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Water Quality of River Musi during 2012-2013, Telangana, India

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ABSTRACT
The River Musi flows for about 256 Kms in Telangana from its origin of Ananthagiri Hills, Vikarabad to confluence with River Krishna near Vajeerabad. The Lakes Osmansagar on Musi and Himayatsagar on Esi a tributary of Musi are constructed in 1920, 1927 with catchments 738, 1311 Sq. Km and storage capacities 110.4, 84.02 MCM (Million Cubic Meters), respectively, after city of Hyderabad experiencing worst floods to River Musi on 28th September 1908. Government of Andhra Pradesh had issued orders G.O.Ms.No.111, M.A., Dated 8th March, 1996 for the protection of catchment areas, 10 Km radius of the full tank level of Himayatsagar and Osmansagar Lakes. Many lakes/ tanks dug in centuries back for drinking and irrigation in the down stream catchment in HMDA area are encroachments in lost five decades, and domestic / industrial increased demand of water due to population explode make the drains joining to river course limited to River Musi for irrigation throughout the year in down course. The TDS concentration in River Musi is increased more than three fold at down stream of HMDA area against supply water (< 300 mg/L), indicate the volume of pollution.
***Keywords* -** Himayatsagar, Osmansagar, Narayanarao Katwa, Musi reservoir

I. INTRODUCTION

The River Musi [1] is one of the major tributaries of River Krishna. It originates in Ananthagiri [2] Hills, Vikarabad, Rangareddy District, runs in the Eastern direction via Hyderabad and Rangareddy Districts and then enters Nalgonda District at Anantharam. It finally joins River Krishna at Panagal near Vazeerabad (Vadapalle), Nalgonda District, 40 km downstream from Nagarjunasagar dam after flowing 256 Km in Telangana [3]. Its original name is Muchukunda [4], which is a saint's name who lived in a cave in Ananthagiri hills and having a mythology linked with the life history of Lord Krishna. Many of the tanks of Hyderabad and Rangareddy Districts are in River Musi catchment [5] are encroachment and receiving sewage / effluents from their catchments covered with human habitation and industrialization. The River bed of Musi at many areas is being utilized for agriculture [6] and encroachment. Its downstream has a series of weirs under which leafy vegetables and food crops are grown on a regular basis. A medium irrigation project Musi Reservoir [7] near Suryapet in Nalgonda District was built in 1963 across the River Musi at about 216 Km from its origin after confluence of a tributary Aleru.

1.1 Source of water supply

Since its inception [8] in 1591, Hyderabad used to rely on water impounded tanks as well as groundwater tapped shallow dug wells. Hussainsagar [9] and Mir Alam Tank [10] were built in 1575 and 1806 to cater the needs of drinking water to the city till 1930 but over a period they are no more drinking water sources due to heavy pollution. The Osmansagar and the Himayatsagar [11] are together supply 205,000 m^3 of water per day from 1927. The quantity of water conveyed to the city was further increased in 1965 and again in 1982, by bringing water from the Manjira Barrage across the River Manjira. In 1975 and 1978, Maharashtra and Karnataka signed two separate agreements with AP, allowing the latter to draw 113 Mm^3 of water per year from the River Manjira in Hyderabad through the construction of a new reservoir. According to the interstate agreements AP built the Singur reservoir on the River Manjira, and started transferring water to Hyderabad in 1991. In 1972, an expert committee of the Government of AP recommended transfer of water from River Krishna [12]. Later in 1986 the Government of AP appointed a second expert committee, which recommended the transfer of 467 Mm^3 from the foreshore of the Nagarjunasagar reservoir on River Krishna [13]. The Krishna river water quality at the offtake point falls under category 'C' and 'A' if not consider the coliforms (Drinking water source without conventional treatment but after disinfection) with TDS < 300 mg/L.

1.2 Source of pollution

The total population leaped from 3,637,483 in the 2001 census to 6,809,970 in 2011 census [14], an increase of over 87%. Migrants from rest of India constitute 24% of the city population. It is considered that the population growth between the study periods is around 100%. Since the rapid growth of the city in the 1980's, River Musi flows continuously which resulted in the year-round cultivation of rice and green leafy vegetables in the downstream that was confined to the months following the monsoon season in the past [15]. Due to exponential population explode in the last five decades, the river bed and the boundaries of lakes are encroachments and some are disappearing and the inhabitants and their unorganized services such as electroplating, leather tanning, engineering, oil extraction and industrial processing are heavily polluting the tanks, lakes and River Musi. As a result the river bearing capacity to flow drastically decreased year after year causing sudden floods in many areas in the city regularly even for a little rain. The growth of the city with availablity of vacant land, educational institutions and highly educated skilled people are leading chemical processing industries to the need of pharmaceutical requirements, formulations and heavy engineering products.

1.3 Treatment systems

II. EXPERIMENTATION

Experimental part consisting of physico-chemical analysis at the Laboratory for (i) Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO); (ii) estimation of inorganic ionic concentrations of Sodium, Potassium, Calcium, Magnesium, Chloride, Sulphate, Carbonate, Bicarbonate, Ammonium, Nitrate, Nitrite, Phosphate, Boron, Fluoride and Heavy metals. Standard Operating Procedures (SOPs) are followed for each parameter for guiding the procedure and recording the results [16, 17]. SOPs were prepared and upgraded from time to time based on the methods discussed with i) APHA (American Public Health Association), 16th (1985), 20th (1998) and 21st Edition (2005): titled "Standard Method for Examination of water and wastewater", ii) "Guide Manual: Water and Wastewater Analysis" published by the CPCB, New Delhi, iii) Indian Standard (IS) methods as mentioned against parameter. Checking Correctness of Analysis [18**,** 17] include pH, EC, TDS and major anionic and cationic constituents that are indications of general water quality. Residual Sodium Carbonate (RSC) is calculated by subtracting the water's calcium and magnesium from its carbonate and bicarbonate {RSC = (CO_3^{2-} meq/L + HCO_3^- meq/L) - (Ca^{2+} meq/L + Mg^{2+} meq/L)}. TABLE 1 show irrigation hazardous water quality rating (Ir. HWQR) [19] based on hazardous effects on plants.

The used water in the city has its way to River Musi and the evaporation losses are not counted due to added pollutants with precipitation run off. The Zero discharge of effluents concept introduced in last 2 decades is promoting Pharmaceutical/ Chemical industries for non-aqueous medium in reactions/ recovery/ purification/ recirculation of process water with RO system by installing Multiple Effect Evaporator (MEE) and recovery of solids by Agitated Thin Film Drier (ATFD). The recovered solvents from MEE having high calorific value are to be sent co-incineration at cement industries. The Toxic Substances Secured Land Fill Disposal Facility (TSDF), Dundigal helps disposal of recovered hazardous solid waste to reduce industrial pollution especially toxic organics, toxic salts and bio-contaminants. The securety and maintenance of this site becomes a liability to the future generation. There are eleven Sewage Treatment Plants (STPs), four Common Effluent Treatment Plants (CETPs) shows only 50% of treated sewage/effluents.

Table 1: Ir. HWQR criteria

Ir.HWQR	Salt conc.as EC (micro mhos/cm)	SAR (milli mole/L)$^{1/2}$	RSC (me/L)	Percent Sodium (%Na)
Low	Below 1500	Below 10	Below 1.5	<20
Medium	1500-3000	10-18	1.5-3.0	20-40
High	3000-6000	18-26	3.0-6.0	40-60
Very high	Above 6000	Above 26	Above 6.0	60-80

Table 2: Limit as per BIS/ IS:11624 (1986), IS 10500:1991, IS 10500:2012

Sl No.	Parameter (expressed as mg/L except pH)	Acceptable Limit	Permissible Limit in absence of alternate source
1	pH	6.5 – 8.5	6.5 - 8.5
2	TDS	500	2000
3	Calcium (as Ca)	75	200
4	Chloride (as Cl)	250	1000
5	Magnesium (as Mg)	30	100
6	Sulphate (as SO4)	200	400
7	Total Alkalinity (TA as CaCO3)	200	600
8	Total Hardness (TH as CaCO3)	200	600

TABLE 2 show Limits of parameters as per BIS/ Guidelines for Quality of Irrigation Water IS 11624 (1986) modified in 2006 and comparable for drinking water standards IS 10500:1991 with its update IS 10500:2012. Hazardous effects of irrigation water [20] are classified into four major groups (1) Total Salt Concentration expressed as the EC in the scale of micro-mhos/cm, (2) SAR in the scale of Square root of millimole/L, (3) RSC in the scale of milIiequivalent/L, (4) Percent Sodium.

