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Pollution in Sanjay Van Lake: A Restored Waterbody of Delhi

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ABSTRACT

Unassuming urban water bodies such as lakes and reservoirs provide a plethora of tangible and intangible services to mankind as well as to the ecosystem. Conservation and proper management of these is imperative now and requires participation of researchers, policy makers, civic authorities and the local population. Routine water quality monitoring is the need of the hour as it gives an insight into the nature and cause of pollution, and is indispensable for designing conservation and mitigation strategies. This study reports water pollution status of five compartments of Sanjay Van lake. Very high levels of alkalinity, hardness and Biological Oxygen Demand (BOD) indicate that all the interlinked compartments are severely polluted. We found fluctuations in the levels of Dissolved Oxygen (DO); and BOD was dependent on rainfall and functioning of the Vasant Kunj Sewage Treatment Plant (STP).

Keywords: Biological Oxygen in Demand (BOD), Dissolved Oxygen (DO), Urban water bodies.

INTRODUCTION

With an expected population of around 2.7 billion by 2025, the Indian subcontinent will need more water than would be available and is already classified as ‘water stressed’. If not addressed immediately, this water crisis may cripple the very existence of life and will be more severe in urban areas. Under the changing climatic scenario, urban water bodies are facing unprecedented challenges. Water bodies such as lakes, rivers and seashores offer a range of services that contribute directly and indirectly to human well-being. In cities such as Delhi, they become all the more important as they provide numerous services to the ecosystem affected by the increasing population pressure and ruthless anthropogenic activities. Use of water for drinking, irrigation, fishing and industrial purposes has an unswerving effect on human life and economy (1). Also, the role played by the urban water bodies in ground water recharge; in supporting local flora and fauna; and providing aesthetic pleasure isindirect but critical for the ecosystem (2). Additionally, in India, water bodies are intimately associated with our cultural and religious practices (3). Mere presence of water bodies in an area is not sufficient, but the quality of water, particularly surface water is equally important. Water quality is influenced by natural factors such as soil and parent rock erosion, and fluctuation in rainfall; and anthropogenic factors such as agricultural and industrial activities, discharge of urban waste, particularly untreated sewage and increased water consumption (4). Adverse effects of anthropogenic factors on water quality are further amplified by increasing population pressure, lack of awareness and sensitivity amongst locals. In megacities such as Delhi, these issues are further compounded by constant immigration and unauthorized settlements.

One of the important issues in maintaining the quality of surface water is discharge of untreated sewage. While in rural areas open defecation is a problem, in urban parts of the country discharge of untreated sewage is rampant (5). Dumping of untreated or partially treated sewage into water bodies adversely affects the biogeochemistry of water by increasing the concentration of heavy metals (6). According to Novotny and Olem (1994) (7), sources of water pollution can be broadly categorized as non-point source and point source. Wastewater effluent carrying municipal and industrial pollutants is considered as a point source. Sewage treatment plants continuously add pollutants to urban water bodies and it is imperative that they are continuously monitored. Water chemistry is under a constant flux as it depends upon several special and temporal factors such as, temperature, precipitation, etc. Such variations make it all the more important to have a monitoring programme and a representative and reliable estimation of surface water (8).

There have been several international as well as national efforts to protect urban water bodies, particularly lakes. The United Nation Environment Program's Global Perspective of Fresh Water Stress, states that "Conservation and restoration requires a systematic and comprehensive plan to study selective and representative freshwater ecosystems." It emphasizes on conducting detailed studies on management and conservation of water bodies. In India, the National Lake Conservation Plan was established in 2001 by the Ministry of Environment and Forests and Climate Change, to restore water quality and ecology of lakes (9). Results obtained from such monitoring studies not only give an insight into the exact cause of pollution, but also make way to curtail and mitigate them. Monitoring programs have been conducted to assess the quality of surface water, and study the level of pollution in water bodies in Greece and USA (10-12). While India accounts for 16% of the world's population and 4% of the fresh water resources, its per capita water availability has reduced to half from what it was in year 1955 (13). Currently, water availability per capita is around 1,170m^3 per person per year (14). Disposal and treatment of sewage is also an important issue as evident from the data that shows only 160 out of 8000 towns in our country to have Sewage Treatment Plants (STP) (15).

Conservation and proper management of water bodies need active participation from scientists as well as policy makers. Involving and sensitizing locals would further enhance the pace and purpose of conservation programs. The first step towards this larger goal should be to create a time wise data base of various pollutants of water bodies. Routine water quality monitoring is the need of the hour as it gives an insight into the nature and cause of pollution, and is indispensable for designing conservation and mitigation strategies. In India there have been scattered attempts to monitor and analyze the quality of surface water bodies, however, the focus of these studies have been primarily on rivers (16-17). Surface water quality is primarily indicated by parameters such as pH, alkalinity, hardness, and concentration of Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD). These parameters indicate the levels of organic pollution in a water body, and are influenced by a combination of several physical, chemical and biological factors. There have been a few attempts to monitor the quality of urban water bodies in Delhi. To the best of our knowledge, this study is the first report indicating temporal fluctuations in physico-chemical parameters in the compartments of Sanjay Van Lake, New Delhi. The objectives were set to monitor water pollution status of five interlinked compartments of Sanjay Van lake through analysis of the physico-chemical parameters of the water.

