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Assessment of Pollution in Lakes Drained by Urban Catchment

Chandra Sekhar. M

Abstract**—**Many metropolitan cities in India including the city of Hyderabad have experienced a very fast rate of urbanization and phenomenal growth of population in the past few decades. The high density of population had resulted in development of many housing colonies, industrial, commercial and institutional building complexes without matching growth in necessary infrastructure such as protected water supply, underground sewerage system and solid waste management. In this process, many of the lakes in the urban areas had given way for water quality deterioration and the lakes still surviving, in the process of urbanization are polluted by discharge of wastewater, storm water, solid wastes and other unauthorized inputs. These problems exist all over the world and especially in the developing and underdeveloped countries. In fact the standards of sanitation and management of liquid and solid waste in an urban area can be judged from the water quality status of lakes in the area. A highly polluted lake usually is a pointer of neglected environmental management in the lake catchment. Saroor Nagar lake in Hyderabad drained by an urban catchment is experiencing the problem of water quality degradation and efforts are made in this paper to assess the impact of the restoration measures taken to control water quality degradation. Results indicate the sewage treatment plant constructed reduced the inputs contributed by point sources, while the other measures taken on catchment scale are also effective in reducing the pollutant load. Mass balance approach is used to assess the inputs and improvements in water quality of the lake.

Key Words: Lake Water quality, Urban catchments, Lake Restoration, Mass balances.

I. Introduction

The interference of humans with the lake ecosystems and the concentrations of pollutants in the lakes are increasing at an alarming rate. This is mainly due to disposal of both domestic and industrial wastewater with or without treatment. Lakes with agricultural catchments also face the same problem because of the indiscriminate application of fertilizers and pesticides for increasing crop yields. In spite of these problems, the existing wastewater treatment techniques do not aim at removal of nutrients from sewage. Hence, these nutrients lead to increase in the nutrient levels of the lake thus accelerating the natural aging of lakes. This ultimately leads to contribution of organic matter and nutrients into the lakes resulting in extensive weed growth and algal blooms and the lakes are subjected to eutrophication, the water body looses all its beneficial uses. Unlike ever flowing water in rivers, water in lakes remains stagnant for several months to decades and in some lakes even longer than hundred years and therefore tends to be easily polluted. Consequently much attention has to be paid for maintaining the lake environment in good conditions in order to coexist with lakes for sustainable use of the resources. Many investigations have been conducted on pollutant contributions by various sources (Zeng and Rasmussen, 2005; Reghunath, et. al., 2002; Palma, et. al., 2010).

II. Methodology

A *Description of the Study Area*

Saroonagar lake is situated in the eastern part of Hyderabad having the geographical location of the lake is latitude 170 21' 20" and longitude 780 31' 40". Location of the lake is given in Fig No 1. The average annual rainfall in the area is about 750mm. Climate is generally dry in summer (March - June) with Monsoon rainfall (June-October) followed by winter (November - February). Average maximum temperature is 42.5oC in May and average minimum temperature is 12.7oC in November. The Lake is a rain fed with lake area about 49.40 hectares. The ground water recharge is estimated to be 3.2 MLD. The average depth of water in the lake is about 2.5m at the end of normal rainy season. The total quantity of water available in the lake is approximately 1000 ML. Due to seepage and evaporation losses the lake becomes totally dry in 192 days if there are no inflows into the lake. The quantity of wastewater inflow into the lake is estimated to be about 4.9 MLD. So a STP of capacity 5 MLD was proposed and implemented for controlling lake water quality degradation.

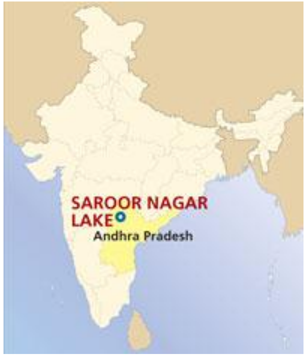

Fig No 1 Location of the Lake

M Chandra Sekhar
National Institute of Technology, Warangal
India

B. *Data Acquisition*

Necessary data for the present study was acquired from HUDA (Hyderabad Urban Development Authority), Tarnaka. Saroornagar lake water quality before the construction of sewage treatment plant and after construction of the STP and the STP effluent characteristics are used for the present work. The data is used for the comparison of lake water quality before the construction of STP with the existing water quality. The water samples for physico-chemical analysis are collected at a depth of 5 to 10 cm below the water surface as per prescribed sampling procedures. Standard methods for examination of water and wastewater (APHA, 1992) were adopted for collection of samples and analysis of various parameters in water and wastewater.

C. *Mass Balances*

Pollutant contributions into the lake are estimated using mass balances. Mass balances are used for estimation of pollutant loads using water and wastewater data during different seasons. Indirect estimation of loads from polluting sources using seasonal data is quite helpful for monitoring studies with limited data. In this approach, it is assumed that the pollutant loads into the lake are contributed by point sources during the dry season (pre-monsoon) and both point and non-point sources contribute pollutants during the monsoon season. For regions with distinct dry and wet seasons this approach can be adopted for estimation of pollutant contributions. Also, using this approach it is possible to estimate unauthorized inflows responsible for water quality degradation. If source inventory is available, this approach can give better results.