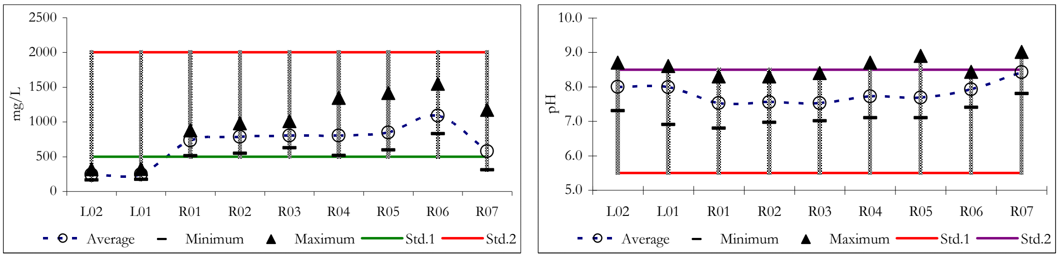
III. RESULTS AND DISCUSSIONS

This study is on two lakes, six River Musi points in downstream, one River Krishna downstream point after confluence with River Musi from more than 270 samples. There are 22 Lakes in and around Hyderabad [9, 21], nine STPs and two CETPs [22] had been studied and the monitoring points, treatment facilities, parameters, methods, standards, pollution indexing methodology, SOPs and validation by checking correctness are also referenced in this sentence. TABLE 3 shows the sequence of monitoring points from upstream to downstream points of River Musi till after confluence point to River Krishna, coded as L01/L02, R01, R02, R05, R03, R04, R06 and R07, respectively.

The data of the first set during 1998-1999 had a deep study for seeking immediate control measures while the second set during 2012-2013 covers many areas of the city with gaining national importance. The 1st set data indicates strong sewage and industrial pollution by way of effluents joining to lakes and their direction to River Musi. It demands authorities for taking remedial measures towards construction or up-gradation of STPs / CETPs and proper maintenance

Table 3: Monitoring ponts with reference code, latlog and Altitude.

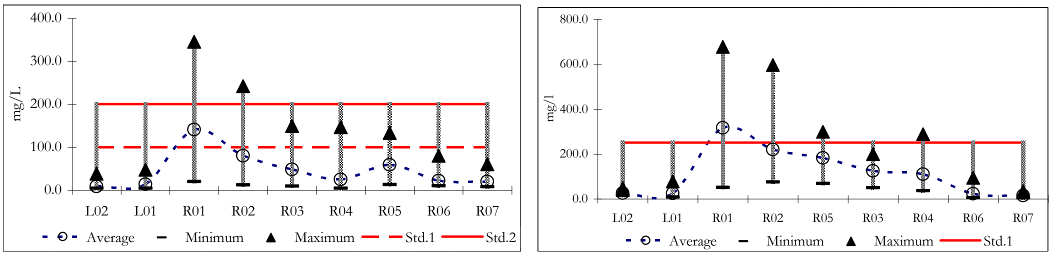
Code	Sampling Points	Latitude N	Longitude E	Alt. M
L01	River Musi at Osmansagar lake	17°22' 51"	78°18' 59"	595
L02	River Esi at Himayatsagar Lake	17°19' 55"	78°21' 49"	569
R01	River Musi at Moosarambagh bridge	17°22' 46"	78°31' 00"	581
R02	River Musi at Nagole bridge	17°22' 58"	78°33' 29"	510
R03	River Musi at Culvert, Pratapasingaram	17°22' 49"	78°40' 03"	442
R04	River Musi at Culvert, Pillaipalli	17°23' 07"	78°44' 14"	434
R05	River Musi at Weir, Narayanarao Katwa, Peerjadiguda	17°23' 18"	78°35' 52"	465
R06	River Musi reservoir at Kasaniguda, Suryapet	17°22' 46"	78°31' 00"	405
R07	River Krishna at Vadapalle after River Musi confluence	17°25' 59"	79°40' 53"	371



(a) (b)

Fig.1: Trends of (a) TDS, (b) pH during 2012–2013

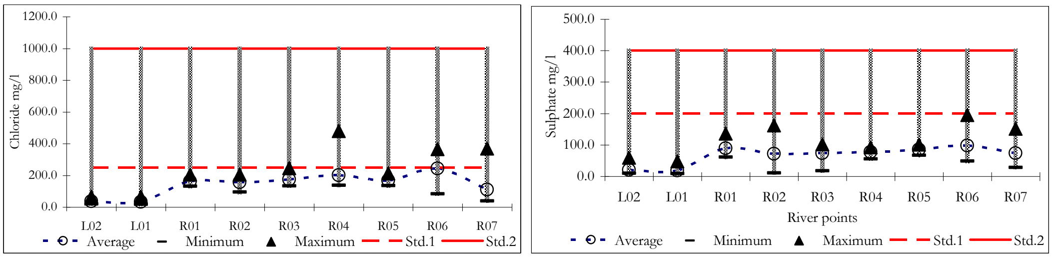
The 2nd set data indicates nearer concentrations to the data generated after implementing treatment facilities in 12 years span, even though industrialization and population expands 100%.



(a) (b)

Fig.2: Trends of (a) TSS, (b) COD during 2012–2013

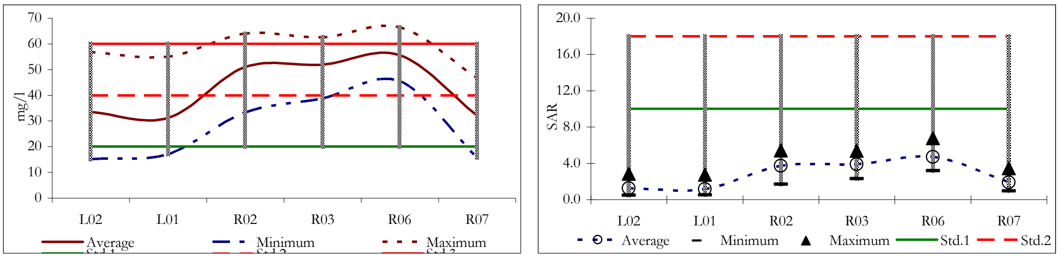
Figs.1-5 are represent average, minimum and maximum trends of TDS, pH, TSS, COD, Chloride, Sulphate, Percent Sodium and SAR, respectively, arranged increasing order of average TDS concentrations, support sequence from upstream to downstream points except R05. R05 is R02 downstream and R03 upstream. The pH is 7.9$\pm$0.4pH slightly basic.



(a) (b)

Fig.3: Trends of (a) Chloride, (b) Sulphate during 2012 – 2013.

The rough and wild terrain of river course on down stream sequence points supports self purification at R03, R04, R06 and R07 as shown at Figs.2-3 in a gradual increase in DO with decrease in COD. Fig.4 show increase order towards downstream in percent sodium and SAR.

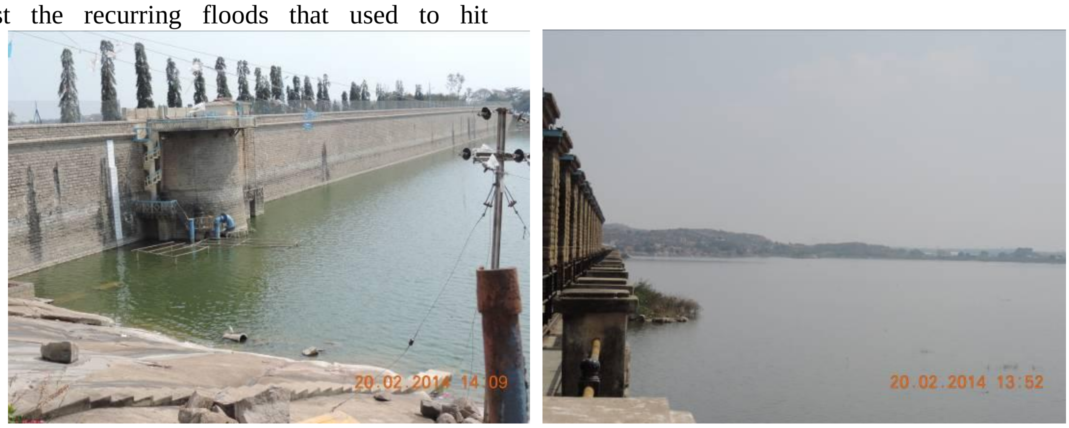


(a) (b)

