

ADVANCES IN ENVIRONMENTAL MONITORING AND MODELING

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Sustainability and treatment potentials of an urban sewage-fed lake in Bangalore, India

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Abstract

This paper reports the functioning of Varthur Lake, Bangalore where the sewage flows into the system through storm water courses creating natural wetlands and anaerobic-aerobic lagoons. The lake receives 500 MLD sewage at BOD 120-200 mg/L which suffers anaerobic digestion in the upper reaches of the lake and subsequently as BOD falls below a threshold the water becomes oxic to facilitate algae driven oxidative BOD reduction to finally reach c.30mg/L. The characteristics of the sludge deposited at various points in the water body were studied to assess its nature corresponding to its age. It was observed that anaerobic sludge (mostly organic) formed in the upper reaches, with water flow towards the outlet begins to be aerated and a matured and improved sludge formed settles closer to the outlets. The study also brings out that such natural phenomena of the water body could be harnessed and engineered to create a sustainable mode of sewage treatment, nutrient and energy capture with water recycling in developing country cities, especially the tier-2 cities that will need to wait a long time to become capable of using conventional wastewater treatment systems.

1. Introduction

A major problem faced by most of the towns and cities across the world is the generation of enormous wastewater everyday. Treatment of wastewater is highly essential as fresh water availability is scarce and demands are increasing perennially. Conventional wastewater collection and treatment systems are expensive, energy intensive and incompatible especially in developing countries which lack infrastructure and the technical expertise to manage and operate them. Consequently, the untreated wastewater is let into several receiving water bodies. The shortfall in sewage treatment have deteriorated the water quality significantly making these aquatic resources unfit for current as well as future use and thence posing critical environmental and health issues.

In Bangalore, sewage streams flow through storm water courses and enter man-made water bodies. This has led to the creation of natural wetlands and anaerobic-aerobic lagoons that seem to carry out the treatment of sewage to near adequate levels. Nearly 500 MLD of city's sewage enters the Bellandur-Varthur chain of lakes in Bangalore south (Chanakya et al., 2006) and the remaining wastewater enters into the streams and near by water bodies thereby contaminating it. The extent of N (nitrogen) flowing through the Belandur-Varthur lake system is large (16.4 t/d; Chanakya and Sharatchandra, 2008) and measured to be 20-40 mg/l. This 500 MLD also serves as a water source for crop irrigation to downstream farmers. Traditionally, Varthur lake was built to store water for drinking and irrigation purposes thousand years ago (Government of Karnataka, 1990). Today, large scale and unplanned developmental activities have resulted in dwindling catchment yields resulting in shortage of water supplies which is supplemented by the sustained influx of fresh sewage, over a decade causing nutrient enrichment(C, N and P) resulting eutrophication. It is receiving about 40% of the city sewage for over 50 years. There are substantial algal blooms, dissolved oxygen depletion and malodour generation and an extensive growth of water hyacinth that covers about 70-80% of lake in dry seasons. It is of interest to determine whether such a lake could be converted to a sustainable and passive sewage treatment system adaptable to other locations, considering that water and energy are fast becoming scarce in the developing world.

There is a lot of work in evaluating appropriate technologies for developing countries as UASB (Upflow Anaerobic Sludge Blanket) reactor (Seghezzo et al., 1998), high rate algae ponds (Shelef, 1982; Oswald et al., 1995), duckweed based ponds (Smith and Moelyowati, 2001; Cheng et al., 2002), where energy or land is a necessary constraint.

However, urban water bodies associated with wetlands proves to be a very promising option. The objective of this study was to examine the nature and extent of changes in water quality (treatment levels) during various seasons along with sludge's organic and nutrient content.

2. Materials and Methods

2.1 Study area: Varthur Lake ($12^{\circ}57'24.98''$ - $12^{\circ}56'31.24''$ N, $77^{\circ}43'03.02''$ - $77^{\circ}44'51.1''$ E, Figure 1), is the second largest fresh water body in Bangalore with a water spread area of 220ha (mean depth 1.1m). Figure 2 exemplifies the spatial extent of macrophytes at Varthur lake in March compared to December. False colour composite (FCC) was generated using geo-referenced LANDSAT data (of 30m spatial resolution) for December and LISS III-IRS data (of 23m) for March. The lake had less macrophyte cover during November–December due to north east monsoon run off and efforts of local population in pushing the macrophytes out of the lake. Macrophytes cover about 70-80% of water spread area during summer, evident from March FCC. During rainy periods, fresh water also enters the lake as runoff.