METHODOLOGY

Study Site: Delhi Ridge serves as a ‘green lung’ for Delhi and plays an important role in overall improvement in the environment by absorption of the toxic pollutants, groundwater-recharge etc. The ridge is divided into Northern, Central, South Central and the Southern zones. Our study was conducted in Sanjay van (77°9'42.79"E/ 28°31'12.97"N), a part of the South-Central ridge, which covers an area of 1,582.5 acres (Fig 1). It has been listed as a permanent wet water body in South Delhi and is currently managed by the Delhi Development Authority (DDA). It has five interlinked compartments (now onwards called as pond), of which Pond No.1 receives water from the Neela Hauz lake and treated sewage from Vasant Kunj Sewage Treatment Plant (STP). The water flows through Pond Nos. 2, 3 & 4 and finally reaches Pond No. 5 (Figure I and II) from where it moves through drain pipes to the Hauz Khas lake, where it is used for recreational purpose. These five ponds can be accessed on foot or by bicycle, and local residents often come to the area for taking walks and sighting birds, during the winter months.

Figure I: Google Map of Sanjay Van

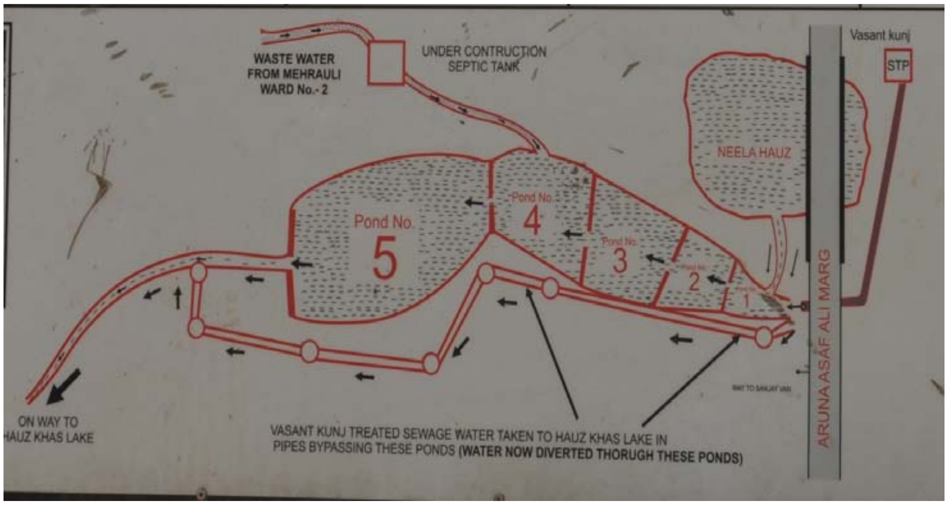


Figure II: Diagrammatic representation of Sanjay Van showing inflow and outflow of water in the five ponds (source: Horticulture Department, Sanjay Van)

Water Sampling: Sampling strategy was designed to give a comprehensive representation of water in the ponds. To indicate alteration in water quality, and to correlate them with the monsoon, sampling was carried out for a period of six months spanning between December 2015 and September 2016. To eliminate any temporal and spatial micro error in sampling, the time of sample collection and the specific spots within the ponds were kept constant throughout the study. For the assessment of various physico-chemical parameters, water samples were collected (in triplicates) in the morning (between 10-11 a.m.) in 250ml pre-washed Schott bottles, from approximately 15cm below the water surface.

Physical parameters: Parameters that can undergo change were recorded soon after sample collection, at the site itself.

Chemical parameters: pH of the collected water samples was determined by using portable pH meter. Standard APHA protocols were followed to determine alkalinity (18) and hardness (19) in the water samples. Alkalinity and hardness were measured in the months of June (pre-monsoon) and September (post-monsoon), 2016. Analysis of DO and BOD were conducted based on standard protocol (20) in the months of December 2015, January 2016, February 2016, March 2016, June 2016 and September 2016.

RESULTS

pH: Average pH values in all the five ponds ranged between 7.5 to 8.

Alkalinity and hardness: Analysis of alkalinity and hardness was conducted in the month of June (pre-monsoon) and September (post-monsoon). The average alkalinity in the five ponds was calculated to be 314.6mg/l in the month of June 2016. Pond no.1 had the most alkaline water (333.3mg/l) and pond no. 3 had the least (301.6mg/l). In the month of September 2016, the level of alkalinity was observed to be reduced with an average value of five ponds being 312.3mg/l. Pond-wise trend remained unchanged. Pond no.1 had the most alkaline water (306.7mg/l) and pond no.3 had the least (280 mg/l) (Figure III). Figure IV shows the level of hardness in the ponds in June and September 2016. Average hardness of water in the five ponds was 246.2mg/l in the month of June 2016, which marginally increased to 256.24mg/l in September 2016. Minor pond-wise fluctuation in hardness level of water was observed in both the months of analyses (Table I).