Fig.4: Trends of (a) Percent Sodium (b) SAR during 2012 – 2013

3.1 Osmansagar (L01) and Himayatsagar (L02) Lakes

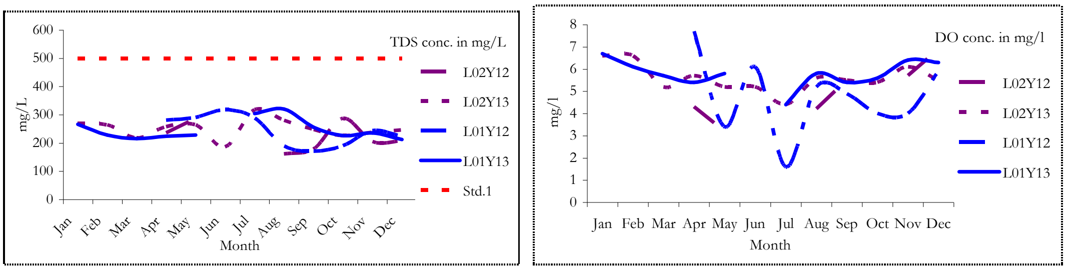
The Musi experienced one of the worst floods on 28th September 1908 when the water level at Afzal Gunj, Hyderabad was about 11 feet [23]. VII Nizam of Hyderabad H.E.H Osman Ali Khan commissioned the construction of two reservoirs approximately 8 km upstream of the city, L01 on the Musi River in 1920, and L02 on the Esi, a tributary of Musi River in 1927 implementing the proposal of Engineer Syed Azam Hussain under the technical supervision of Sir M. Visweswaraya [24]. The catchment areas for these tanks are 738 and 1311 Sq. Km and their storage capacities are 110.4 and 84.02 MCM (Million Cubic Meters). The L01 and the L02 [25] together provided protection against the recurring floods that used to hit Hyderabad, and for a supply of 205,000 m^3 of water per day. Based on the recommendations of a committee constituted by the Hyderabad Metropolitan Water Supply & Sewerage Board (HMWSSB), the former Government of Andhra Pradesh issued an order [26] for the protection of River Musi catchment areas covering 10 Km radius of the full tank level of L01 and L02 Lakes. The famous tanks in Hyderabad and Rangareddy Districts [27, 1] in the Musi catchment are serving for drinking and irrigating more than 80,000 acres of land. Fig.5 is photographic views of (a) L01 U/s of Musi at Gandipet [28] and (b) L02 on Esi before confluence with Musi.



(a) (b)

Fig.5: photographic view of (a) L01 and (b) L02 Lakes.

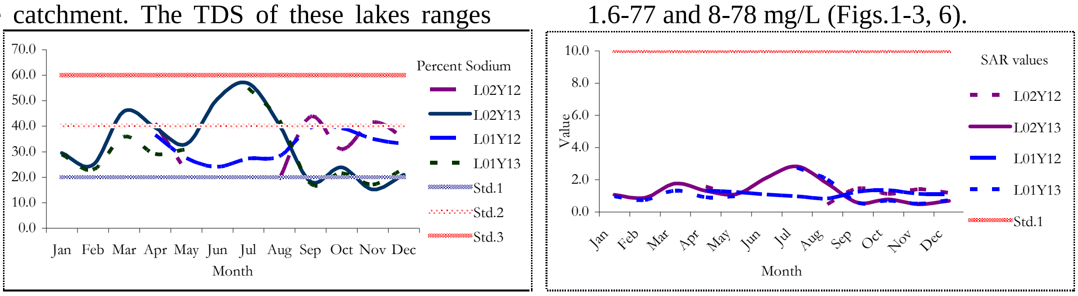
The L01 u/s of Musi at Gandipet and L02 u/s of Esi a tributary of River Musi are almost equal trends of all the parameters as their catchments are part of river bed, overlapped and adjacent.



(a) (b)

Fig.6: (a) Trends of TDS and (b) DO of L01 and L02 during 2012 – 2013.

Trends for L01 and L02 during 2012–2013 shown at Figs.6-7 are similar trends for all parameters. Trends of TDS are with in acceptable limit, little fluctuations and few pollution sources in the catchment. The TDS of these lakes ranges 160–320 mg/L. Averages of TDS, TSS Chloride, Sulphate, DO and COD are far below the standards, and of 245, 11, 33, 19, 5.1 and 24, respectively, ranging 162-320, 4-47, 19-65, 9-59, 1.6-77 and 8-78 mg/L (Figs.1-3, 6).



(a) (b)

Fig.7: (a) Percent Sodium of L01 and L02, (b) SAR of L01 and L02 during 2012 – 2013.

Range and averages of pH, Percent Sodium and SAR are 6.9-8.7, 8; 15-57, 33; and 0.5-2.8, 1.1 respectively. These lakes show TDS around 242 mg/L representing excellent drinking quality water requires with the aid of conventional filtration for 13–47 mg/L suspended solids (TSS) removal. This quality is attained by protection of lakes catchment. The DO never decreases 1.6, and on average 5.3 mg/L is excellent for aquatic life. The COD is around 25 mg/L. Percent Sodium show medium hazard class is void due to low TDS, represent low hazard class and SAR values are 1.1 represent an excellent water class under Ir. HWQR. The 8±0.7 pH represents slight basic and low deviations indicate these lakes are protected. The MPN counts total and fecal coli-form (~50, ~3) support fecal contamination. The domestic sewage joining from catchment requires disinfection for domestic use.

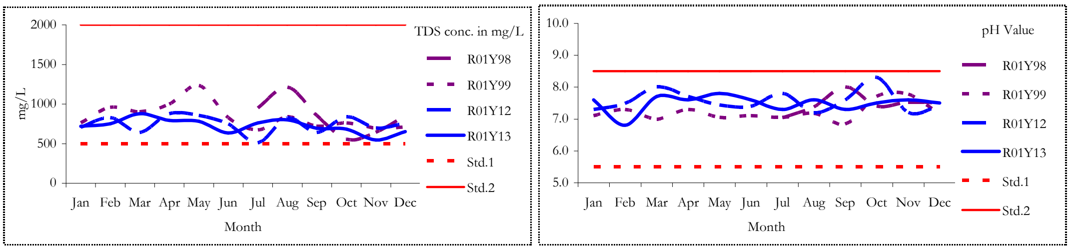
3.2 River Musi at Moosarambagh Bridge (R01)

River Musi at R01 is after the confluence of the major drains from hart of the city and before confluence of Amberpet STP outlet shown at Fig.8(a).

(a) (b)

Fig.8: A view of (a) River Musi at R01, (b) R02.

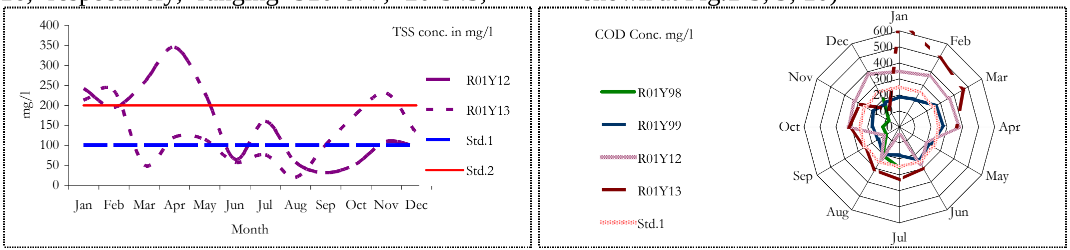
The trends of R01 during 1998–1999 and 2012–2013 for TDS, pH, TSS, COD, Chloride, Sulphate Percent Sodium and SAR are shown in Figs.9-12. The DO is zero at R01 indicating organic load.



(a) (b)

Fig.9: (a) TDS and (b) pH of R01 during 1998 – 1999 and 2012 – 2013.

