Surface Water & Ground Water Quality Monitoring for Restoration of Urban Lakes in Greater Hyderabad

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ABSTRACT

Hyderabad Urban Development Authority has taken up restoration of urban lakes around Hyderabad city under Green Hyderabad Environment Program. Restoration of Mir Alam Tank, Durgamcheruvu, Patel cheruvu, Pedda Cheruvu and Nallacheruvu lakes have been taken up under the second phase. There are of six lakes viz., RKPuramcheruvu, Nadimicheruvu (Safilguda), Bandacheruvu Patelcheruvu, Peddacheruvu, Nallacheruvu, in North East Musi Basin covering 38 sq km. Bimonthly monitoring of lake water quality for BOD, COD, Total Nitrogen, Total phosphorous has been carried out for two hydrological cycles during October 2002- October 2004 in all the five lakes at inlet channels and outlets. The sediments in the lake have been also assessed for nutrient status. The nutrient parameters have been used to assess eutrophic condition through computation of Trophic Status Index, which has indicated that all the above lakes under study are under hyper-eutrophic condition.

The hydrogeological, geophysical, water quality and groundwater data base collected in two watersheds covering 4 lakes has been used to construct groundwater flow and mass transport models. The interaction of lake-water with groundwater has been computed for assessing the lake water budget combining with inflow and outflow measurements on streams entering and leaving the lakes. Individual lake water budget has been used for design of appropriate capacity of Sewage Treatment Plants (STPs) on the inlet channels of the lakes for maintaining Full Tank Level (FTL) in each lake. STPs are designed for tertiary treatment i.e. removal of nutrient load viz., Phosphates and Nitrates. Phosphates are removed through addition of Alum to the influent stream to the STPs whereas Nitrates reduction is achieved by sending the treated wastewater from the STP through a wetland before entering the lake. STP capacity ranging from 2 –10 MLD has been recommended depending on lake water budget of individual lake and considering surrounding urbanization. Sediment nutrient data has helped for deciding the need for dredging of lake bed for removal of phosphates.

INTRODUCTION

Hyderabad is having a number of water bodies adding beauty to the city's landscape. Urban Forestry, Hyderabad Urban Development Authority (HUDA) envisaged assessment of lake water interaction with groundwater and water quality of 5 urban lakes in the HUDA area falling under Mir Alam Tank, Durgamcheruvu watersheds and NE Musi basin under urban lake restoration program (Fig. 1). Six lakes in a chain viz., RK Puramcheruvu, Nadimicheruvu (Safilguda) and Bandacheruvu Patelcheruvu, Peddacheruvu, Nallacheruvu, drain North East Musi Basin covering 38 sq km (Fig. 2). Groundwater level and water quality monitoring has been carried out by establishing 80 observation wells. Surface water samples and sediment samples were collected bimonthly at 14 locations to assess the nutrient load at the inlet/outlet channels of the lakes. Depth to groundwater level in the watershed is found to be varying from 1.8 to 18.0 m bgl during October 2002, 1.2 to 27 m bgl during June 2003 and 1.1 – 15.6 m during October 2003. The top clay layer inferred from the geophysical and lithologic data along the vertical cross section increases in thickness from 1.5 m around Patelcheruvu to 4 m near Peddacheruvu and about 3 m in the foreshore of Nallacheruvu. The top clay is underlain by sandy soil with varying thickness up to 3 m around Patelcheruvu to 6 m at Peddacheruvu and 4 m around Nallacheruvu.

Sediment analyses of Patelcheruvu show that combined silt and clay percentage is about 87% at the bed level whereas it is about 75% with increase in clay content at 0.9 m depth. Sand content in the sediment is lowest in Nallacheruvu and mostly consists of silt and clay. Sand content increases in the Peddacheruvu from 8% at bed level to 29% at 0.9 m depth. The permeability of the lakebed sediments has been found to be varying from 5.06×10^{-4} m/day to 9.0×10^{-4} m/day

Groundwater quality analyses have indicated that maximum TDS, Chloride, Sulfate, Nitrate, Fluoride and Sodium values in groundwater were 3693 mg/l, 1600 mg/l, 249 mg/l, 880 mg/l, 8.4 mg/l and 440 mg/l respectively during October 2002. The violations of groundwater samples exceeding WHO standards limits with respect to TDS, Chloride, Nitrate and Fluoride have been observed in 50% (800 mg/l), 40% (200 mg/l), 50% (45 mg/l) and 50% (1.5 mg/l) samples respectively.

LAKE WATER QUALITY

Surface water quality measurements indicate that TDS concentrations are ranging from 960 – 1600 mg/l during June and 760 – 1370 during October 2003. In general TDS concentration is found increasing down the flow path and maximum values are found in Nallacheruvu. TDS is mainly constituted from chlorides, nitrates, bicarbonates and sodium. BOD concentration in lake water is varying from 10 – 70 mg/l during October 2002 & 03 to 38 –169 during June of 2003 & 04 (Fig. 3).