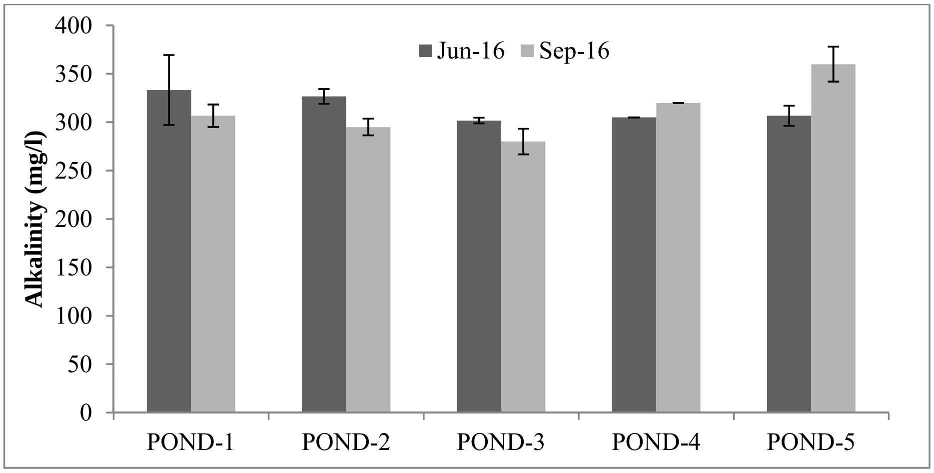


Figure III: Alkalinity (mg/l) of water of Sanjay Van Lake

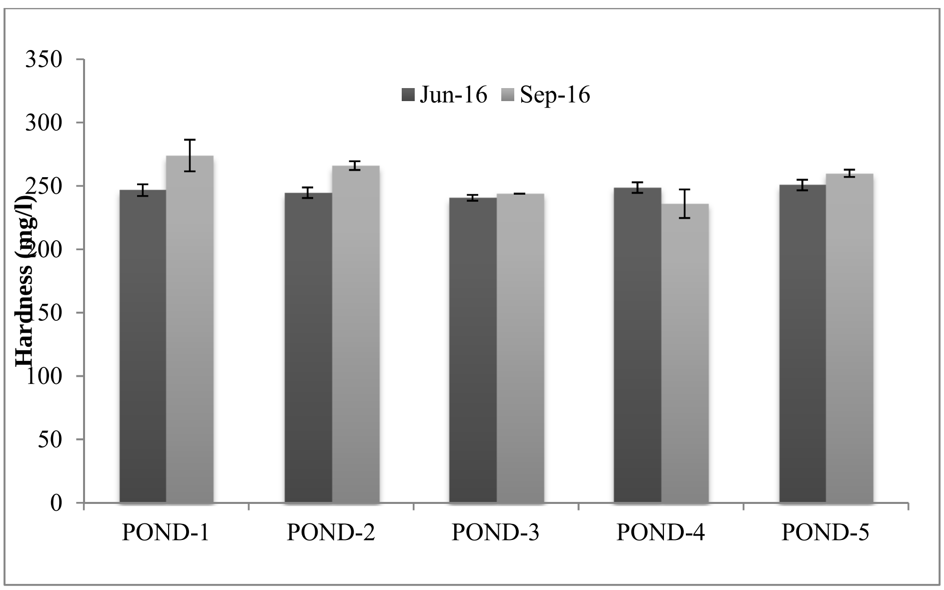


Figure IV: Hardness (mg/l) of water of Sanjay Van Lake

Analyses of water samples showed that levels of DO as well as BOD were very high in all the five ponds. Average DO level of the ponds for all the six months was observed to be lowest in pond no. 4 (3.2mg/l), and highest in pond no. 3 (4.15mg/l). The average value of BOD in the ponds was alarmingly high, highest being in pond no. 2 (10.27mg/l) and lowest in pond no. 3 (8.55mg/l) (Figure V). Levels of DO showed temporal fluctuations in all the five ponds in different months. In December 2015, minimum DO level was recorded in pond no. 4 and maximum in pond no. 1, while January 2016 showed lowest DO levels amongst all the five ponds, followed by higher values in the months of March 16, February 16 and June 16. Highest DO level was observed in the month of September 16 (Figure VI)