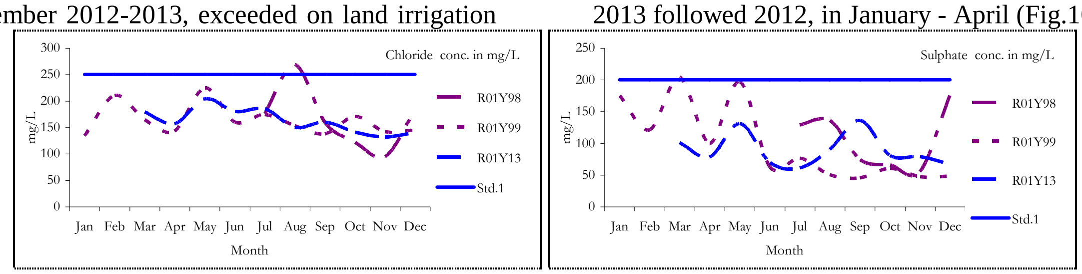
The averages of TDS, TSS, Chloride, Sulphate, DO and COD are 733, 140, 163, 89, 0 and 316, respectively, ranging 510-877, 20-345, 132-204, 61-136, 0 and 51-677 mg/L. The range and average of pH is 6.8-8.3 and 7.5 respectively, shown at Fig.1-3, 9, 10)



(a) (b)

Fig.10: (a) TSS and (b) COD of R01 during 1998 – 1999 and 2012 – 2013.

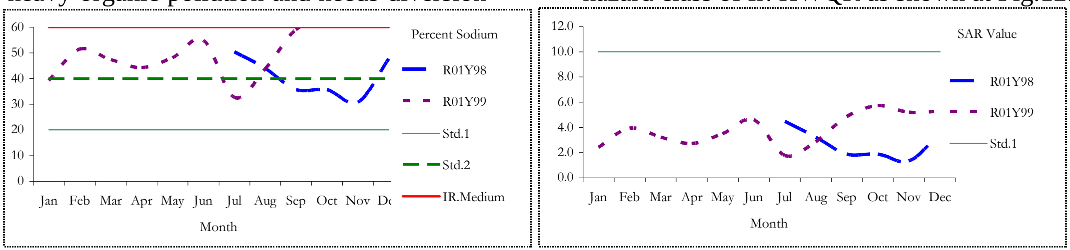
The TSS exceeds inland surface water standards (100 mg/L) except June, August and September 2012-2013, exceeded on land irrigation standards (200 mg/L) on March, April and November 2013 (Fig.10a). High COD found in 2013 followed 2012, in January - April (Fig.10b).



(a) (b)

Fig.11: (a) Chloride and (b) Sulphate of R01 during 1998 – 1999 and 2012 – 2013.

The Chloride is crossing desirable limit on August 1999 and Sulphate is in limit (Fig.11). R01 shows heavy organic pollution and needs diversion of drains through Amberpet STP. Percent sodium is medium and high hazard class and SAR is low hazard class of Ir. HWQR as shown at Fig.12.

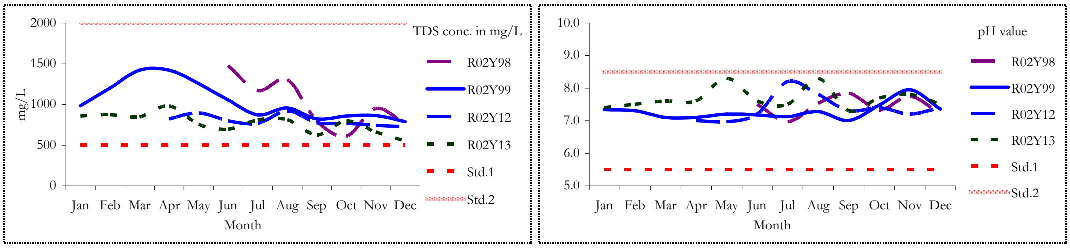


(a) (b)

Fig.12: (a) Percent Sodium and (b) SAR of R01 during 1998 – 1999 and 2012 – 2013.

3.3 River Musi at Nagole bridge (R02)

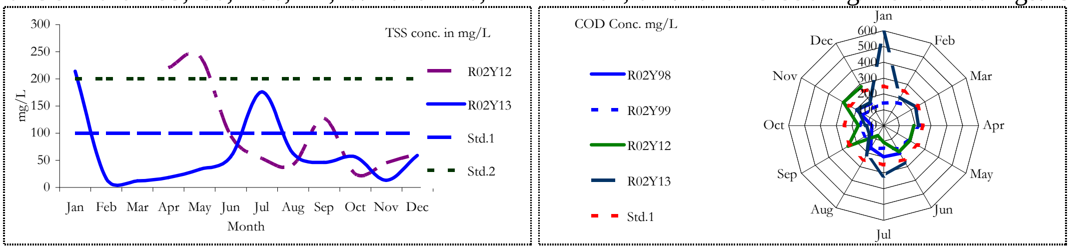
Fig.8(b) shows River Musi at R02. It is after confluence Amberpet STP outlet and some drains in south central parts of the city. The DO levels of River Musi at R02 are zero. Trends of R02 during 1998–1999 and 2012–2013 for TDS, pH, TSS, COD, Chloride, Sulphate, Percent Sodium and SAR are represented in Figs.1-4, 13–16.



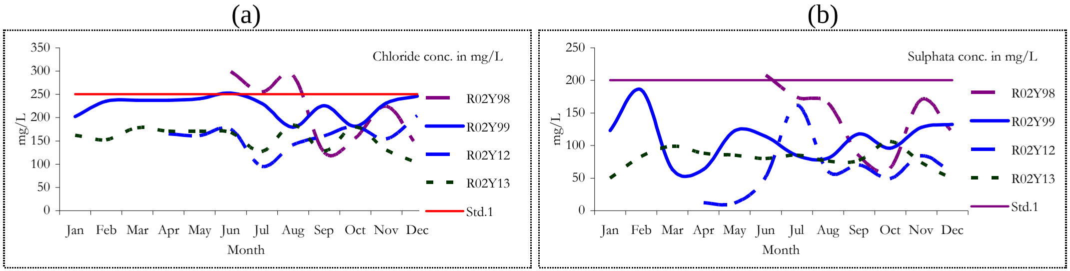
(a) (b)

Fig.13: (a) TDS, (b) pH of R02 during 1998–1999 and 2012–2013.

Averages of TDS, TSS, Chloride, Sulphate, DO and COD are 783, 80, 156, 72, 0.1 and 220, respectively, ranging 548-979, 12-242, 95-204, 11-162, 0-2.2 and 75-596 mg/L shown at Figs.13-15.



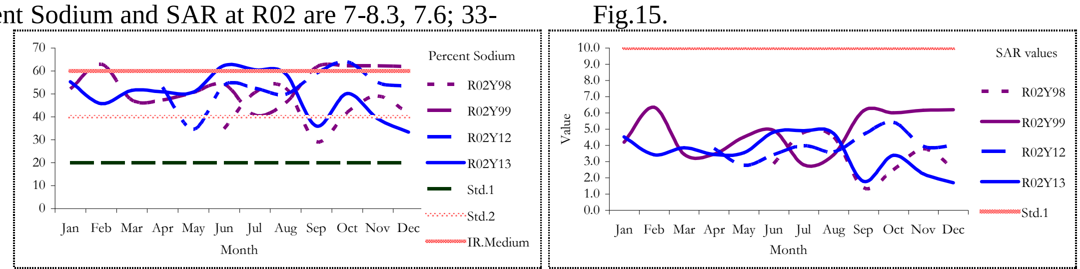
(a) (b)



(c) (d)

Fig.14: (a) TSS, (b) COD (c) Chloride, (d) Sulphate of R02 during 1998 – 1999 and 2012 – 2013.

TSS exceeded the desirable limit in May 2012. The Chloride and Sulphate crossed desirable limit in June 1998 (Fig.14). Range and averages of pH, Percent Sodium and SAR at R02 are 7-8.3, 7.6; 33-64, 51 and 1.7-5.4, 3.7, respectively. Percent sodium is in medium and high hazard class and SAR is low hazard class of Ir. HWQR as shown at Fig.15.



(a) (b)

Fig.15: (a) Percent Sodium, (b) SAR of R02 during 1998–1999 and 2012–2013.