Maximum BOD has been found in Peddacheruvu and Nallacheruvu lakes. Minimum

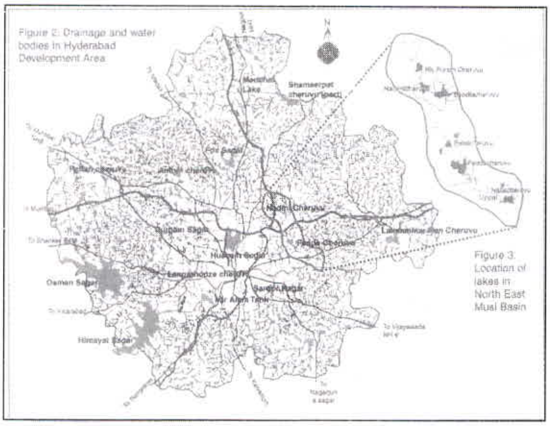

Fig.1 : Lakes in Hyderabad Urban Development Area

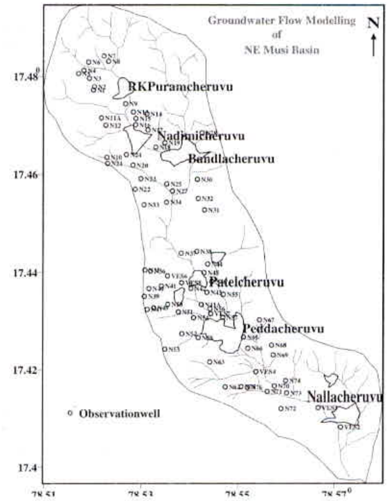

Fig. 2 : Location of Observation wells & chain of Lakes in NE Musi Basin

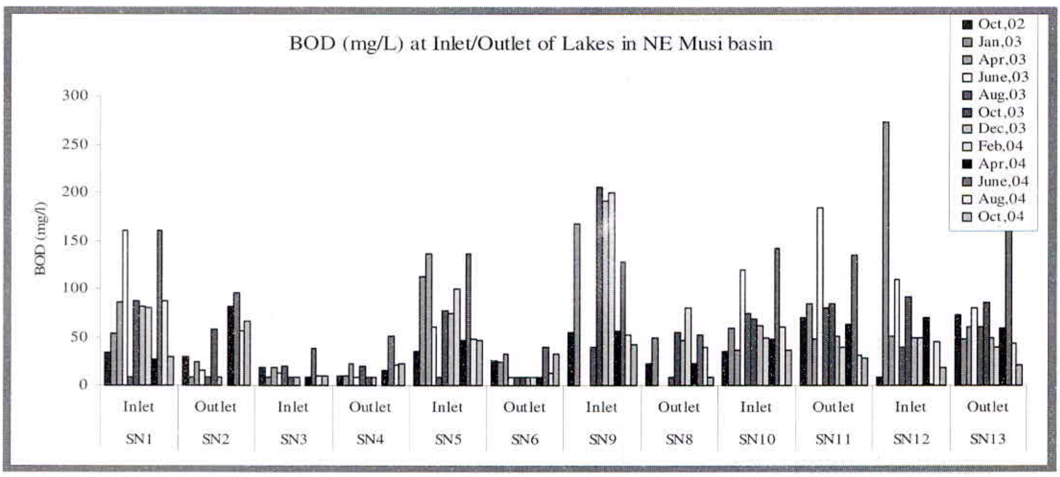

Fig. 3 : BOD levels in Musi Basin Lakes

values have been found in Nadimicheruvu due to entry of treated wastewater from STP. The maximum COD has been found in Peddacheruvu and Nallacheruvu lakes. The minimum value of COD is maintained in Nadimicheruvu (Fig. 4). The average COD concentration in the lakes varies from 140 – 450 mg/l.

Nutrient load in terms of Total Nitrogen (TN) and Total Phosphorous (TP) has been estimated in lake water as well as in the sediments. TN concentration in lake water is found varying from 0.2 – 90 mg/l. Minimum TN values have been reported from Nadimicheruvu < 10 mg/l and maximum from Nallacheruvu (Fig. 5). TP concentration in lake water has been varying from 0.2 – 30 mg/l (Fig. 6). The sediments are also found