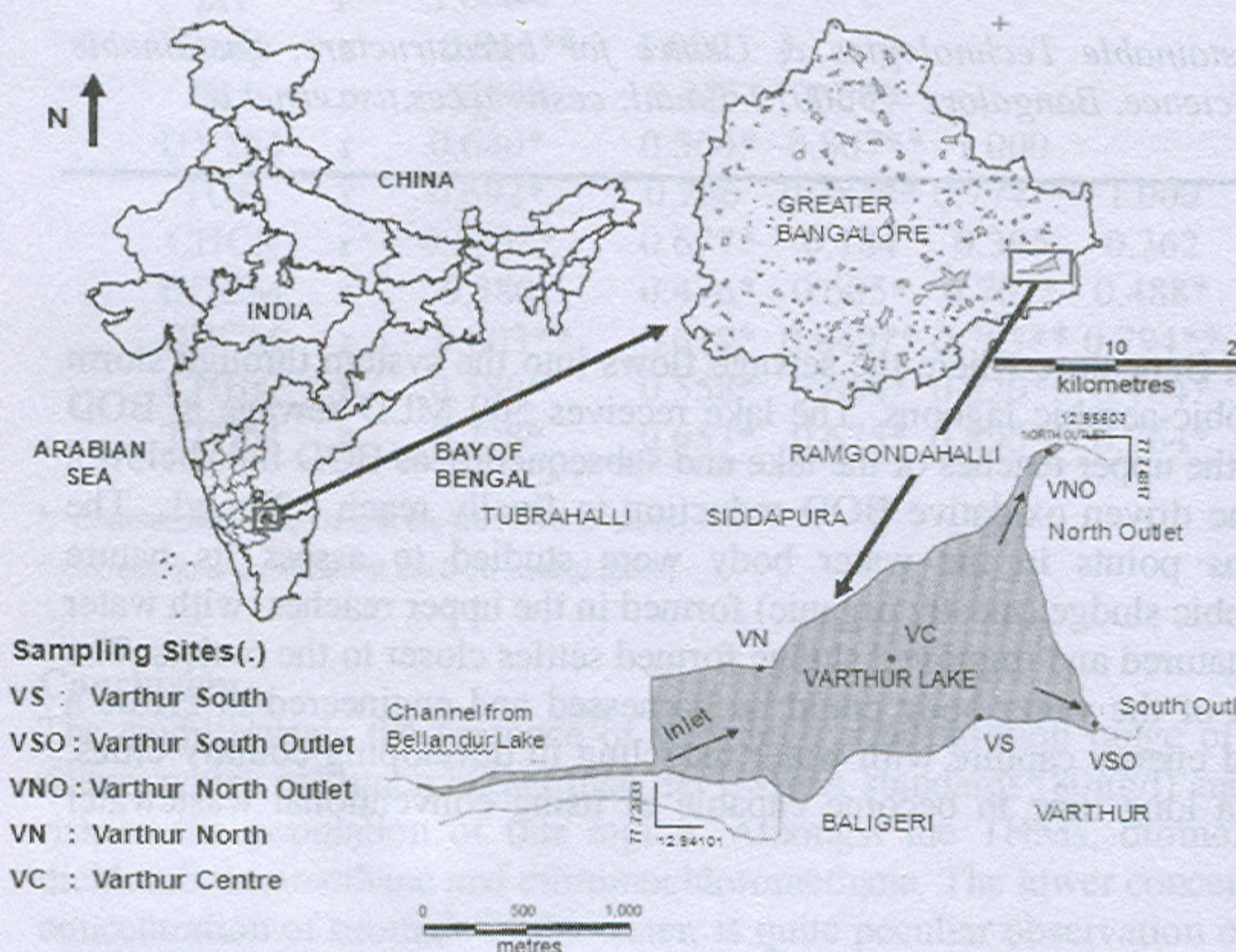


Figure 1: Varthur lake, Greater Bangalore, India with sampling locations.