Seasonal variations are used for estimating of loads contributed by point sources (mainly domestic waste water) and non-point sources (predominantly storm run-off). In the preset study area, dry season is followed by wet season, the contributions to the lake during summer months are point loads. The pollutant loads in the wet season contributed by both point and non-point sources. Using mass balances the difference between total and point loads is the non point load. In the absence of experimental data to arrive at non-point loads in catchments, this indirect method using mass balances gives an appropriate estimation of non-point loads.

III. RESULTS AND DISCUSSION

A. *Impact of Construction of STP on Lake Water Quality:*

The water quality data of lake waters pertaining to different seasons is presented in Table No1. Water quality of the lake waters before and after construction of STP is used for assessment of the impact on lake water quality. Characteristics of the effluent from STP are also given in Table No. 1. The effluent from STP adheres to the effluent standards prescribed for disposal of treated wastewaters into inland surface waters. The improvement in lake water quality is distinctly visible in terms of various parameters after the construction of STP.

The pH of lake water before the construction of STP was alkaline in summer and acidic in the other two seasons. However, after construction of STP, the lake waters were always alkaline. The alkaline conditions are favorable for the growth of algal species while acidic conditions are detrimental. Consistent algal productivity enhances the oxygen intake and helps in maintaining higher productivity. Turbidity values are significantly lower after construction of STP when compared with turbidity values in lake waters before construction of STP. After construction of STP, the turbidity values in the monsoon are found to be higher than pre monsoon and post monsoon and this is attributed to contributions from non point sources. In summer the turbidity contribution is very low indicating very low contribution through effluent from STP.

The value of TSS in monsoon is found to be higher than the pre monsoon and post monsoon because the first flush storm water from urban catchments consists of variety of solids and hence higher levels in the monsoon season. Unavailability of TSS data pertaining to lake waters before the construction of STP has curtailed the scope for drawing meaningful observations. BOD and COD in lake water before the construction of STP indicates significant organic pollution, however after the construction the BOD and COD levels reduced indicating improvement in water quality and lower contribution from discharge of domestic wastewater. After construction of STP, BOD and COD values in monsoon season are higher indicating contributions from non point sources.

B. *Estimation of Pollutant Contributions*

Pollutant loads are estimated using data pertaining to pre monsoon and monsoon and presented in Table No. 2. Estimation is carried out by multiplying the mean concentration with discharge. Loads before and after construction of STP are calculated using mean concentrations in every season and discharge. The estimated loads indicate the success of the restoration attempts by way of construction of STP in reducing the pollutant contributions to the lake. The loading trends after the construction of STP indicate the efficiency with which the STP is working. The decreased loads especially in organics contribution indicate that the STP is making a big difference in improving the lake water quality by reducing the inputs. The seasonal trends indicate that there is much more to be done in controlling the non-point source contributions into the lake.

C. *Source Contributions*

The lake drains part of Hyderabad in addition to other areas around the urban area. The point load contribution is mainly by discharging the effluent from STP. The point loads are estimated and presented in Table No 3. The other point sources include uncontrolled and unauthorized discharges from residential and commercial buildings in the periphery of the lake. It is very difficult to estimate the contributions by these sources as they are in diffuse in origin. The point load contributions are more are less same in both premonsoon and monsoon.

D. *Source Apportionment*

Mass balance approach has been utilized in the present study to assess the contribution of point and non-point sources of pollution to the lake and the results have been presented in Table Nos 4 and 5. The estimated differential loadings for various parameters compare favorably with point source loadings of the corresponding constituent, considering that the later does take into account uncharacterized non-point sources of pollution. Therefore it can be argued that the difference in loadings may be mainly due to the contribution of non-point sources. Similar conclusions can be drawn by the study to estimate the contributions from rain water and un-authorized inflows into the lake. Flooding of storm drains due to disposal of solid wastes in the drains during the pre-monsoon season contributes considerable loads to the lake.

Generally, non-point loads that arise from the catchment area are determined using rainfall data and the specific loads that arise from different land use activities. The specific loads are to be obtained by analyzing the storm runoff collected from different land uses. However, in the present study, the contributions by non-point sources are estimated by using mass balances. The accumulation of pollutants is quite significant in the lake under study as there is no outflow from this system, except for pumping to meet the water supply requirements. This can ultimately lead to eutrophication and hence, deterioration of lake water quality. As estimates for the lake indicate the success of the STP, the results of the study are useful for emphasizing the urgent need for controlling the storm runoff and treatment to reduce its contribution to lake pollution. This can considerably reduce the non- point loads to the lake and result in improvement in the lake water quality. Also there is a considerable contribution from unauthorized inflows from the nearby areas which needs to be addressed immediately.