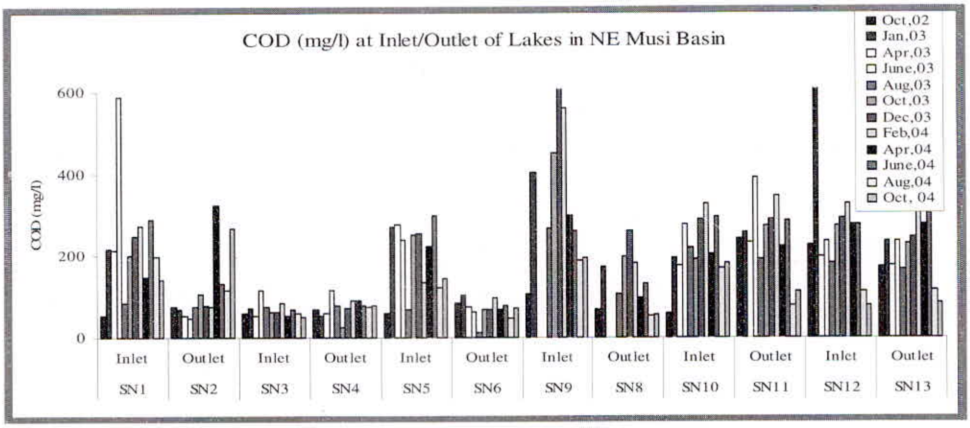

Fig. 4 : COD levels in Musi Basin Lakes

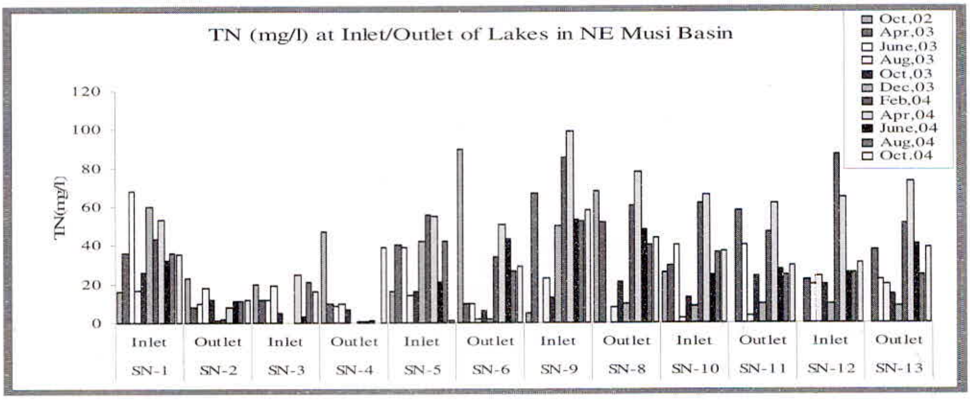

Fig. 5 : Total Nitrogen in Musi Basin Lakes

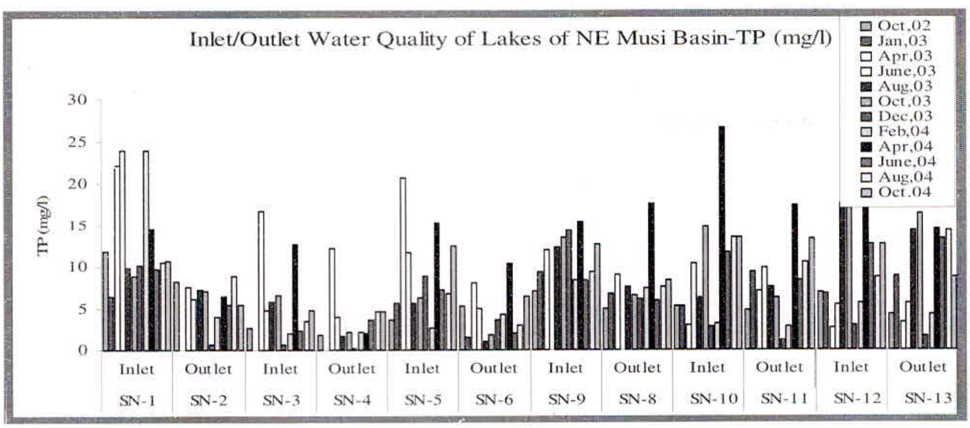

Fig. 6 : Total Phosphorous (mg/l) at inlet/Outlet Channels of Lakes in NE Musi Basin

adsorbing the TN and TP and their enrichment and depletion depends on the lake water conditions. Cyclic behavior of enrichment during summer months and depletion during rainy season has been noticed. The cyclic behavior, particularly for TP can be controlled through dredging of lakebed sediments. TN & TP concentrations in sediments are found varying from 0.9 –136 mg/kg and 4.6 – 343 mg/kg depending on the period of observation. Trophic Status Index (TSI) is a measure expressing the lake water quality based on nutrient inputs, based on TN and TP values. TSI index based on TN is varying from 33 – 121 whereas TSI based on TP is varying from 81 –153. The TSI indicates that the lakes are mostly phosphate limited. These conditions indicate that lakes are under hyper-eutrophic condition.

LAKE WATER BUDGET IN NE MUSI BASIN

Surface water flow measurements on constructed weirs of Patelcheruvu, Peddacheruvu and Nallacheruvu indicate that the maximum inflow/outflow had occurred during August - October 2003 and minimum during January to June 2004. Maximum inflows of 40.8, 77.6 and 33.6 MLD (Million Liters per day) in Patelcheruvu, Peddacheruvu and Nallacheruvu respectively had been observed during August – October 2003. The minimum inflows of 13, 17.4 and 15.6 MLD in the above lakes respectively, had been observed during January - February 2004. As regards outflow from lakes the maximum outflow were 80, 42 and 26 MLD in Patelcheruvu, Peddacheruvu and Nallacheruvu respectively during August – October 2003. Storage capacity of lakes from the bathymetric survey of June 2005 indicates that Patelcheruvu can hold 115 Million Liters (ML) at FTL (Full Tank Level) after raising the bunds. Bathymetric surveys of 2003 indicate that at FTL of Peddacheruvu could hold about 368 ML and Nallacheruvu storage volume being 226 ML. Residence time of lakes has been computed based on the storage capacities, inflow/outflow measurements is 1.5 days for Patelcheruvu, 8.8 days for Peddacheruvu and 8.7 days for Nallacheruvu (Gurunadharao et al., 2005).

Lake Water budget has been computed using average actual evaporation loss @ 4.5 mm/d from lake water surface of 11 ha, 17ha and 17ha at full tank level for Patelcheruvu, Peddacheruvu and Nallacheruvu respectively. The groundwater flow model of the NE basin has computed groundwater-lake water interaction for different lakes in the watershed. Considering seepage losses and evaporation losses for maintaining the FTL in lakes, the STPs of 2 MLD have been recommended at RKPuram Cheruvu, Nadimicheruvu and Bandacheruvu (Fig. 7). As regards Patelcheruvu, Peddacheruvu and Nallacheruvu the estimated interaction between lake water- groundwater and evaporation losses from lake water surfaces would need 3.0 MLD, 10 MLD and 10MLD Tertiary Treatment Plants (Fig. 8). Consideration has been given for fast growing urbanization around the lower end lakes in the watershed for enhanced capacity of tertiary treatment plants. Further likely contamination of groundwater through lake water interaction would be showing impact up to 600 –800 m in the downstream, as inferred