2.2 Water and sludge sampling and analysis: Water samples were collected every month during July08-June09 from five sampling sites inlet, outlets and midpoints as shown in Figure 1 to examine the influent and the effluent water quality. On site measurements comprise estimation of pH, water and ambient temperature, TDS, conductivity, dissolved Oxygen and transparency. The samples were then carried to the lab and were analyzed for the various organic and inorganic parameters. All the parameters were analyzed according to Standard Methods, APHA 1998. Water samples were also collected from the inlet stream and outlet stream of water passing through the wetland and were analyzed according to standard methods. Sludge samples collected at various locations from inlet to outlet were examined for the Total organic Carbon, Total nitrogen content and available phosphorous according to Standard methods.

3. Results and discussion

The volume of the studied lake was calculated to be 2.42×10^9 liters at an average water depth of the lake of 1.1 m with a water spread area of 220 ha. The sewage received into this lake is about 5.00×10^8 l/d (500 MLD) which gives a retention time of 4.84 days. The channel connecting Bellandur and Varthur lakes surpasses two wetland areas covered with floating as well as rooted macrophytes round the year (Figure 2) as a result water flow occurs in a narrow and open channel. The macrophyte species found were *Typha augustifolia*, *Colocasia esculenta*, *Cyperus* spp., *Alternanthera phylloides*, *Eichhronia crassipes*, *Lemna major* (duckweed), *Pistia stratiotes*. It has been observed that the primary colonizer of this zone is water hyacinth followed by *Alternanthera*. Algae species were mostly dominated by *Nitzschia*, near inlet; *Chlorella* and *Cocconies* in the middle and euglenophytes, *Lynbya* and *Occillatoria* near outlet.