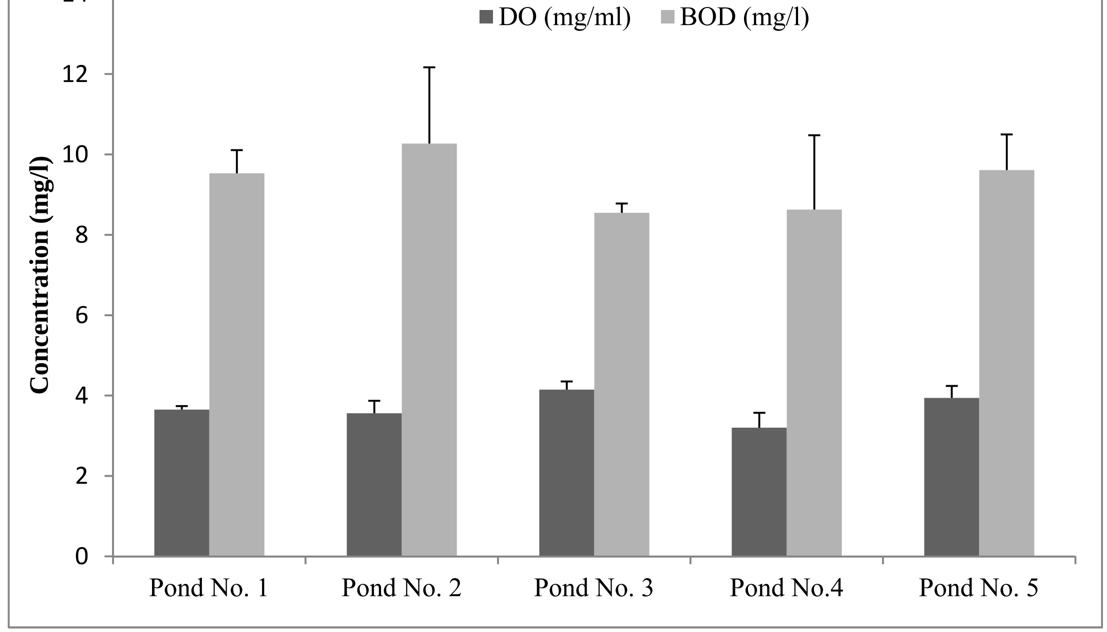
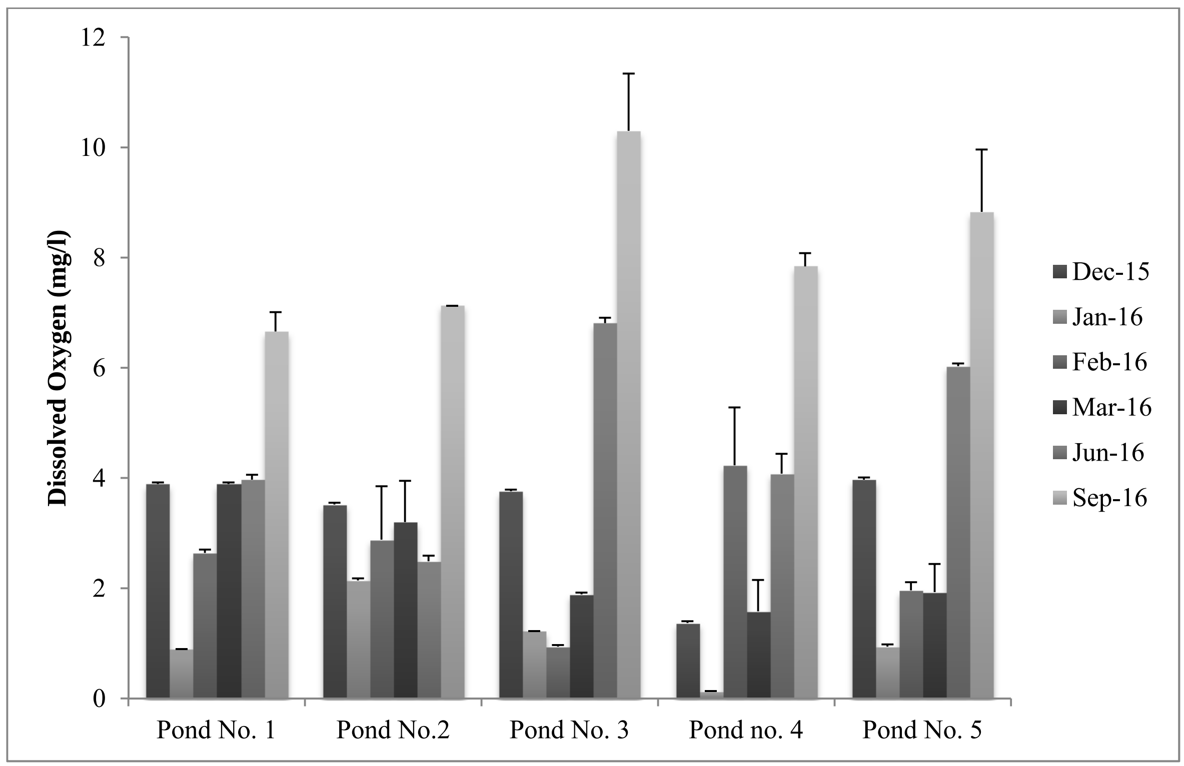