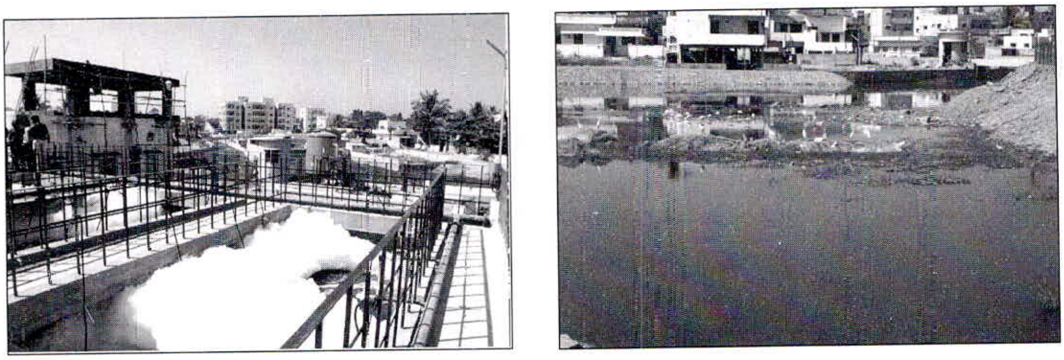

Fig. 7 : STP (Tertiary Treatment Plant) & Associated Wet Land at Nadimicheruvu

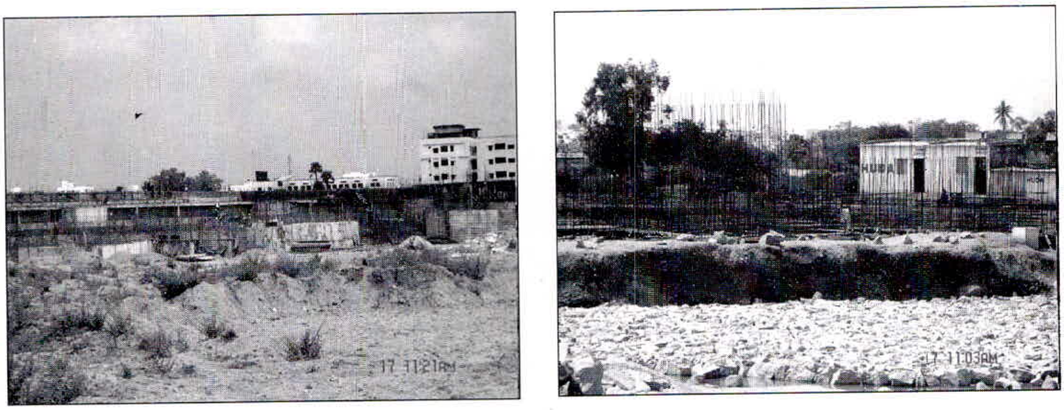

Fig. 8 : Upcoming STPs (Tertiary Treatment Plants) at Peddacheruvu and Patelcheruvu

from groundwater flow and mass transport modeling for next 20 years. Nitrate contamination, if any, would also be expected within this zone. Envisaged plan for establishment of STPs for tertiary treatment, associated wetland for nitrate removal and dredging of lakebed for phosphorous removal have been found imperative. However, minor modifications in the capacity of STPs are incorporated as lake water interaction with groundwater is playing a vital role in lake water budget in addition to sewage generation from surrounding urban area. Surplus inflows to lakes >STP capacity has to be diverted through separate surface runoff carrying channels bypassing the lakes

MIR - ALAM -TANK

The Mir-Alam- Lake is formed on a third order stream and the watershed covers 18.5 sq km and is located in the southern part of Hyderabad city. Lake water quality has been measured at 14 Locations (Fig. 9). In general lithologic sections show topsoil followed by weathered rock, fractured rock underlain by bedrock. Weathered zone thickness varies from 5 - 15 m and the fracture zone has maximum thickness of 35 m. Depth to basement varied from 35- 50 m bgl (Fig. 10). Groundwater occurs under phreatic conditions in the shallow weathered zone and under semi confined to confined conditions in the fractured and sheared zones at deeper levels. In general, weathered zone thickness is limited to 10-15 m. The groundwater level measurements on 33 observation wells have indicated that average depth to water is about 9.5 m bgl in the watershed. Groundwater fluctuations are influenced by local pumping conditions. Groundwater level contours show a predominant groundwater flow direction towards the Mir Alam tank. Average annual rainfall in the watershed is 700 mm and 14 years average annual evaporation is 2440 mm (IMD).