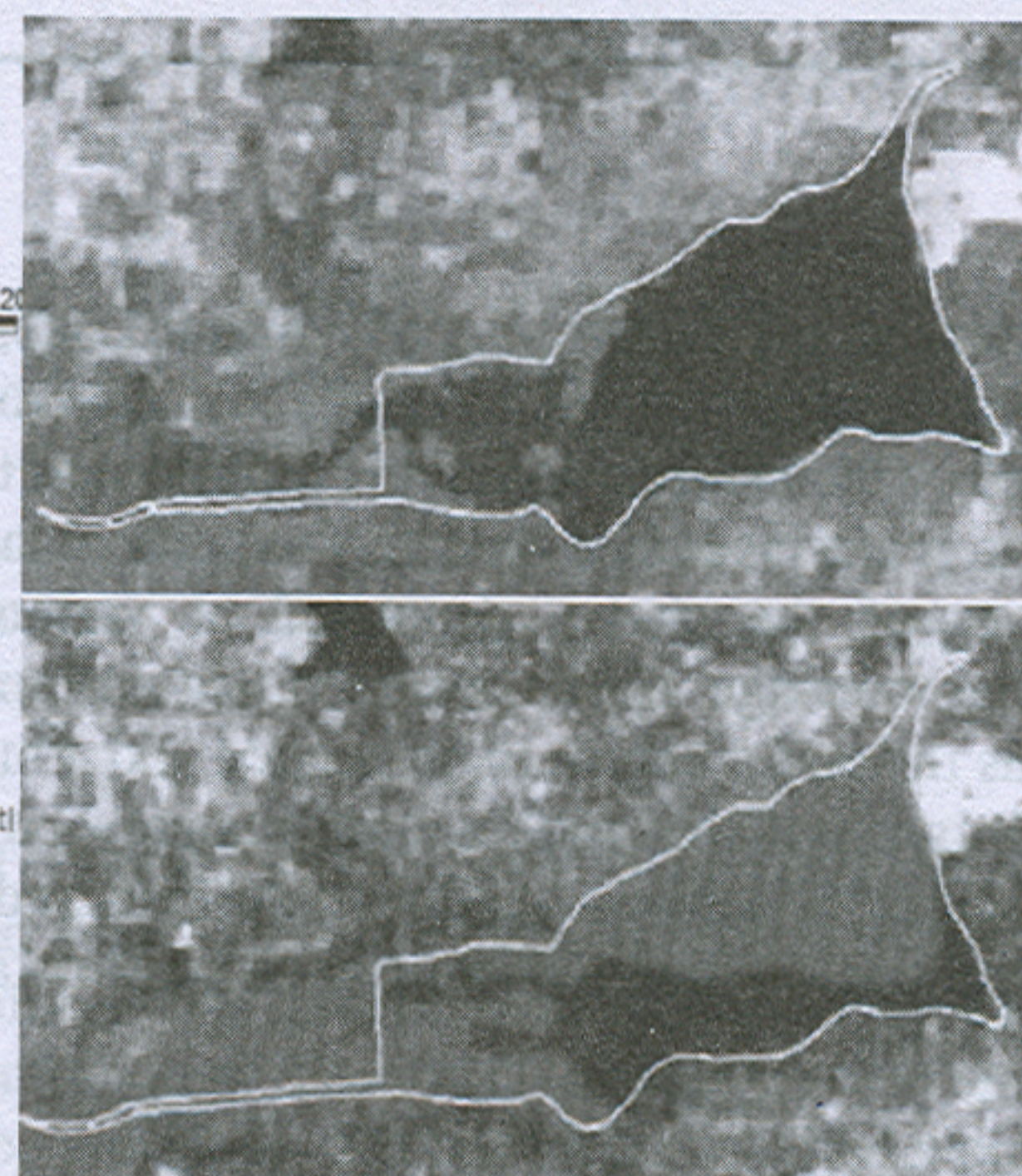


Figure 2: FCC of Landsat (30 m) and IRS LISS-III (23 m).

