

RESULTS AND DISCUSSION

Table 1 shows the characteristics of Rachenahalli Lake water quality; and **Table 2** shows the characteristics of Amruthalli Lake Water quality.

TABLE 1 : Rachenahalli Lake Water Quality Results

I PHYSICAL PARAMETERS :				
PARAMETERS	**SAMPLE 1**	**SAMPLE 2**	**SAMPLE 3**	**SAMPLE 4**
PH**	7.2	7.65	7.95	7.54
ELECTRICAL CONDUCTIVITY*	0.33	0.628	0.428	0.262
TEMPERATURE (oC)	25.5	26	25	23
COLOUR**	YELLOW	YELLOW	YELLOW	YELLOW
II CHEMICAL PARAMETERS:				
DISSOLVED OXYGEN	2.3	4.5	4.8	7.5
ALKALINITY	8.4	200	116	124
ACIDITY	16	15	28	20
CHLORIDES	70.98	175.9	173.94	83.98
TOTAL HARDNESS	136.25	301.5	201.65	158.05
CALCIUM	81.75	180	136.25	109
MAGNESIUM	54.5	121.5	65.4	49.05

SODIUM	29.24	55.78	42.52	27.01
POTASSIUM	6.07	10.91	8.097	5.26
TOTAL SOLIDS	352	580	584	332
TOTAL DISSOLVED SOLIDS	296	510	512	285
TOTAL SUSPENDED SOLIDS	56	70	72.4	47
SULPHATES	23.8	23	37	31.94
NITRATES	0.3107	0.3067	0.3016	0.2928
PHOSPHATES	0.01	0.015	0.009	0.0085

TABLE 2 : Amruthalli Lake Water Quality Results

PARAMETERS	**SAMPLE 1**	**SAMPLE 2**	**SAMPLE 3**	**SAMPLE 4**
I PHYSICAL PARAMETERS:				
PH **	7.46	6.7	6.9	6.87
ELECTRICAL CONDUCTIVITY*	0.768	0.313	0.401	0.409
TEMPERATURE(oC)	23	23	22.5	23.5
COLOUR**	GREENISH	GREENISH	GREENISH	GRENISH
TRANSPARENCY(cm)	NA	NA	NA	NA
II CHEMICAL PARAMETERS:				
DISSOLVED OXYGEN	NIL	NIL	NIL	NIL
ALKALINITY	350	195	190	175
ACIDITY	45	55	55	60
CHLORIDES	183.94	67.978	101.97	89.97
TOTAL HARDNESS	392.4	218	205.75	201.65
CALCIUM	250.7	130.8	125.75	119.9
MAGNESIUM	141.7	87.2	80	81.78
SODIUM	56.498	32.28	34.9	24.834
POTASSIUM	9.163	6.378	5.45	5.5776
TOTAL SOLIDS	718.88	404.44	398.2	446.66
TOTAL DISSOLVED SOLIDS	644.44	340	342.7	342
TOTAL SUSPENDED SOLIDS	74.44	64.44	55.5	104.6
SULPHATES	61.95	26.89	23.12	23.39
NITRATES	0.46	0.3599	0.451	0.488

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PHOSPHATES	0.2415	0.201	0.131	0.1975
* ms/cm, ** no unit, Rest denotes mg/l unless Otherwise it is mentioned.				

Figure 1. and **Figure 2.** gives an idea about the water quality parameters value variation during different set of cycles in Rachenahalli and Amruthalli lakes respectively.

Fig.1. Rachenahalli lake water charecterstic variations during bio-monthly sampling