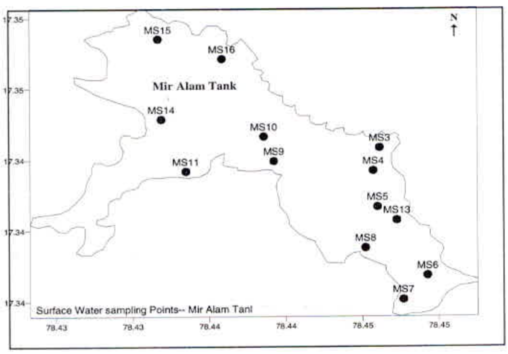

Fig. 9 : Location Lake water sampling in Mir –Alam- Tank

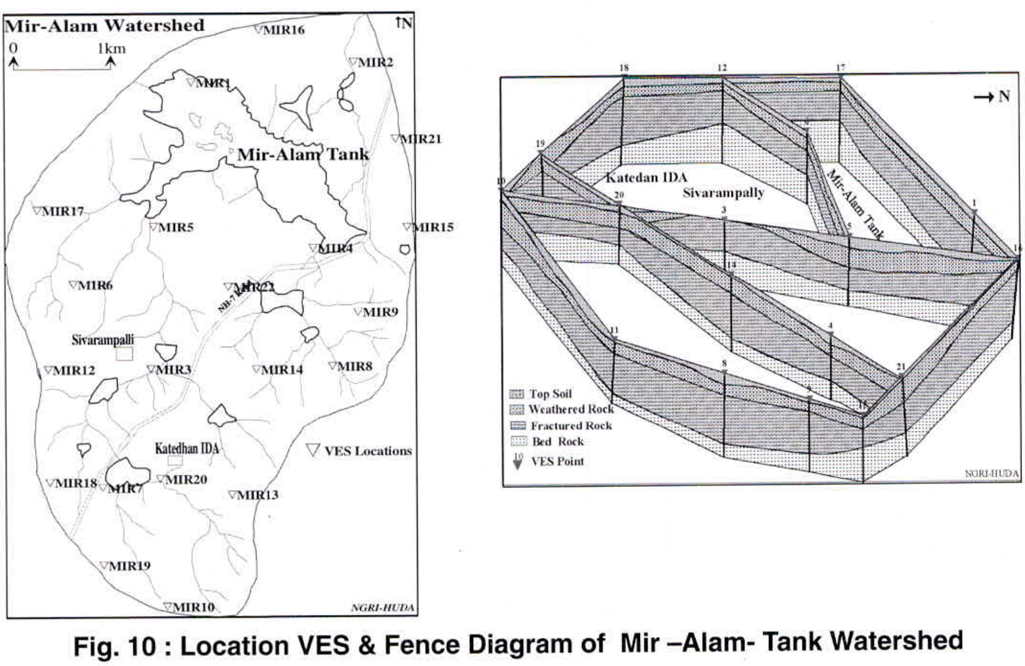

Fig. 10 : Location VES & Fence Diagram of Mir –Alam- Tank Watershed

Total Dissolved Solids (TDS) concentrations in groundwater have shown elevated TDS between Katedan IDA to Mir Alam Tank and slightly lower concentrations below the Mir Alam Tank. TDS concentrations of groundwater in the Katedan IDA are ranging from 416 – 4058 mg/l with an average of 1640 mg/l. Chloride concentration > 300 mg/l, sulfates > 270 mg/l and nitrate > 50 mg/l are found in 60% of samples. Fluoride concentration in groundwater is very high and ranges from 1 – 5.4 mg/l with an average of 2.7 mg/l. Katedan IDA established two decades back is catering to the industrial needs of textiles, metallic industries and battery manufacturing in the watershed. The IDA is situated in the recharge area of watershed and whatever effluent outflows from IDA may travel down the flow path and likely to contaminate groundwater in the watershed. Thus trace element analyses of groundwater samples indicated that except one or two places, the concentration of Arsenic, Nickel was found slightly higher and conspicuously lead concentrations were below WHO limits. Rest of trace element concentrations are also found to be within reasonable range below WHO limits.

MIR ALAM TANK WATER QUALITY

Lake water samples have been collected in the Mir Alam Tank and analyzed for major cations and anionic concentrations, trace element concentrations to assess their presence if any, in lake water. Pesticide residue analyses of lake water have been carried out during January 2004 for assessing persistence of organo-chlorine pesticide residues. Persistence of Endosulfan and metabolites of DDT suggest that a substantial agricultural runoff seems to be entering the lake. TDS concentration in lake water as well as inlet channels is varying from 717 – 1331 mg/l with an average concentration of 1100 mg/l. TDS concentration of pre-monsoon has been found in the range of 327 – 1224 mg/l with an average of 1090 mg/l. Post monsoon monitoring during October 2003 has shown TDS values of 337 – 2189 mg/l with an average concentration of 1073 mg/l. Chlorides, sulphates, sodium ions dominate TDS.

The nitrate as nitrate concentration in surface water has been found to be in the range of 4.5 – 45 mg/l. The lake water is Na-Mg-Cl-HCO_3 type during October 2003 whereas it is Na-Mg-HCO_3-Cl type during pre monsoon. As regards heavy metal concentrations in Mir Alam tank, average concentrations of Arsenic, Chromium, Copper, Nickel and Lead are ranging 10-23 ìg/l, 2 -21 ìg/l, 5- 39 ìg/l, 59 –157 ìg/l and 1-67 ìg/l respectively. The attributed concentration may be of anthropogenic as well as in situ rock origin. Groundwater TDS contours indicate the contaminant plume from Katedan IDA (Fig.11).

Bimonthly sampling of lake water has been analyzed for assessment of Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN) and Total Phosphorus (TP). Also 6 sediment samples have been collected at a depth of about 2 m for estimation of adsorbed TN and TP. Average DO in lake water varied from minimum of 2.1 mg/l during October 2003 to 6.9 mg/l during

August 2004. The BOD values of lake water are varying from 19 – 35 mg/l with a BOD of 199 mg/l in the inlet channel near Hasan nagar boating point (Fig. 13). Chemical oxygen demand of surface water has varied from 43 – 85 mg/l. COD levels have been found elevated > 200 mg/l in the inlet channels (Fig. 14).