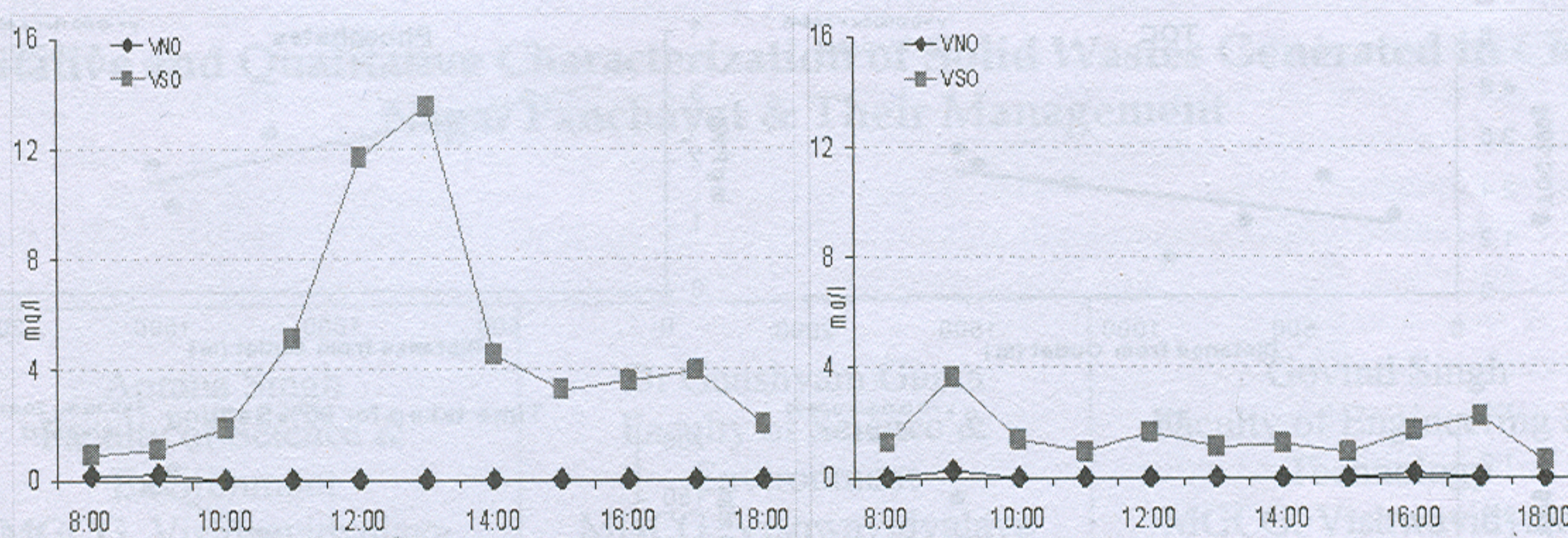


Figure 3: Diurnal changes of DO levels during Jan and Apr, 09 at south and north outlets.

Diurnal (January 2009 & April 2009) changes of DO levels in water influenced by the presence of macrophytes especially water hyacinth in the lake is depicted in Figure 3. The graph on the left (in Figure 3) shows DO measured at the south outlet when it is free of water hyacinth while the right side shows DO measured near macrophyte infested area. There was no improvement in the DO levels of the North outlet because of persistent stagnation and the presence of floating macrophytes. South outlet area had high DO in January where there was no water hyacinth cover. However, this became low in summer when water hyacinth covered this area. North outlet always covered by water hyacinth, showed low DO both in summer and monsoon periods. Summer flow with high detergent resulted in large frothing.

The entry of partially treated sewage and direct inflow of raw sewage from the catchment to the inflow channel renders the inlet zone anaerobic, characterized by dark colour, heavy accumulation of organic sludge as well as low DO. This anaerobic zone occupies a third of the distance from the inlet during rainy and winter months (July to January). From February to June, the spread of the macrophytes cover is also high and the anaerobic zone extends to over two thirds of the water spread area. The months of mid-June to December (monsoon period) is accompanied by gusty and high velocity winds that play a major role in the spread and dispersal of floating macrophytes across the water spread area and high runoff pushing floating macrophytes towards the outlet and down the spillways. In the absence of floating macrophytes, following a short and dark anaerobic zone the water rapidly turns green to indicate the presence of microalgae and their possible role in treating water. Macrophyte cover greatly increases in summer covering almost 70-80% of the water spread area and impedes the aerobic functioning of the lake. The algal photosynthesis and consequently algal removal of N and oxidation of BOD is arrested which completely changes the way the lake functions towards purifying the wastewater. Similarly sludge is also lost from the lake and creates sustainable use. However, it is observed as presented below, the lake functions to purify the partially treated water that is let into it.