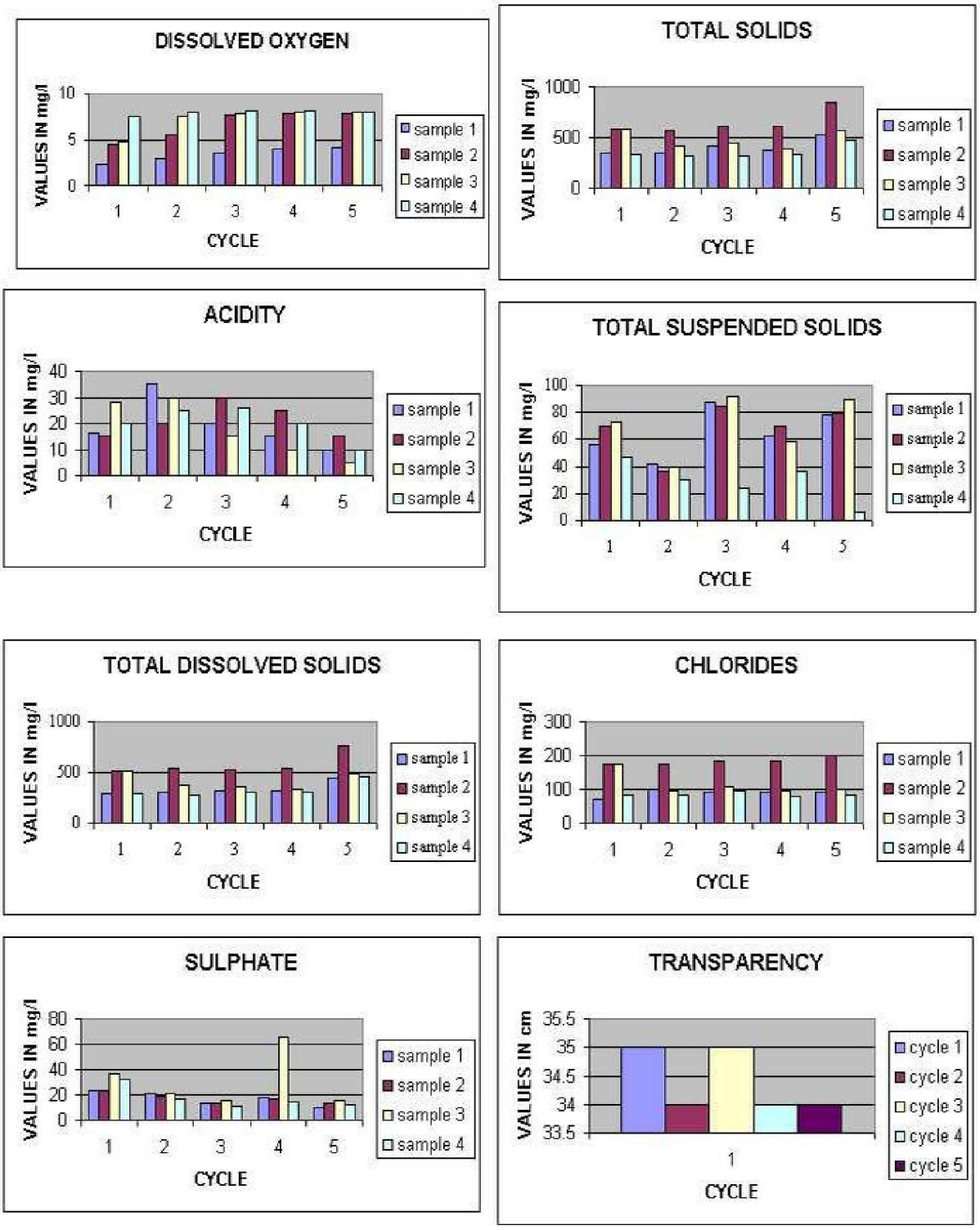

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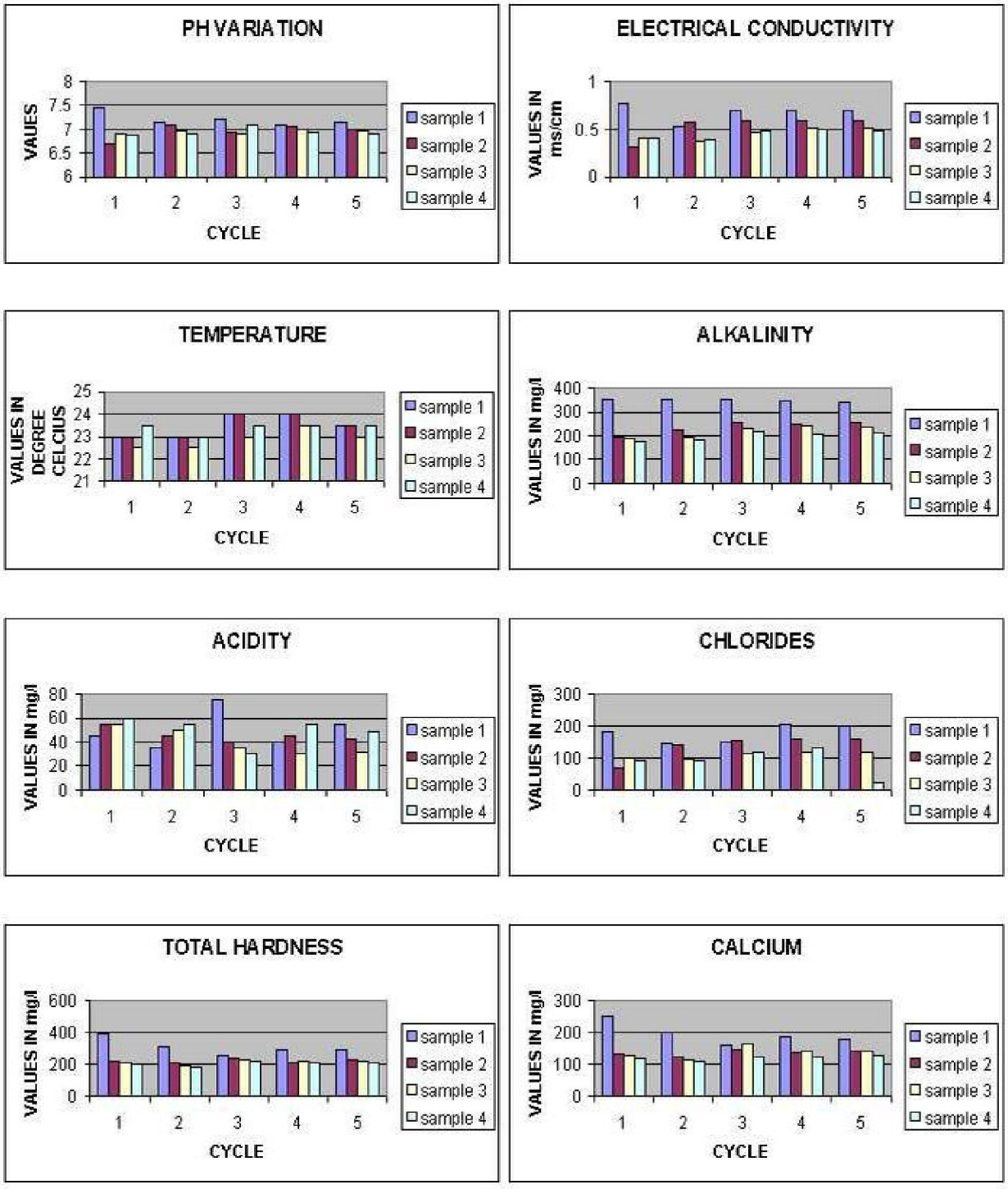
Fig.2. Amurthahalli lake water charecterstic variations during bio-monthly sampling