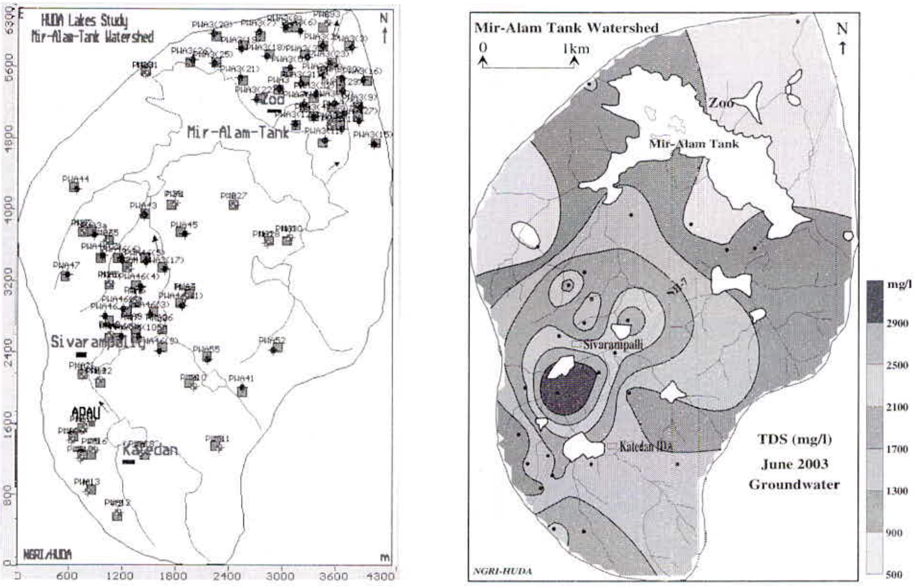

Fig. 11 : Observation wells and TDS concentration in Groundwater June 2003

Mir Alam Tank receives surplus flows from NM Kunta during monsoon season. Presence of chromium, copper, nickel and lead in substantial concentrations in surface water warrants continuous monitoring of trace metals in the inlet channels to restrict toxic metals entry into the lake.

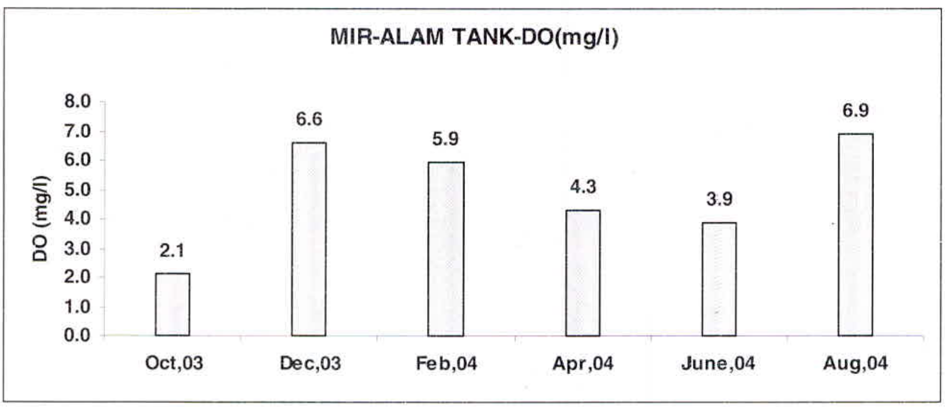

Fig.12 : Average dissolved oxygen in the water of Mir-Alam Lake water (Oct 03 – Aug 04)

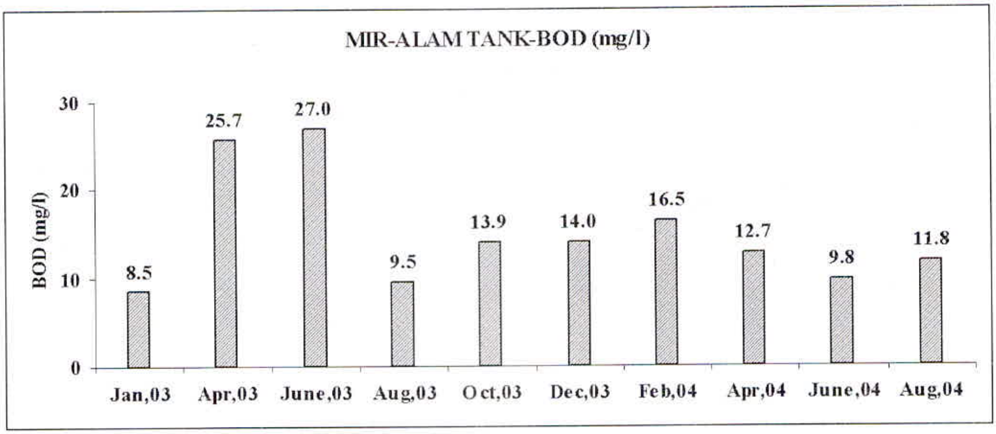

Fig. 13 : Average BOD in the water of Mir-Alam Tank (Jan 03 – Aug 04)