Figure V: Average Dissolved Oxygen (mg/l) and Biological Oxygen in Demand (mg/l) level of water in Sanjay Van Lake



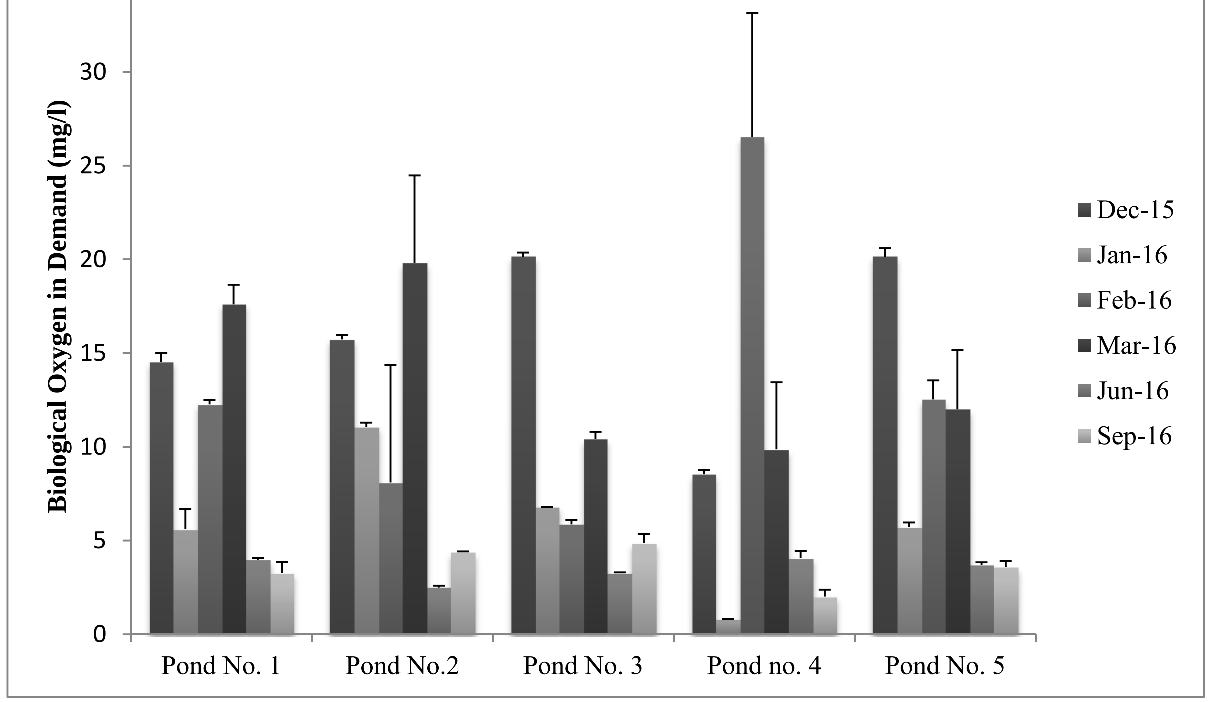


Figure VII: Temporal variation of Biological Oxygen in Demand (mg/l) of water in Sanjay Van Lake.

Table-I: pH, Average DO, BOD, alkalinity and hardness of Sanjay Van lake in pre-monsoon and post-monsoon months

Except pH all values are in mg/l

	Pre-monsoon				
Parameter	Pond no.1	Pond no.2	Pond no.3	Pond no.4	Pond no.5
pH	7.8	7.6	7.9	8	7.8
DO	3.05±0.04	2.84±0.37	2.92±0.03	2.27±0.4	2.96±0.15
BOD	10.79±.58	11.43±2.29	9. 9.29±0.18	9.16±2.15	10.81±1.00
Alkalinity	333.33±23	326.67±11	301.67±5	305±1	306.67±12
Hardness	246.67±5	244.67±3	240.67±2.5	248.6±3.1	250.6±2.8

Highest BOD levels were observed in the pre-monsoon months of February and March 2016. In pond no. 4 the levels were as high as 26.53mg/l. The levels reduced post rainfall and in the month of September 2016, it was calculated as 2.01mg/l in pond no. 4 (Table I) (Figure VII)

Table-II: Water quality criteria as listed by CPCB (http://www.cpcb.nic.in/Water_Quality_Criteria.php) (15)

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	Total Coliforms Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organised)	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH between 6.0 to 8.5 Electrical Conductivity at 25°C micro mhos/cm Max. 2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

DISCUSSION

Rapid degradation in the urban ecosystems is a consequence of increasing population and ruthless anthropogenic interference. Amidst the city chaos, the water bodies have been drastically affected. For ecological sustenance and well-being of a city, their conservation is pivotal, as they selflessly provide many 'ecosystem services' whose importance cannot be undermined. Grizzetti et al., 2016 (21) has emphasized on the role of ecosystem services provided by water bodies to promote their conservation and restoration. Services provided by freshwater bodies have been classified into provisioning, regulatory, and cultural services (22). Factors that are directly affected are the microclimate, drainage and sewage system of the area, at the same time facilitating clean air and recreation for the city residents. Moreover these areas harbor a variety of flora and fauna and act as 'cradles of biodiversity', which are at threat due to habitat destruction. Identification and restoration of these ecosystems in a city thus directly benefits its inhabitants by enhancing the health and quality of their lives. The present study focuses on the identification of such urban green spaces in New Delhi and assesses their competence and contribution in the overall well-being of our environment.