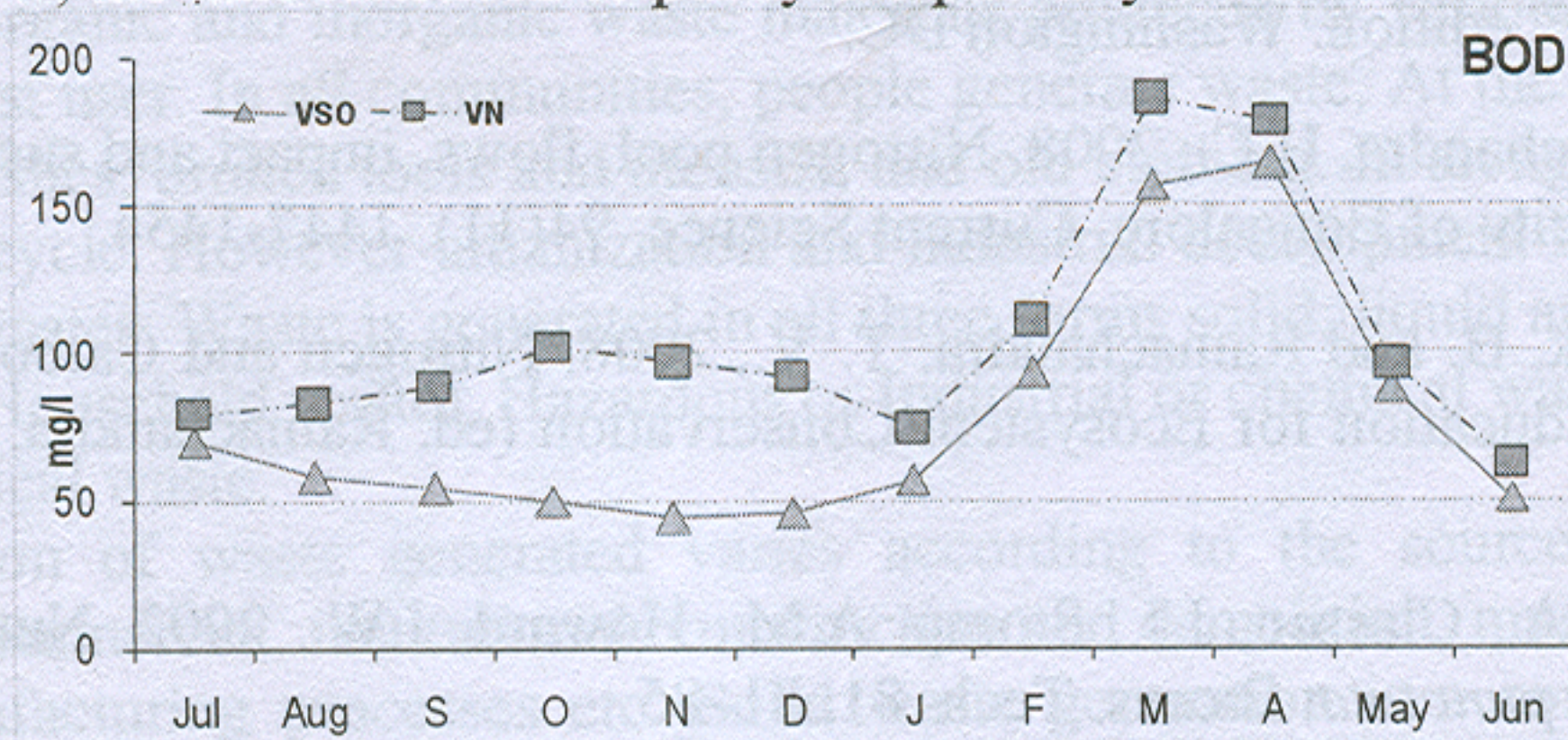


Figure 4: Month-wise BOD at Inlet and outlet.

BOD values ranged from 44 mg/l(Nov) – 186 mg/l(Mar). A considerable reduction in BOD upto 50% (from 100 mg/l to 50 mg/l) <20-30 mg/l filterable was observed between the inlet and the outlets during August-January. However the extensive coverage of macrophytes during February to May, lowered the organic decomposition which can be attributed to the very high concentration of sewage; inadequate algal photosynthesis; enormous growth of water hyacinth covering almost the entire lake surface area and hence BOD removal was much lower during this period. The lake bottom sludge collected at from outlet to inlet roughly at an interval of 250 m were analyzed for TOC, TN, Phosphates and Time taken for 90% settling. The results show that inlet portions are rich in organic matter indicating obligate anaerobic environment with TOC 3.5g/100g of sludge and TN value of 1g/100g Sludge dry wt.(Figure 5). However, the phosphates showed, much higher concentrations towards the outlets (3 mg/Kg dry wt., Figure 5) compared to the inlets (1.3 mg/Kg dry wt.). The time required for 90% settling reveals improved sludge found at the outlets which are mostly mature (Figure 5).