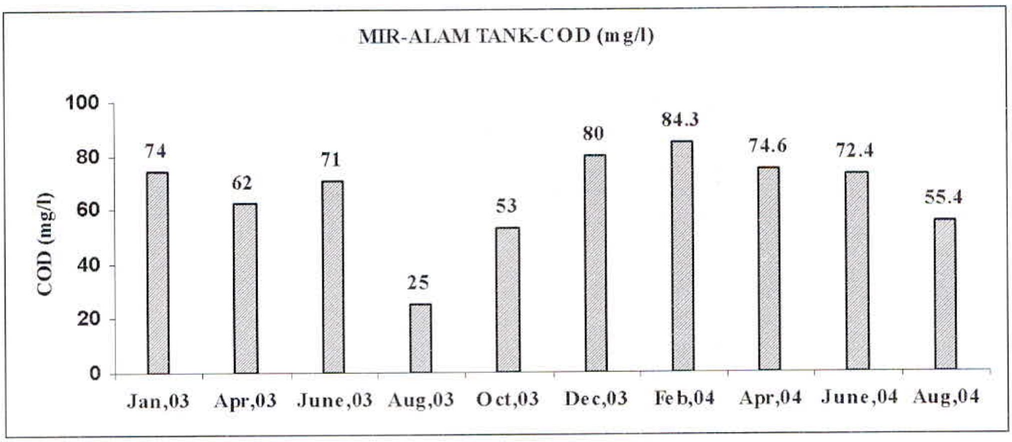

Fig. 14 : Average COD (mg/l) in the Water of Mir-Alam Tank (Jan 03 – Aug 04)

Average TP in lake water has been found to be > 9 mg/l up to June 2003 and thereafter reduced to <5 mg/l. Soluble Reactive Phosphate, which is readily available for algal blooms constitutes to be about 40% of TP (Fig.15). Lakebed sediments have TP concentration of 7 -10 g/kg. Trophic Status Index (TSI) based on TP values is ranging from 114 –122. The lakes are under hyper Eutrophic condition, which reconstitutes for removal of phosphorous from lakebed sediment.

Average TN concentration in lake water has been found to vary from 2 –14.2 mg/l. Maximum TN values have been observed during June 2004, which is about 5 times that of minimum value (Fig. 16). Due to drought conditions, lake has not received good surface runoff and thereby resulted in low TN values of 5-6 mg/l. The TN concentration in sediment has been found varying from 1500 – 4000 mg/kg. Average TSI(TN) values for Mir Alam Tank water are varying 60-90, which seems to be slightly lower than TSI(TP).

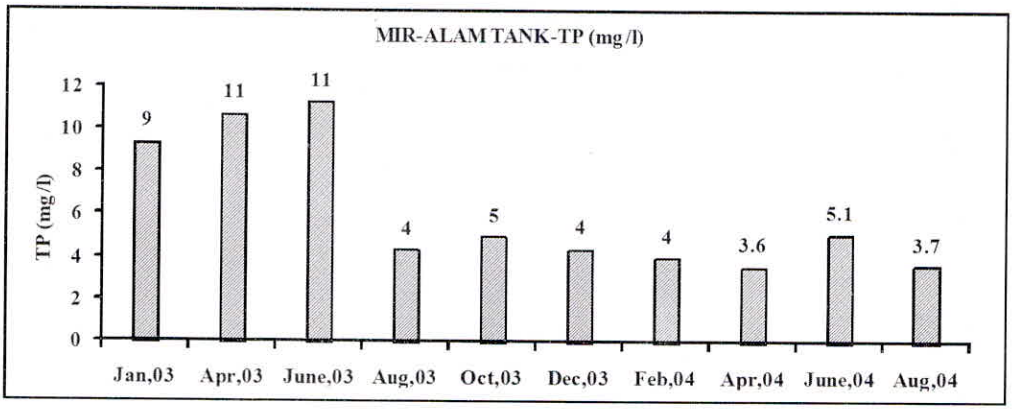

Fig.15 : Average Total Phosphorous (mg/l) in the water of Mir-Alam Tank (Jan 03 –Aug 04)

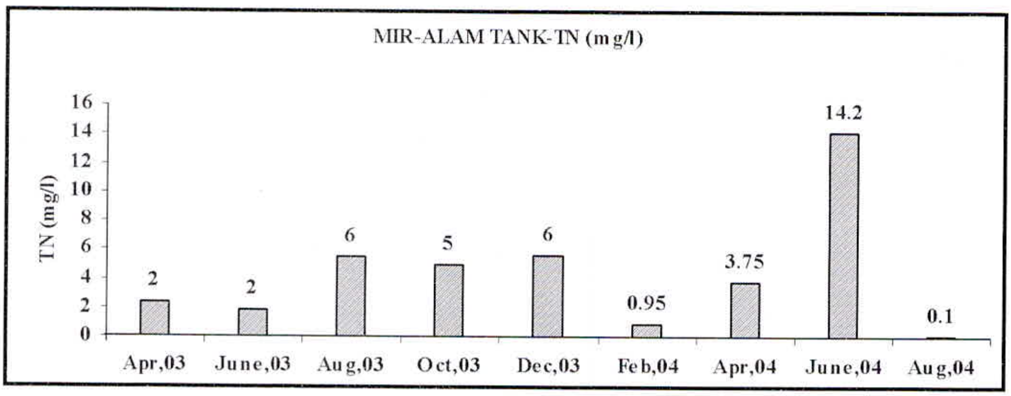

Fig. 16 : Average Total Nitrogen (mg/l) in the Water of Mir-Alam-Tank

Mir –Alam – Tank Water Budget

Bathymetric survey of Mir Alam tank has indicated that the water level is +515.375 m with a water spread area of 1.3806 M.sq.m during May 2003. The tank volume has been computed as 7.42516 MCM at the FTL + 517.4 m. Maximum depth in the tank was 9.6 m. For an outflow of 25 MLD from the Mir Alam Tank, the residence time of lake-water would be 300 days. The lake has lost about 700 ML capacity during last two decades due to encroachments. Flow measurements on inlet channels have shown an average total inflow of 8 MLD with maximum total inflow observed being 13 MLD (Fig. 17).