Our study gives the first report on the quantitative analyses of various water pollution indicators in the pond ecosystems of Sanjay Van, a restored waterbody. We found all five ponds to contain poor quality water which was not even suitable for recreational purposes, especially in the pre-monsoon period. pH of water in all the five ponds was higher than 7.0. pH plays a very crucial role in governing the physico-chemical characteristics of water, and also influences the distribution of flora and fauna. High pH indicates rapid growth of algae that actively photosynthesize, creating an imbalance in CO_2 concentration in water bodies (23). The observation is reinforced by the fact that the ponds receive sewage from the Vasant Kunj Sewage Treatment Plant (STP).

Average alkalinity was observed to be as high as 314.6 mg/l in June 2016, which marginally decreased to 312.3 mg/l in September 2016. Likewise, the level of hardness was recorded to be 246.2 mg/l in the month of June 2016 that marginally increased to 256.2 mg/l in September 2016. Alkalinity and hardness are important parameters to reflect upon the water quality. Total alkalinity indicates the quantity of base present in water such as bicarbonates, carbonates, whereas, hardness represents the overall concentration of divalent salts (calcium, magnesium etc.) (24). Hardness contributed by calcium and magnesium, bicarbonate and carbonate mineral species in water is called carbonate hardness; hardness in excess of this concentration is called non-carbonate hardness. Water containing Calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60-120 mg/l, moderately hard; 120-180 mg/l, hard; and more than 180 mg/l, very hard (25). Our data shows the hardness in pond water to be very high, indicating inflow of partially or untreated sewage. Also, water from Neela Hauz plays a crucial role in governing the water status of Sanjay Van. Another important factor is the Vasant Kunj STP. Sanjay Van receives treated sewage from Vasant Kunj STP that has a capacity of 5 Million Gallons per Day (MGD). Release of partially treated sewage has an adverse effect on the water quality. Shiddamallayya and Pratima (2008) (26) have analyzed the effect of domestic sewage on water quality and concluded that sewage has a significant effect on pH and hardness of water. Hard water is not only unsuitable for drinking but is also hazardous for human and animal health (27-29). Various international and national agencies such as APHA, World Health Organization (WHO), Bureau of Indian Standards (BIS), Central Pollution Control Board (CPCB), and Indian Council of Medical Research (ICMR) have documented limits for various physico-chemical parameters for drinking water (30).

Dissolved oxygen is also important to aquatic life because detrimental effect can occur when DO levels drop below 4-5 mg/L, depending upon the aquatic species. Oxygen levels that remain below 1-2 mg/L for few hours can result in fish kills.When the processes related to the consumption of DO exceed the processes contributing to the DO in the river, the DO levels can reach very low values. Low DO levels or anaerobic conditions can kill fish and imbalance the aquatic ecosystems (31). Equally important is the level of BOD of the water body that is defined as the amount of oxygen, divided by the volume of the system, taken up through the respiratory activity of microorganisms growing on the organic compounds present in the sample (e.g. water or sludge) when incubated at a specified temperature (usually 20^{o} C) for a fixed period (usually 5 days, BOD 5). It is a measure of organic pollution of water and is usually expressed in milligrams O_2 per litre (32). BOD is significant primarily for three reasons. First, it is an indicator of wastewater discharge.

Second, in wastewater treatment plants, the ratio between BOD and COD (chemical oxygen demand) indicates the biodegradable fraction of an effluent. Third, the ratio COD/BOD is an indicator of the size of a wastewater treatment plant required for a specific location (32). In the present study BOD levels were observed to be high in all the ponds, maximum being in pond No. 2, followed by pond no. 5 and then 1. It is important to note that the pond no 2 gets discharge from Neela Hauz lake, hence indicating Neela Hauz water to have elevated levels of microbial population. We observed water in all the five ponds of Sanjay van to not match up to CPCB-standards (15), and rather found it to be unsuitable for drinking and outdoor bathing and unfit for consumption even after its conventional treatment. In the post-monsoon period, the water quality was in class D and was suitable for harboring fish (Table-II). Since, the ponds receive water from Vasnt Kunj STP, water quality of the ponds can be directly correlated to the efficient functioning of the STP. In an analysis of 16 STPs of Delhi, Jamwal and Mittal (2010) (33), reported very high count of fecal coliform and fecal *Streptococcus* in Vasant Kunj STP. Delhi generates 2.98 × 106 cubic meter sewage per day (m^3/d) and has 17 STPs for proper waste disposal. The actual treatment capacity of STPs of Delhi watershed is 1.44×10^6 m^3/d, thus around 50% of the total wastewater generated gets treated and can be reused. Efficiency of STPs ranges from 66% to 82 % (34). Reuse of wastewater has recently been looked up as a potential option to cope up with the increasing water stress, particularly in urban areas. Reclaimed water may be used for several purposes such as toilet flushing, cleaning, industrial reuse, ground water recharge and environmental enhancement (35-38). Hence, because of its stable quantity, reclaimed water from domestic STPs may serve as a reliable alternative water resource. It has also been suggested that the Vasant Kunj STP can be reused for ground water recharge (33).