IV. CONCLUSIONS

Increasing population along with increasing intensities of industrial, agricultural and recreational activities are causing larger degradation of natural resources, and damage to the environment and ecological system around the world. Surveillance of water quality parameters of lakes, especially with urban catchment is very essential to have a clear idea of the state of eutrophication and to restore the lake ecosystem from further deterioration. The present work concentrates on water quality assessment of Saroornagar lake, which is under restoration programme.

The quality of the lake water deteriorates considerably as a result of pollutants discharged into the lake from both point and non-point sources. The pollutant loadings obviously reduce the self purification capacity of the receiving water body. The important point sources existing in the area are domestic wastewater outfall. The wastewater originating from these sources is now collected by a sewer network and treated in the STP as a part of the restoration programme. At present, the STP is working well which is indicated in terms of loads contributed by point sources before and after construction of STP. In spite of the STP, there still occur few unauthorized inflows into the lake resulting in lake pollution on most occasions. Considerable contribution from the non-point sources also reaches the lake during the monsoon and post monsoon seasons. The catchment, mainly comprises of large urban area and partly other areas with mixed land uses, as such the runoff from these areas directly joins the water body with considerable amount of pollution. Hence, there is a need to have a designed urban stormwater network to control pollution in the lake.

It is essential to restore the water quality of the lake by dredging of sediments, catchment treatment/management, source control, vertical mixing, etc., to improve the water quality of the lake. The present investigation provides an account of the advantages of using indirect approach for lake water quality for assessment and estimation of pollutant loads. This approach is also useful to detect changes in water quality constituents within the system. Indirect modeling of point and non-point sources carried out in the present work provides a better alternative for a systematic study over the conventional techniques. However, the limitations such as source classification, data limitations, etc., have to be considered carefully. As the study indicates major contributions of pollution from non-point sources, it is essential to emphasize the importance of control of non-point sources to achieve goals of water quality management programs and restoration practices.

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Table 1 Summary of Lake Water and Wastewater Analysis

S No	Parameter	STP Effluent	Before Construction of STP			After Construction of STP		
			Summer	Monsoon	Post-monsoon	Summer	Monsoon	Post-monsoon
1	pH	7.2	8.4	7.9	7.2	8	8	8
2	Turbidity	-	214	160	185	49	90	60
3	BOD	5	70	90	39	28	33	39
4	COD	27	152	244	129	112	125	69
5	TSS	5	--	--	--	82	119	95
6	TKN	10	--	--	--	9	9	10

Table No 2 Estimated Pollutant Contributions in to the Saroornagar Lake

S. No	Parameter	Before Construction of STP		After Construction of STP	
		Pre-monsoon (Kg/day)	Monsoon (Kg/day)	Pre-monsoon (Kg/day)	Monsoon (Kg/day)
1	TSS	--	--	406	583
2	TKN	--	--	42	44
3	Turbidity	1050	784	238	475
4	BOD	341	453	138	162
5	COD	747	1196	549	613

Table 3 Estimated Point Load Contributions by STP Effluent

S No	Parameter	After Construction of STP	
		Pre-monsoon (Kg/day)	Monsoon (Kg/day)
1	TSS	22	29
2	TKN	47	58
3	Turbidity	--	--
4	BOD	23	24
5	COD	148	122

Table No 4 Estimated Nonpoint Source Contributions - Monsoon

S No	Parameter	Total Pollutant Load - Monsoon (Kg/day)	Load Contribution by STP Effluent – Monsoon (Kg/day)	Non point Load Contribution (Kg/day)
1	TSS	583	29	554
2	TKN	68	58	10
3	Turbidity	--	--	--
4	BOD	162	24	138
5	COD	613	122	491

Table No 5 Estimated Nonpoint Source Contributions - Premonsoon

S No	Parameter	Total Pollutant Load - Premonsoon (Kg/day)	Load Contribution by STP Effluent – Premonsoon (Kg/day)	Load Contribution due to unauthorized Inflows to the Lake (Kg/day)
1	TSS	406	22	384
2	TKN	52	47	5
3	Turbidity	--	--	--
4	BOD	138	23	115
5	COD	549	148	401

About Author (s):

Author graduated from Sri Venkateswara University College of Engineering, Tirupati and later awarded Ph D at National Institute for Technology, Warangal At present he holds the post of Director (Academic Affairs) at Institute for Electronic Governance, Govt of Andhra Pradesh. He coordinates all academic Initiative Programs in Jawahar Knowledge centers across the state. His Professional Experience includes 18 years of teaching experience at National Institute of Technology, Warangal. He is involved in teaching, research and consutancy assignments at NIT, Warangal. Authored a text Book titled Environmental Science. His publications include 12 papers in Peer reviewed journals, 8 reviewed articles, 20 in International Conferences and 10 in National Conferences. He is invited for Research Discussions at the University of Essen, Germany and Technical University of Vienna, Austria. Invited by UN to teach a course at the Prestina Summer University.