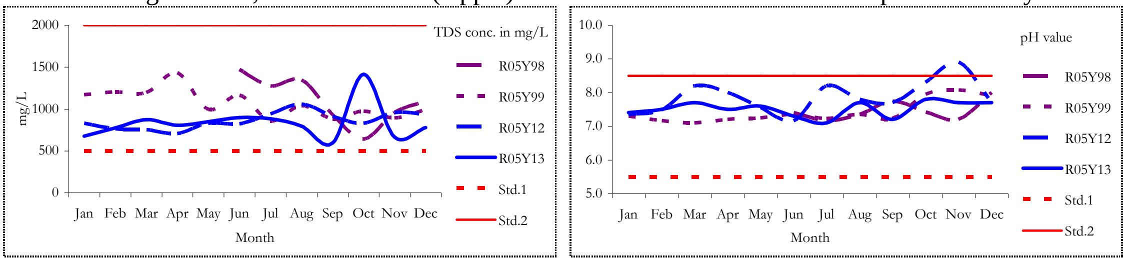
3.4 River Musi at Weir, Narayanarao Katwa (R05)

Photographic views of River Musi at R05 shown at Fig.16(a) the silt with water hyacinth, (b) encroachment with municipal dump and construction activities.

(a) (b)

Fig.16: View of River Musi at R05 (a) the silt with water hyacinth, (b) encroachments.

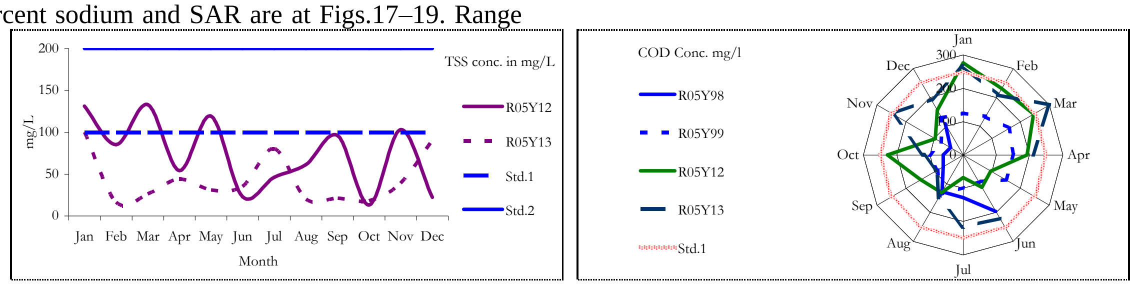
R05 is the River Musi point after confluence of outlets from Nogole STP, Nallacheruvu (Uppal) STP, major drains connected through Nallacheruvu outlet from the northeast part of the city.



(a) (b)

Fig.17: (a) TDS, (b) pH of R05 during 1998–1999 and 2012–2013.

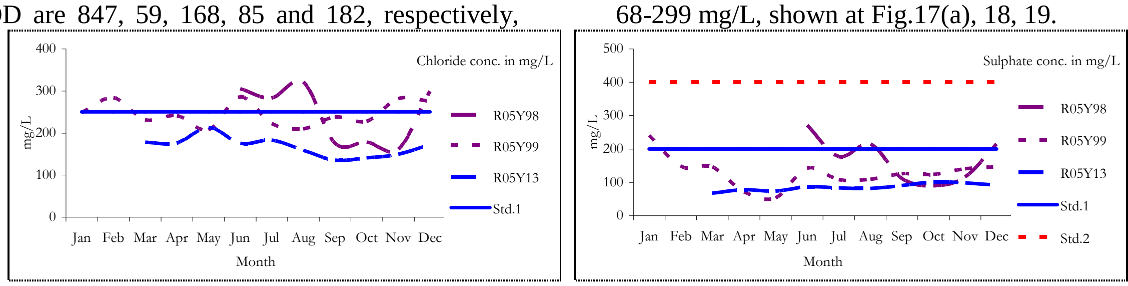
Trends of R05 during 1998–1999 and 2012–2013 for TDS, pH, TSS, Chloride, Sulphate, COD, percent sodium and SAR are at Figs.17–19. Range and averages of pH are 7.1-8.9 and 7.7 respectively, shown at Fig.17(b).



(a) (b)

Fig.18: (a) TSS, (b) COD of R05 during 1998–1999 and 2012–2013.

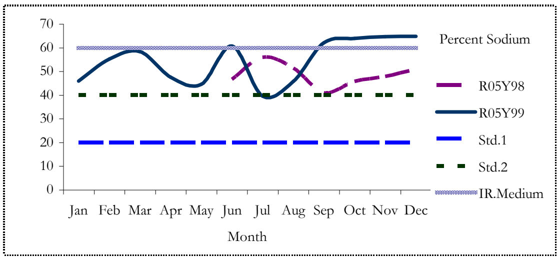
Averages of TDS, TSS, Chloride, Sulphate and COD are 847, 59, 168, 85 and 182, respectively, ranging 595-1414, 13-133, 135-213, 67-101 and 68-299 mg/L, shown at Fig.17(a), 18, 19.



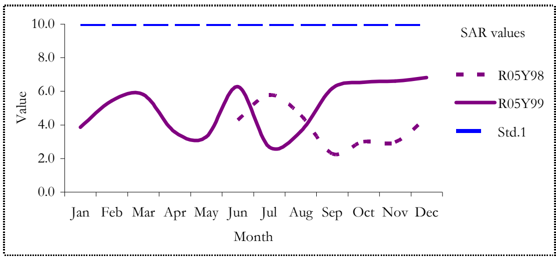
(a) (b)

Fig.19: (a) Chloride, (b) Sulphate of R05 during 1998–1999 and 2012–2013.

The Chloride and Sulphate fluctuating and exceed the desirable limit frequently in 1998 (Fig.19). Up to this point there is no scope for aquatic life as the DO is negligible. Percent sodium is medium and high hazard class and SAR is low hazard class of Ir. HWQR shown at Fig.20.



(a)



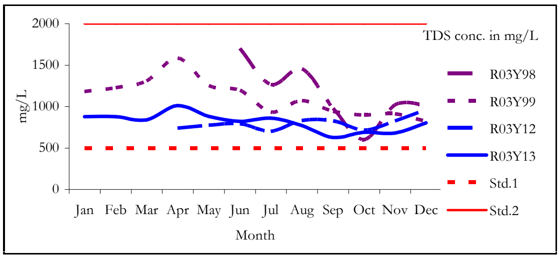
(b)

Fig.20: (a) Percent Sodium, (b) SAR of R05 during 1998–1999 and 2012–2013.

3.5 River Musi at Pratapasingaram (R03)

Fig.21 is a photographic view of River Musi at R03 [29] at immediate downstream of the R05. Trends for R03 for parameters during 1998–1999 and 2012–2013 are at Figs.21b, 22–25.

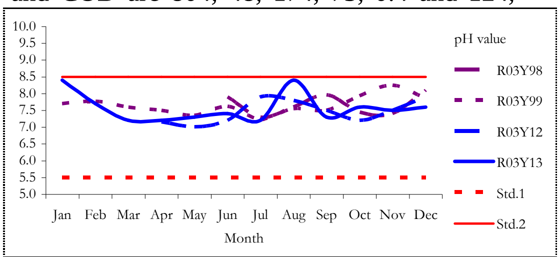
(a)



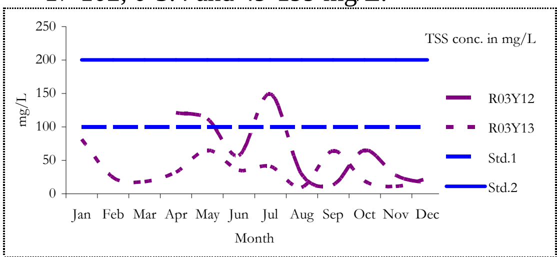
(b)

Fig.21: (a) A view of River Musi at R03, (b) TDS of R03 during 1998–1999 and 2012–2013.

Averages of TDS, TSS, Chloride, Sulphate, DO and COD are 804, 48, 174, 73, 0.4 and 124, respectively, ranging 626-1010, 9-149, 134-246, 17-102, 0-3.4 and 49-199 mg/L.