In addition to the effect of STP functioning, we tried to analyse the influence of rainfall on the water quality and observed interesting correlation between the levels of DO and BOD and the rainfall. Significant rise in DO with a concomitant fall in BOD was observed in all the five ponds in the month of September 2016, which we think could be attributed to the rainfall in the June-September period. According to the report on rainfall statistics of India, Delhi received 343.3mm of rainfall in the monsoon in 2016, of which 292.8mm was received in July and August, 2016 (39). Therefore, it may be inferred that the dilution, mediated by rainfall plays an important role in governing the oxygen status of water bodies.

CONCLUSIONS

The study is the first report of monitoring of water pollution status of Sanjay Van. We find the five interlinked compartments (ponds) of Sanjay Van lake to be highly polluted and that the levels of various physico-chemical indicators of pond water are influenced by factors such as water quality of Neela Hauz lake, efficiency of Vasant kunj STP and fluctuations in received rainfall. Comprehensive mitigation strategies are required to be designed to make effective use of the waste water from STP and the ponds of Sanjay Van.

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REFERENCES

1.http://moud.gov.in/pdf/584e4e1bd994657f1ef2427e6aUrban%20Development_04.pdf

2. Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N, Smith, V. H. (1998). Non-point pollution of surface waters with phosphorus and nitrogen. *Ecological Applications, 8*(3), 559-68.

3. Koduru, S. and Dutta, S. (2013). Urban ecosystems: Preservation and management of water bodies. *Creative Space, 1*(1), 19-37.

4. Simeonova, V., Stratisb, J. A., Samarac, C., Zachariadisb, G., Voutsac, D., Anthemidis, A., Sofonioub, M., Kouimtzisc. (2003). Assessment of the surface water quality in Northern Greece. *Water Research*, *37*, 4119-4124.

5. Bhateria, R. and Jain, D. (2016). Water quality assessment of lake water: a review. *Sustainable Water Resource Management*, *2,* 161-173. doi: 10.1007/s40899-015-0014-7.

6. Lone, M. I., Saleem, S., Saifullah, T., Hussain, G. (2003). Heavy metal contents of vegetables irrigated by sewage/tubewell water departments of soil science and agronomy, University of Arid Agriculture, Rawalpindi, Pakistan. *International Journal of Agriculture & Biology*, *5*(4), 533-535.

7. Novotny, V., Olem, H., (1994). *Water Quality: Prevention, Identification, and Management of Diffuse Pollution,* New York, NY: Van Nostrand Reinhold

8. Sa´nchez, E., Colmenarejo, M. F., Vicente, J., Rubio, A., Garcı´a, M. G., Travieso, L., Borja, R. (2007). Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. *Ecological Indicators*, *7*, 315-328.

9. http://www.moef.nic.in/sites/default/files/nlcp/NLCP_guideline.pdf

10. Voutsa, D., Samara, C., Kouimtzis, T. (1994). Groundwater quality in the major industrial area of Thessaloniki, Greece. Part 1: Chemical composition − geochemical processes. *Toxicology and Environmental Chemistry*, *45*,105-19.

11. Voutsa, D., Zachariadis, G., Samara, C., Kouimtzis, T. (1995). Evaluation of chemical parameters in Aliakmon River/ Northern Greece. Part II. Dissolved and particulate heavy metals. *Journal of Environmental Science and Health*, *30*(1), 1-13.

12. Hagedorn, C., Robinson, S.L., Filtz, J.R., Grubbs, S.M., Angier, T.A., Renaeau, J. (1999). Determining sources of fecal pollution in a rural Virginia watershed with antibiotic resistance patterns in fecal streptococci. *Applied Environmental Microbiology*, *65*, 5522-5531.

13. Aidan, A., Cronin, Prakash, A., Priya, S., Coates S. (2014) Water in India: situation and prospects. *Water Policy, 16*, 425-441.