The analysis results shows that the Dissolved oxygen ranges from 2.3 to 8.2 mg/l in Rachenahalli lake and nil values in Amruthalli lake, Alkalinity ranges from 135 to 175 mg/l and 175 to 355 mg/l in Rachenahalli and Amruthalli lakes respectively, Total hardness ranges from 136 to 278 and 185 to 392 mg/l in Rachenahalli and Amruthalli lakes respectively, the Total suspended

solids ranges from 6 mg/l to 92 mg/l in Rachenahalli lake and 31.4 to 150 mg/l in Amruthalli lake,the concentration of total phosphorous ranges from 0.0065mg/l to 0.0429 mg/l in Rachenahalli and 0.09 mg/l to 0.28 mg/l in Amruthalli lake and the Nitrate nitrogen concentration ranges from 0.10 mg/l to 0.333-mg/l and 0.204 mg/l to 0.488 mg/l in Rachenahalli and Amruthalli lakes respectively.

These results were compared with Indian Standard Specifications (NEERI) and Water quality datas of Sankey tank in Bangalore, collected during this period and that of Rachenahalli lake is slightly polluted by the parameters like nutrients, alkalinity and hardness, whereas Amruthalli lake is heavily polluted by nutrients, weed infestations, oxygen deficiency, odour, suspended solids, alkalinity and hardness, and has attained the eutrophic condition, as a results of urbanisation and various anthropogenic activities in the surrounding area.

Table 3 shows the economic dependency of the people residing closer to wetlands. The values are expressed in Rupees. **Table 4** shows the valuation of Rachenahalli and Amruthalli lakes.

Table 3 : Socio-economic details

ITEMS	Quantity of Amruthalli lake resources	Amruthalli lake value in Rs.	Quantity of Rachenahalli lake resources	Rachenahalli lake value in Rs
Domestic consumption	277.9 lits/ house/day	1.667/house/day	214.97 lits/house/day	1.289/house/day
Livestock consumption	59.28 lits/Cow/day	35.5 /100 cows/day	60.39 lits/cow/day	36.18 /100 cows/day
Agricultural consumption	7201.02lits/Hectare/day	43.19/hectare/day	12087.8 lits/hectare/day	72 /hectare/day
Agricultural products: Paddy Raggi Flowers Gowa Vegetables Coconut	 :15.1Q/ha/0.5year :7.6Q/ha/0.5year :3.95Q/ha/year :74.23Q/ha/year : -- :3000Nos./ha/yr	 21140/ha/0.5year 4560/ha/0.5year 11847.9/ha/year 37115/ha/year --- 11253/ha/year	 32.01Q/ha/year 12.5Q/ha/.05year 6.64/ha/year 60.1Q/ha/year 7.69Q/ha/year 5100.2Nos./ha/yr	 44814/ha/year 7500/ha/0.5year 19920/ha/year 30050/ha/year 10381.5/ha/year 19125/ha/year
Energy resource	0.47 Kg/person/day	117.5/1000	1.298 Kg/person/day	324.5/1000 persons/day
Fishing products	-----	-------	75 Kg./day	900/day

Table 4 : Valuation of Rachenahalli and Amruthalli lakes

Lake	Direct use		Indirect value	Existence Vlue
	Use	Value in Rs.		