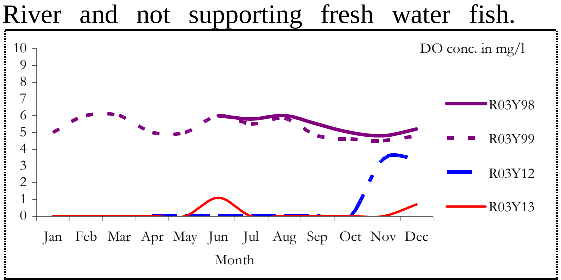
(a)



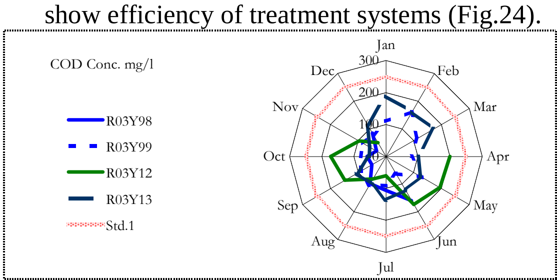
(b)

Fig.22: (a) pH (b) TSS of R03 during 1998–1999 and 2012–2013.

DO during 1998-1999 is ranging 4-6 and during 2012-2013 is near "0" indicate deterioration of River and not supporting fresh water fish. Chloride fluctuates and exceeds the desirable limit frequently and high in 1998-1999 than 2012-2013 show efficiency of treatment systems (Fig.24).



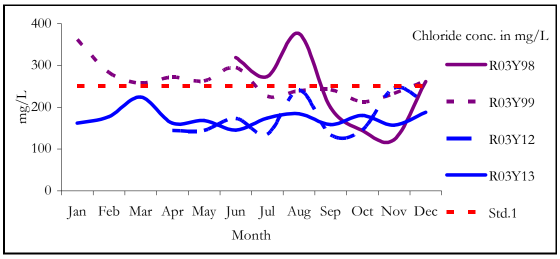
(a)

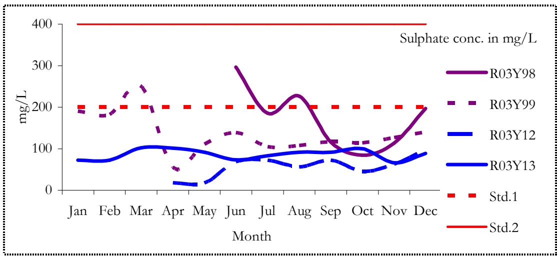


(b)

Fig.23: (a) DO (b) COD of R03 during 1998–1999 and 2012–2013.

The Sulphate exceeds the desirable limit in June and August 1998 and show higher concentrations during 1998-1999 than 2012-2013 and would be the result of CETP/STP facilities.

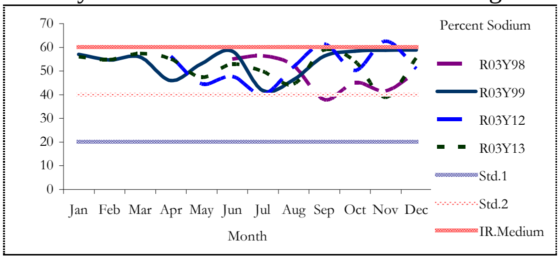


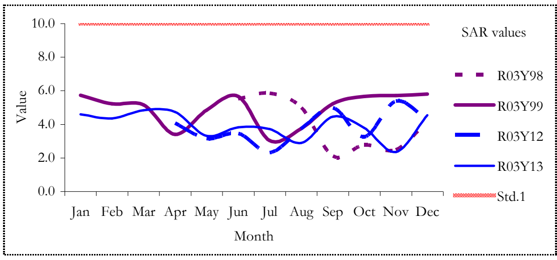


(a) (b)

Fig.24: (a) Chloride (b) Sulphate of R03 during 1998 – 1999 and 2012 – 2013.

Range and averages of pH, Percent Sodium and SAR are 7-8.4, 7.5; 39-62, 52 and 2.3-5.4, 3.9 respectively. Percent sodium is in medium and high hazard class and SAR is low hazard class of Ir. HWQR shown at Fig.25.



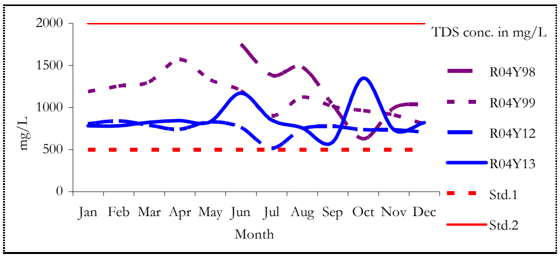


(a) (b)

Fig.25: (a) Percent Sodium (b) SAR of R03 during 1998–1999 and 2012–2013.

3.6 River Musi at Pillaipalli (R04)

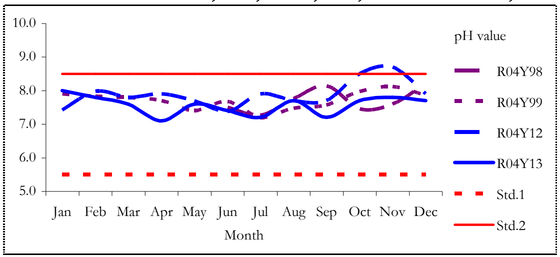
Fig.26 is a photographic view of River Musi at R04 immediate downstream of R03. Trends for R04 during 1998–1999 and 2012–2013 for parameters are at Figs.27b–28.

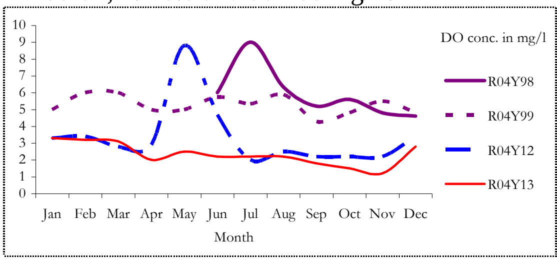


(a) (b)

Fig.26: A photographic view of River Musi at R04 (b) TDS during 1998–1999 and 2012–2013.

Averages of TDS, TSS, Chloride, Sulphate, DO and COD are 804, 25, 200, 77, 2.9 and 110, respectively, ranging 514-1346, 4-146, 138-480, 55-92, 1.2-8.8 and 36-288 mg/L.

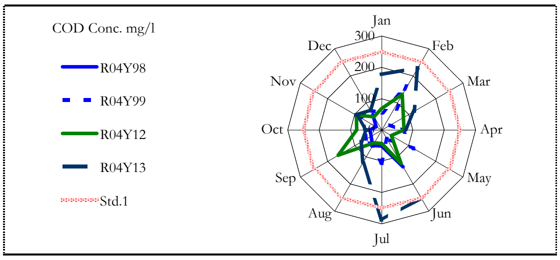


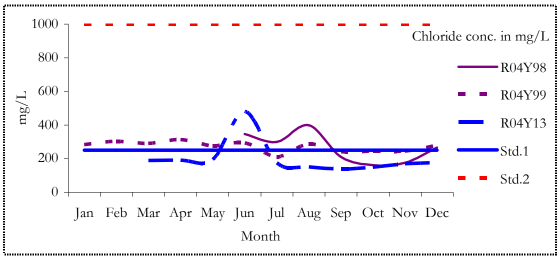


(a) (b)

Fig.27: (a) pH (b) DO of R04 during 1998–1999 and 2012–2013.

The range and average of pH are 7.1-8.7 and 7.7 respectively, shown at Fig.27(a). DO is 4-7 and 1-3 mg/L during 1998-1999 and 2012-2013, respectively, as shown at Fig.27(b). Chloride exceeds the desirable limit frequently on 1998-1999, and July 2013 and with in limit during 2013 except June. The Sulphate exceed in June to August 1998.



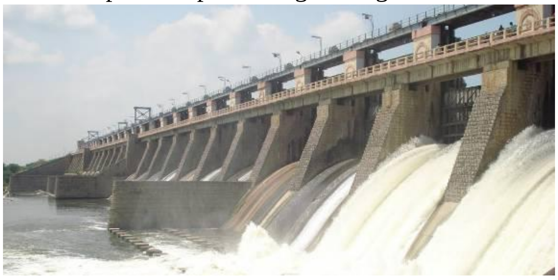


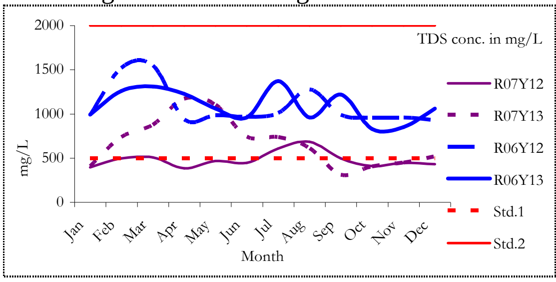
(a) (b)

Fig.28: (a) COD (b) Chloride of R04 during 1998–1999 and 2012–2013.