14. National Institute of Hydrology (NIH) (2010).*Water Resources of India*. NIH, Roorkee, Uttarakhand.

15. http://www.cpcb.nic.in/Water_Quality_Criteria.php

16. Gangwar, S.(2013). Water Quality Monitoring in India: A Review. *Int. Journal of Information and Computation Technology*, *3*, 851-856.

17. Paul, D. (2017). Research on heavy metal pollution of river Ganga: A review. *Annals of Agrarian Science*, *15*, 278-286.

18. APHA (1998). Standard methods for the examination of water and waste water.part 2320 B-CO_2, D., (pp. 2-27) 20th edn. New York: American Public Health Association; 1998. APHA.

19. APHA (1998). Standard methods for the examination of water and waste water. part 2340, C, pp. 2-36). 20th edn. New York: American Public Health Association; 1998. APHA.

20. APHA, 1998; Standard methods for the examination of water and waste water. part 4500 – OC, (pp. 4-131). 20th edn. New York: American Public Health Association

21. Grizzetti, B., Lanzanova, D., Reynaud, A., Cardoso, A.C. (2016). Assessing water ecosystem services for water resource management. *Environmental Science & Policy, 61*, 194-203.

22. Aylward, B., Bandyopadhyay, J., Belausteguigotia, J., et al., (2005). Freshwater ecosystem services Ecosystems and Human Well-being. *Policy Responses*, *3*, 213-256.

23. Tucker, C.S., and Louis, R. (2008). *Managing high pH in freshwater ponds.* SRAC Publication No. 4604. www.ca.uky.edu/wkrec/high-ph-ponds.pd.

24. Wurts, W. A., Durborow, R. M. (1992). Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds. *Southern Regional Aquaculture Center.* Publication No. 464. www.ca.uky.edu/wkrec/interactionsphetc.pdf
25 McGowan, W. (2000). *Water Processing, Residential, Commercial, Light Industrial*. (Ed. Harrison, J. F.), 3rd edn, pp. 309 Water Quality Association, Lisle, Illinois, USA 60532-1088.

26. Shiddamallayya, N., Pratima, M. (2008). Impact of domestic sewage on fresh water body. *Journal of Environmental Biology*, *29*(3), 303-8.

27. Miyake, Y., Yokoyama, T., Yura, A., Iki, M. and Shimizu, T. (2004). Ecological association of water hardness with prevalence of childhood atopic dermatitis in a Japanese urban area. *Environmental Research*, *94*(1), 33-37.

28. Sengupta, P. (2013). Potential Health Impacts of Hard Water. *International Journal of Preventive Medicine, 4*(8), 866-875.

29. Tripathi, K., Ahmad, I., Jamal, Y. (2015). Comparative study of ‘BOD’, ‘DO’ and pH of distillery treated and untreated waste water. *International Journal of Scientific and Research Publications*, *5*(9), 1-7. ISSN 2250-3153 www.ijsrp.org.

30. Kumar, M., Puri, A., (2012). A review of permissible limits of drinking water. *Indian Journal of Occupational and Environmental Medicine*, *16*(1), 40-44. doi: 10.4103/0019-5278.99696.

31. Haider, H. (2010). *Water Quality Management Model for Ravi River*, Ph.D. Thesis, Institute of Environmental Engineering and Research, UET, Lahore.

32. Jouanneau, S., Recoules, L., Durand, M.J., Boukabache, A., Picot, V., Primault, Y., Lakel, A., Sengelin, M., Barillon, B., Thouand, G. (2014). Methods for assessing biochemical oxygen demand (BOD): A review. *Water Research*, *49*, 62 -82.

33. Jamwal, P., Mittal, A.K. (2010). Reuse of treated sewage in Delhi city: Microbial evaluation of STPs and reuse options. *Resources, Conservation and Recycling*, *54*, 211-221.

34. http://delhi.gov.in/wps/wcm/connect/Water+Bodies_SOUTH.pdf

35. El-Gohary, F.A., Nasr, F.A., El-Hawaary, S. (1998). Performance assessment of a wastewater treatment plant producing effluent for irrigation in Egypt. *The Environmentalist, 18*, 87-93.

36. Scott, T.M., McLaughlin, M.R., Harwood, V. J., Chivukula, V., Levine, A., Gennaccaro, A., et al. (2003). Reduction of pathogens, indicator bacteria, and alternative indicators by wastewater treatment and reclamation processes. *Water Science Technology: Water Supply, 3*, 247-52.

37. Jimenez, B., Chavez, A. (2002). Low cost technology for reliable use of Mexico City's wastewater for agricultural irrigation. *Environmental Technology*, *9*, 95-108.

38. Chiou, R.J., Chang, T.C., Ouyang, C.F. (2007). Aspects of municipal wastewater reclamation and reuse for future water resource shortages in Taiwan. *Water Science and Technology, 55*, 397-405.

39. Purohit, M. K., Kaur, S. (2017) Rainfall Statistics of India – 2016. Indian Meteorological Department, New Delhi.
http://hydro.imd.gov.in/hydrometweb/