Rachenahalli	*Agricultural *Fuel *Fish *Livestock consumption	9173.0 324.5 900 37.5	*Ground water table varies from 50 (vicinity of lake) 250ft (at 2-3 km away from lake) *It has greater capacity to retain flood waters from heavy rainfall and disposal of treated water from JNCASR	* birds and migratory birds *Culture and heritage value. *Pooja during festivals	
Result	Total value is Rs. 10435 Per day, during Cropping and fishing Season.		Ground water recharge and flood protection is increased due to lakebed perviousness.	Functional aspects, bio-diversity and cultural, recreational aspectsindicates importance of wetland eco system.	
Amruthalli	Use	Value in Rs.	*Ground water table varies from 180ft (vicinity of lake) 400ft(3 km away from the lake) *It has lower flood protection value.	*Existing lake has no culture, heritage and biodiversity value	
	*Fuel *Livestock consumption	12.5 7.5			
Result	Total value is Rs. 20.0/day. Lower value is due to eutrophic condition of the lake which made the wetland resources unusable		It has no ground water recharge and fewer flood control values mainly due to impervious lakebed resulting from the accumulation of silt.	This is due to pollution on account of anthropogenic activities in and around the lake.	

The economic valuation is done to assess the dependency on wetlands. In the case of Rachenahalli lake by surrounding villages is estimated to be about Rs. 10,435/day (during cropping and fishing season) and Amruthalli lake is about Rs.20.0/day. This shows that, the economic dependency in the case of Rachenahalli lake is more than that of people living around the Amruthalli lake due to better water quality and ecosystem. The ground water table of Rachenahalli lake ranges from 50 ft in the immediate vicinity and 250 ft at farther places (2-3 kms), while surrounding region of Amruthalli lake ground water table ranges from 180 - 400 ft. This is mainly due to, sediments accumulated in lake bed has become impervious which hinders recharging Sediment accumulation is due to siltation, which is a result of removal of vegetative cover in the catchment area. Apart from this, waste disposal in lake has resulted in eutrophic condition of the lake as consequence of urbanisation and industrialisation.

Bathymetric analysis confirmed sediment accumulation through reduction in depth and area (reduced considerably during last two decades). Water spread area has also declined due to encroachment f peripheral areas for agricultural purposes, settlements, construction of roads and institution etc.,

CONCLUSION

This study shows that Amruthalli lake was polluted severely by nutrients from streets, sewage and industrial effluents than Rachenahalli lake;and its quantified value and functions are also less than that of Rachenahalli lake. It also shows that people in these areas are very much dependent on these lakes for their daily consumption; and depth and area of both the lakes have been considerably reduced during last two decades, due to siltation and encroachments for developmental activities. Eutrophic condition is seen in Amruthalli lake. Hence there is an immediate need to restore, conserve and preserve these existing wetlands to maintain and improve the ecological balance.

GIS approach provides the decision-makers a powerful tool for collecting, storing, analysing and displaying the information layers of data. Integration of water quality and quantity along with socio-economic and population informations has aided in arriving at appropriate restoration conservation strategies of Rachenahalli and Amruthalli lake waters. Some of the Best Management Practices(BMPs) are suggested in managing and restoring wetlands. It includes the following practices:

- Pollution prevention practices might be applied to reduce the generation of non-point source of pollution and pollution from industrial, residential, agricultural and institutional areas through source reduction, waste minimisation and process control.
- Promoting public education programs regarding proper use and disposal of household and agricultural hazardous waste materials.
- Afforestation around the lake to control the entry of silt from run off.
- Infiltration trenches might be useful in reducing the storm water sediment loads to downstream wetlands by temporarily storing the runoff.
- Extended detention dry basins might be provided in removing pollutants primarily through the settling of suspended solids.
- Constructed wetlands are recommended for the purpose of stormwater management and pollutant removal from the surface water flows.

Apart from this, following restoration methods are also suggested to improve the catchment conditions and the quality of water.

Desiltation, to improve the catchment yield; aerating the lake water and harvesting of macrophytes to improve the quality of water, oxygen content, removal of odor from water and to avoid eutrophication condition;prevention of pollutants like phosphorus, nitrogen, suspended solids, by waste water treatment methods like screening, stabilization pond, aerated lagoon and water harvesting structures with removal efficiency of 50 - 90 % of suspended solids, 25- 75% of total phosphorus and 30-80 % of nitrates; and prevention of encroachments through legal action along with public participation's are suggested. Restored wetlands could be used for recreational purposes such as boating and fishing; and for agricultural purposes, conditioned that care should be taken to maintain the prevention of point and non-point source of pollution that drained in to it.

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