3.7 Musi reservoir (R06) [30] and River Krishna after confluence with River Musi at Vadapalle (R07)

Fig.29 is a photographic view of R06 [31, 32] at Kasaniguda, Suryapet, Nalgonda. R06 is the River Musi point representing storage after the confluence of a Tributary Bikkeru. Trends are prepared for R06 and R07 from the monitoring data during 2012–2013 at Figs.30–32.

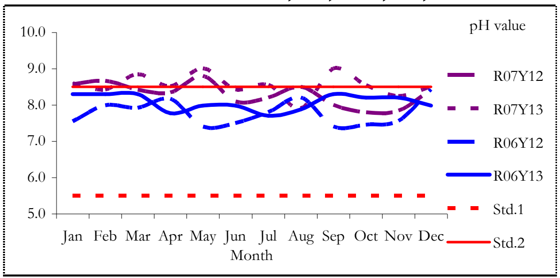


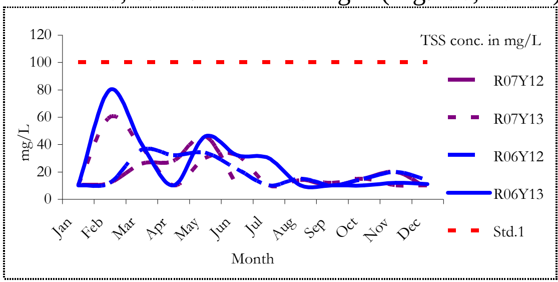


(a) (b)

Fig.29: (a) A view of R06 (b) TDS, of R06 and R07 during 2012–2013.

Averages of TDS, TSS, Chloride, Sulphate, DO and COD at R06 are 1090, 22, 243, 97, 4.8 and 23, respectively, ranging 830-1547, 10-80, 84-365, 48-195, 3.1-7.0 and 5-95 mg/L (Fig.29b, 30–32).

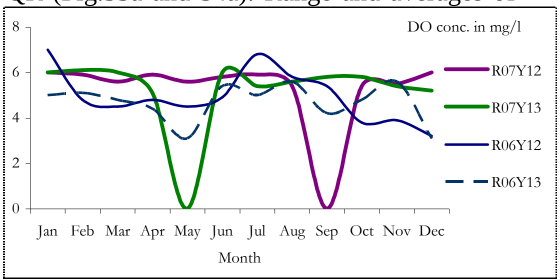


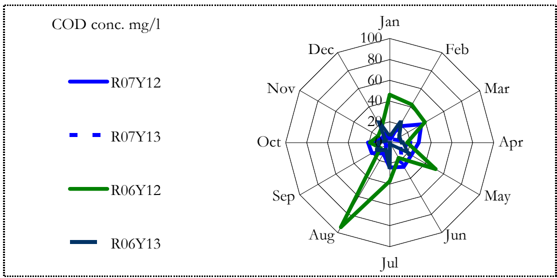


(a) (b)

Fig.30: (a) pH (b) TSS of R06 and R07 during 2012–2013.

Chloride exceeds desirable limit very frequently at R06 and Percent Sodium frequently reaches to very high hazard with respect to Ir. HWQR (Fig.33a and 34a). Range and averages of pH, Percent Sodium and SAR at R06 are 7.4-8.4, 7.9; 45-66, 56 and 3.2-6.8, 4.7, respectively (Figs.30a, 33).

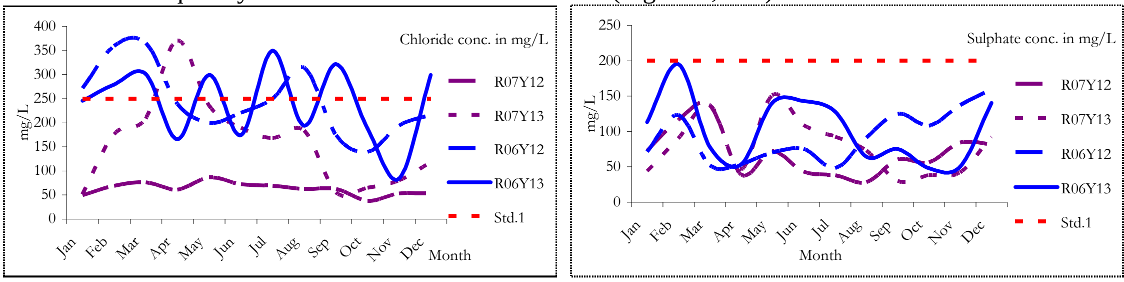




(a) (b)

Fig.31: (a) DO (b) COD, of R06 and R07 during 2012–2013.

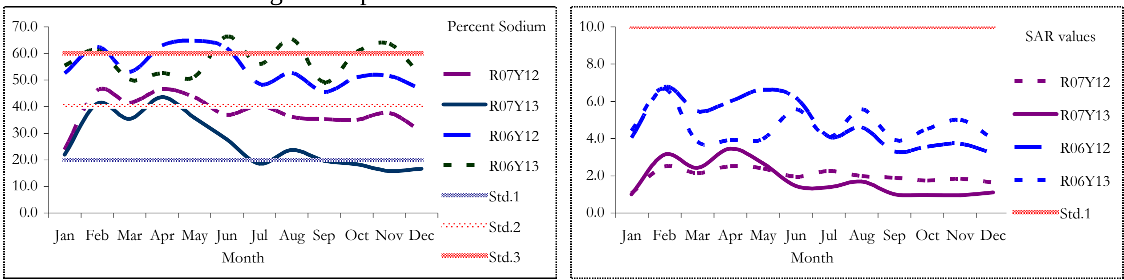
R07 is the River Krishna point after the confluence of River Musi. Averages of TDS, TSS, Chloride, Sulphate, DO and COD at R07 are 576, 20, 110, 74, 5.2 and 15, respectively, ranging 310-1173, 8-60, 38-370, 28-151, 0-6.1 and 4-35 mg/L (Figs.29b, 30–32). COD attained high value in August 2012. The pH and Chloride exceeds desirable limit frequently in 2012-2013 at R07 (Figs.30a, 31b).



(a) (b)

Fig.32: (a) Chloride (b) Sulphate of R06 and R07 during 2012–2013.

Range and averages of pH, Percent Sodium and SAR at R07 are 7.8-9.0, 8.4; 16-47, 32 and 1.0-3.5, 1.9 respectively (Figs.30a, 34). The flow of River Krishna at R07 is meager except few months and village drains joined it resulting to low DO, higher values of COD, TSS, TDS, Chloride and Sulphate.



(a) (b)

Fig.33: (a) Percent Sodium (b) SAR of R06 and R07 during 2012–2013.

3.9 Health indicator bacteria and nematode species [33]

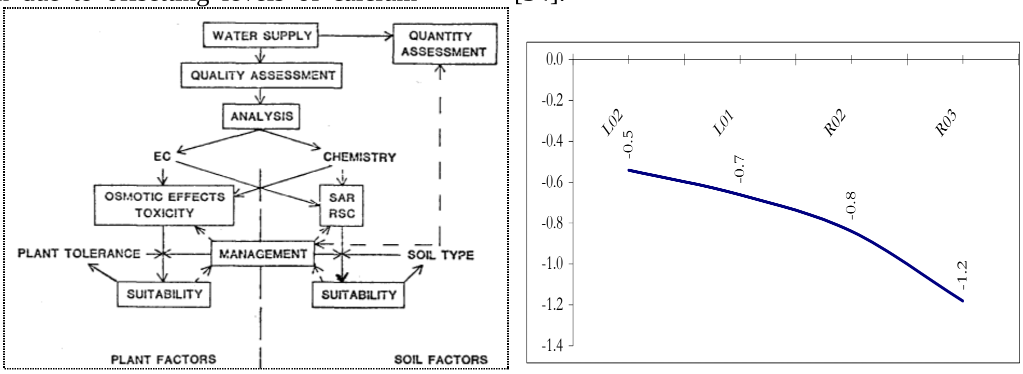
A study during the course of the survey (January 2003 – December 2005), 143 (66%) water samples from various points were found to be positive for Helminthes eggs. Three different Helminth species were detected; hookworm was the most common (65%) of all samples, followed by Ascaris (45%) and Trichuris (9%). Hookworm and Ascaris concentrations were found to be similar at the first two sample points, while Trichuris concentrations were found to be much lower. Concentrations of all three Helminths decreased rapidly at sampling points after the first weir 'Narayanarao Katwa (R05) at Peerjadiguda and decreased further with each additional weir up to 30 Km stretch on down stream of River Musi consisting 13 weirs finally Musi Reservoir. Trichuris eggs were the first to disappear from river water, followed by Ascaris, while hookworm eggs were the last to disappear from the river. The E. coli and F. coli concentrations during 1998-99 and 2012-2013 at the first weirs were high and comparable with those in raw sewage though they decreased rapidly with increasing distance from the city.