Assessment of interaction between Mir Alam Tank and groundwater regime was computed through a zone budget of groundwater balance in a groundwater flow model. Mir Alam Tank contributes about 2 MLD towards seepage to the groundwater regime. Considering the lake surface of about 140 ha with an average evaporation rate @ 4.5

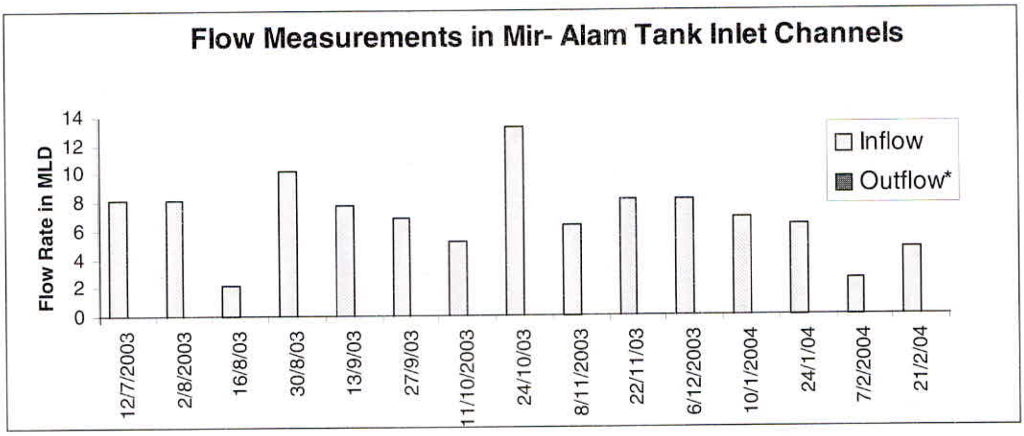

Fig. 17 : Average Inflow through inlet channels into the Mir-Alam-Tank

mm/day, the lake would lose about 6.3 MLD through evaporation. For maintaining Full tank Level (FTL) of the lake, there should be a balance between total inflows and outflows in the lake. It is recommended to establish a STP of 10 MLD. Presently, average total inflow to Mir Alam tank is about 7 MLD and rest of 3 MLD influent sewage has to be gathered at the inlet of STP for tertiary treatment (Gurunadharao et al, 2004 a). Computed Groundwater level and extent of contamination from groundwater flow and mass transport models in the watershed are shown in Fig. 18 and Fig.19 respectively.

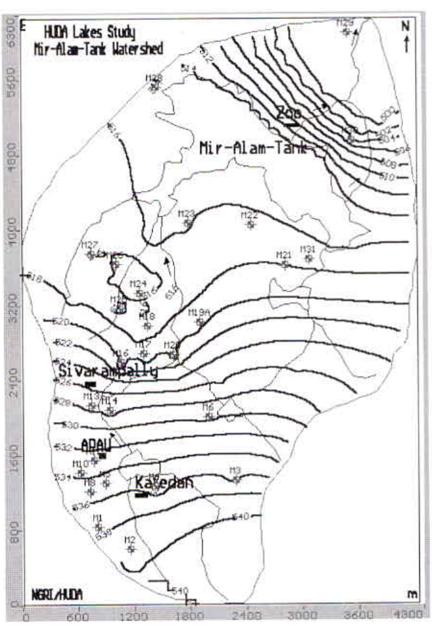

Fig. 18 : Groundwater Level contours in m (amsl) in Mir-Alam-Tank watershed

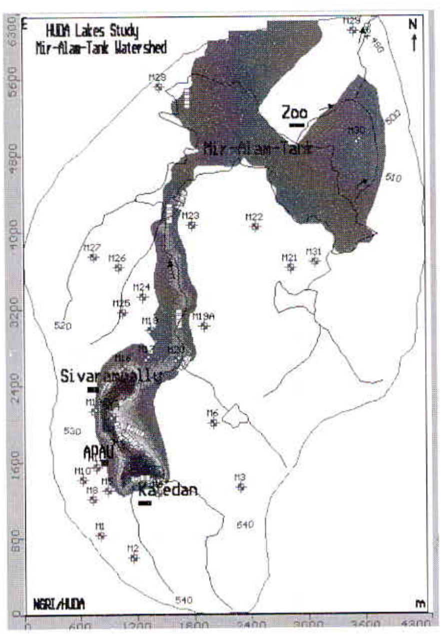

Fig. 19 : Predicted TDS (mg/l) from Katedan IDA in theWatershed

Groundwater flow model has computed groundwater velocity of < 15 m/yr. The prediction of contaminant plume shape from the mass transport model clearly shows that contaminants from the Katedan IDA does not reach Mir Alam tank, which indirectly is saving the lake water free from groundwater contamination.

CONCLUSIONS

Lakes are manifestation of landscape and runoff processes within a watershed. The problems of urbanization have changed the landscape as well as the land use around the lakes. Lakes have become receptors of urban sewage and solid waste disposal. Negligence of civic authorities for protecting the water bodies has added to the problems. The major problem of nutrient enrichment through phosphorous and nitrates are causing problem of eutrophication in lakes. Diversion of the inflows through ring drain through STP for tertiary treatment and letting the treated water in wetland will help reduction of nutrient loading through influent channels of the lakes. Hyderabad Urban Development Authority is envisaging restoration of urban lakes through installation of STPs(Tertiary Treatment Plants), wet lands, which can be replicated elsewhere.

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