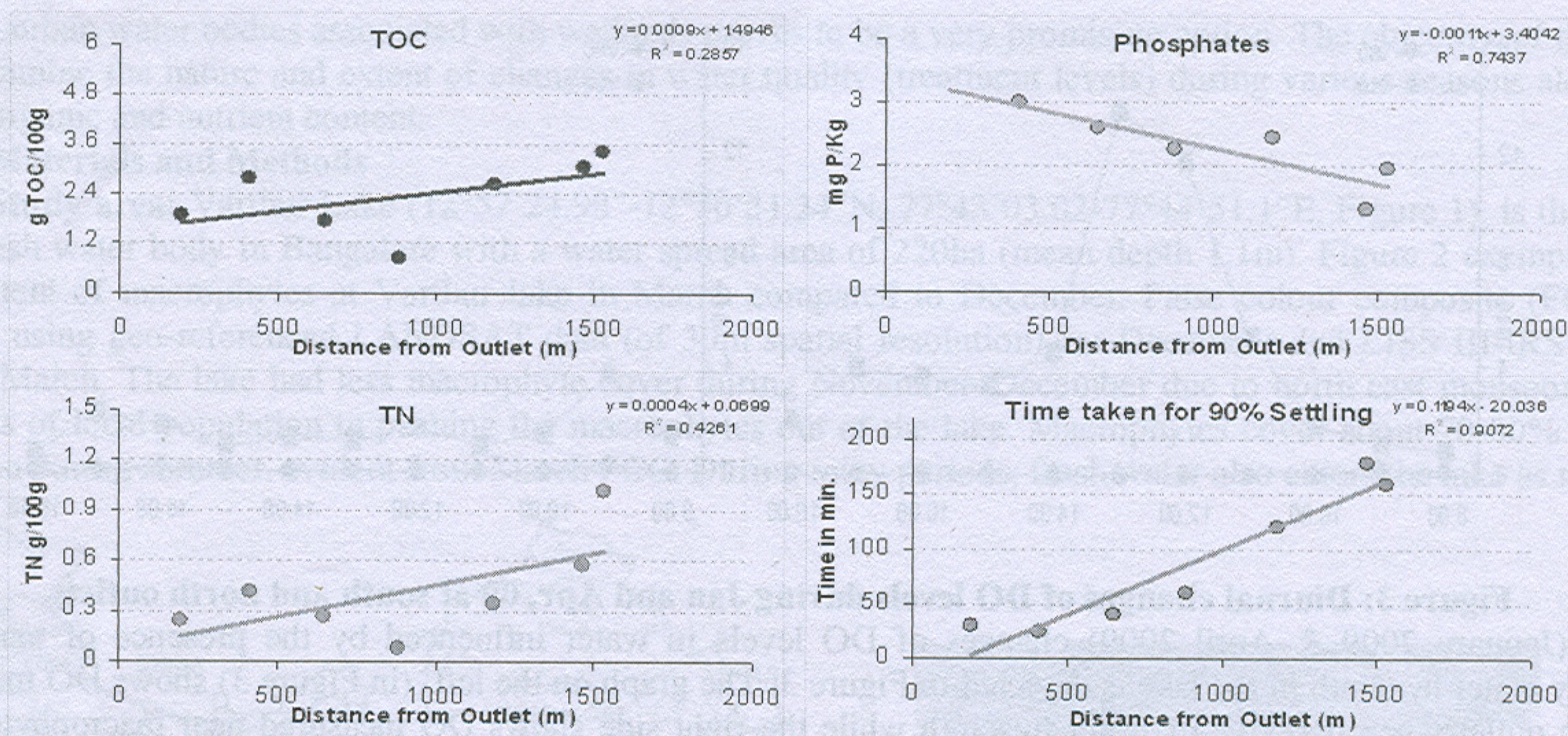


Figure 5: Sludge Characteristics.

The potential of these sewage fed water bodies in terms of wastewater treatment and recycle, various ecosystem services, generation of revenue, better water and aquatic-food security makes it a prospective alternative compared to conventional wastewater treatment systems which could be sustainably extended to other tier-2 cities and help in combating the monstrous problem of wastewater reduction and management to a great deal. This not only ensures a pollution free environment but also makes the water safe to be reused in myriads of forms and can be recycled which addresses future water security.

4. Conclusion

Varthur lake behaves as an anaerobic-aerobic lagoon and helps in treating the wastewater with a 60% BOD removal efficiency. The lake functions well in the rainy season bringing down the BOD to <20-30 mg/l, however presence of macrophytes restricts the aerobic functioning of the lake arresting BOD removal. The time required for 90% settling showed heavier and more matured sludge formed at the outlets indication improved sludge characteristics most of the sludge being organic in nature. The study showed improvisation in water quality after the water passes through the lakes, with an estimated retention time of a few days, these lakes can be made more sustainable with a minimal technological intervention which would help us restore water quality significantly.

5. References

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