IV. CONCLUSIONS

The TDS of supply water source to HMDA is less than 300 mg/L indicating excellent quality water sourcing from Osmansagar, Himayatsagar, River Manjeera (a tributary of River Godavari) and Nagarjunasagar, which is storage site of River Krishna bed on upstream of River Musi confluence. The resultant discharges to Lakes and finally River Musi from its catchment covering HMDA hiked more than threefold in respect of the TDS and much more for TSS and COD. The treatment facilities are capable to process 673 MLD sewage per day against 1300 MLD supplied water through HMDA which is nearly 50%. The COD and TSS are controllable parameters with treatment facilities. Chloride concentration is in linear correlation with Sodium ion concentration and is the major contribution of TDS. The contact with soil and fused rock enriched with $Na^{+}/K^{+}/Ca^{2+}/Mg^{2+}/Fe^{2+}$ having basic nature and the production of ammonia, the water in the river course gaining higher value of pH than the neutral pH and regulated by stripping ammonia with DO on surface air currents.

The TDS, Percent Sodium and SAR are the deep markers for quality assessment. The percent sodium increased along the river course from 32 to 55 but this parameter alone does not dictate the water quality and requires additional parameter such as TDS or EC. The average TDS increased from 300 to 1090 mg/L in the river course which exceeded double the desirable limit (500 mg/L) but within permissible limit of 2000 mg/L on the condition of non availability of other desirable sources as per IS 10500 (1991 or 2012). Fig.4b, 7b, 12b, 15b, 20b, 25b and 33b show SAR average value increase in the river course from 1.2 (Osmansagar/ Himayatsagar) to 4.7 (Musi Reservoir) via 3.7 (Narayanarao Katwa Weir) indicating excellent water class in Ir.HWQR. The Sulphates present in water are transformed into suspended matter in the presence of Ca and Mg ions and enrich the soil leading to the marginal decrease in TDS of river water. RSC is a quick test to determine if irrigation water can reduce free calcium and magnesium in the soil, and negative. A negative value indicates little risk of sodium accumulation due to offsetting levels of calcium and magnesium. Fig.35(b) showing River Musi increased negative trend for RSC indicating increased suitability for irrigation while going down stream.

The COD and TSS are controllable parameters with treatment facilities. Chloride is in linear correlation with Sodium ion concentration and these are the major contributors of EC and TDS. The contact with basic soil and rock base, the production of ammonia by micro-organisms are resulting to higher pH than the neutral pH. In the course of its flow Group IA and VIIA ions of the periodic table are accumulated causing higher values of Percent Sodium, TDS and SAR which are unfavourable for using this water. This is explained with a flow diagram Fig.34(a) as ready reference [34].



(a) (b)

Fig.34: (a) Flow diagram for evaluation of water quality, (b) RSC at some points in River Musi.

On observation of results during 1998–1999 and 2012–2013 for Lake and river points, the influence of insignificant ions (SO_4^{2-} +SiO_3^{2-} +NO_3^-+F^- +PO_4^{3-}) [9, 16] contribution is within the acceptable limits of data variations [18] and the impact is insignificant. Hence, for the Musi points, monitoring is conducted for significant/ major pollutant estimations. The concentrations of heavy metal ions such as Nickel, Chromium, Arsenic, Lead, Cadmium, Mercury, Vanadium and Selenium are below the detectable levels and other ions are below the standards. Data analysis reveals that the natural biological system of degradation reduced organic matter and many of heavy metal ions from water and separates to sludge. The river purification indicates in increase of DO along the river course from weir Narayanarao Katwa to Musi Reservoir showing from "0" to 4 mg/L, respectively. This study shows stable TDS along the River Musi course with the drastic reduction of TSS and COD. The average COD trends along the river course decreased from more than 300 to 23 mg/L.

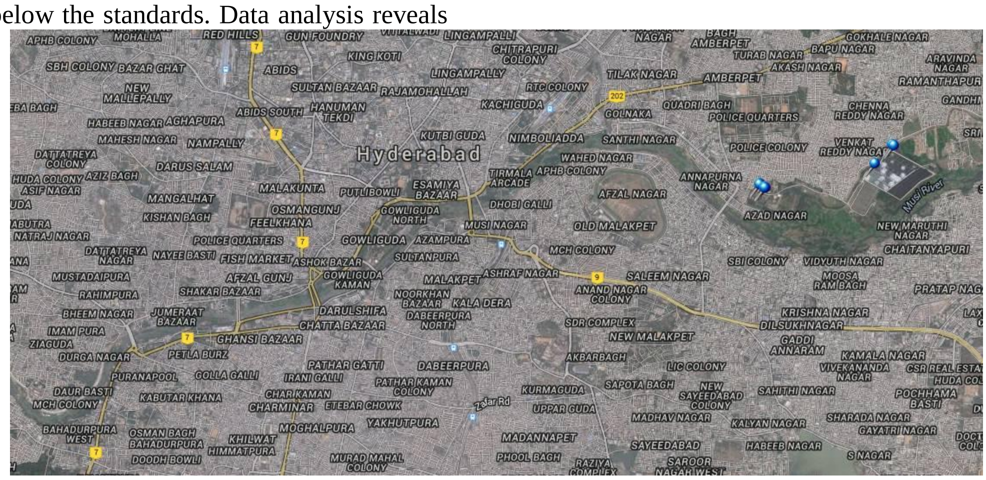


Fig.35: River Musi topographical stretch of Bahadurpura – Amberpet – Venkatareddy Nagar

Simultaneously the tanks used for drinking and domestic water sources got polluted through the drains of catchment covered by habitation and industrial activity. Many parts of the River Musi encroached with huge constructions for public activities example inter state/district bus bay, Amber pet STP (Fig.35), Metro rail service/control junction etc. To evaluate the pollution in the tanks and assessment of drains adjoining them, the author participated in the analysis and data management during 1997–1999 by implementing knowledge acquired in the field of computer software. The monitoring data of different points in the city covering most of the catchment of the lakes and tanks during 1998–1999 show the evidence for high levels of pollution.

V. REMEDIATION

The River Musi catchment covered in terms of lake catchments, those are urbanized with human colonies, the sewage generated is joining the lakes and its boundaries are encroachments. The only alternative is establishment treatment facility for the drains joining the river. Hence, every lake inlet/ River inlet drain should be through STPs in addition to preliminary treatment of rain water for removal of silt, Suspended Solids and plastic waste. Lake Boundaries should be reestablished to possible extent with clearing encroachments for retaining the capacity of lake allowing self treatment, charging the ground water table with good quality water and for recreation / park for the public to feel the nature [35].

The river bed is to be retained for the distributed shallow flow that support and retain strata for self purification. The silt deposited at weirs on different places of the river courses is to be removed regularly. The RO rejects from the plants/ industries are to be treated with cascading ROs resulting in high TDS which has to be further treated with MEE. The recovered solids to be disposed at secured land fill or toxic solid waste disposal facility (TSDF). The disposal standard for TDS is to be more stringent as the soil is continuously exposed and charged with this water, leading to accumulation of TDS and might become unfit for use. Further, the water class crosses the desirable criteria with twice the TDS and is not suggestible for drinking purpose. Its domestic use is subject to disinfection and treatment. The water enriched with nutrients leads algal bloom which can be removed by using fish saplings. Another option to contain the nutrients is cultivation of a special type of blue green floating algae [36] for converting nutrients into manure / cattle feed / biodiesel [37].

The River Krishna is experiencing high pollution from the River Musi [38], indicated by the TDS crossing the desirable criteria. The down stream of River Krishna from Nagarjunasagar dam is meager most of the period and the algal bloom is high in the water packets due to high nutrients. Hence, it requires further study on the impact of River Musi and the tributaries in the down stream of River Krishna as they are collecting mostly sewage and high TDS.

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