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Impact of sewage treatment plant effluent on water quality of Dal Lake, Kashmir, India

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Abstract
Present paper attempts to study and discuss the impacts of sewage treatment plant effluent on water quality of a typical urban Dal Lake situated in Jammu & Kashmir. Using Correlation analysis and Principal component analysis changes in water quality were analysed. The result showed that Fluidised Aerobic Bed reactor (FAB) based STP was malfunctioning and resulted in increasing the concentration of electrical conductivity, othro-phosphate, nitrate-nitrogen and nitrate-nitrogen at influx of sewage into the lake. This has resulted in bifurcating the lake into two distinct zones, one being polluted and other being unpolluted. The main reason being the release of partially treated effluents directly into the lake.

Keywords: FAB STP, Sewage, Dal Lake, PCA, Water quality

Introduction

Dal Lake is known as "liquid heart" of Srinagar, the summer capital of Jammu and Kashmir. It is located between geographical co-ordinates of 34º07`N and 74º52`E at an altitude of about 1584m above mean sea level. It is a multi-basin freshwater post glacial lake comprising of five basins viz.; Hazratbal, Nishat, Nehrupark, Nigeen and Brarinambal. Each basin maintains its individual character and vary in their morphometry, water quality and biodiversity (Abubakr and Kundangar, 2005) [4]. The morphometric data of each basin of Dal Lake is presented in Table 1.

Dal lake has a huge catchment area, according to estimates of AHEC (2000) [10], lake catchment area is spread over to 337.17 sq. kms of which the largest segment is Telbal-Dachigam with 234.17 sq. kms (69%), followed by Hill side 14 sq. kms, Srinagar city (North and Central) 14.5 sq. kms and the lake 18.5 sq. kms. The catchment area under different land use is given in Table 2.

Telbal Nallah is the main inflow channel to the Dal Lake which drains mostly through Harwan, Burzukot and Mahadev range. Moreover, 10-12 small channels discharge their water into Dal Lake. Approximately 292×10^6 m^3 of total inflow to the lake, 80% is supplied by the Telbal Nallah. Two perennial outflow channels, one known as Dalgate exit and other Nallah Amir Khan drain the water out of the lake (Kundangar and Abubakr, 2001) [18].

Dal lake ecosystem is under tremendous anthropogenic pressure since more than four decades now, with people still living within the lake in hamlets, houseboats and doonga boats. As per recent estimate of 2020, about 4792 families are living in 60 hamlets in Dal interiors. The myriad ways in which people use the lake, along with numerous pollutant generating activities have stressed the lake ecosystem in diverse ways. These stresses have caused significant impairment to lake quality.

Based on the importance of Dal Lake, a number of restoration plans by National and International agencies were implemented from time to time. Lately and finally, Ministry of Environment and Forests (MoEF) (now Ministry of Environment, Forest and Climate Change i.e., MoEFCC), Government of India, decided to invite Alternate Hydro Energy Centre (AHEC), University of Roorkee (now IIT, Roorkee), to prepare a Detailed Project Report (DPR) on Dal lake, Srinagar. The final project report, submitted to the Govt. in December 2000, was finally accepted in 2005 and Govt. started implementation of various recommendations. Among the number of recommendation, one recommendation was treatment of sewage entering into Dal Lake using Fluidised Aerobic Bed reactor (FAB) technology.

Kundangar (2003) [17], while monitoring the FAB based STP at one of the hotels in the immediate vicinity of Dal Lake, had cautioned about the adoption of this technology for Dal Lake sewage treatment. However, ignoring scientific acumen, Govt. installed three FAB based STP at Hazratbal, Habak and Laam area around Dal Lake for treatment of sewage entering into the lake. Adnan and Kundangar (2008) [5] and Adnan and Kundangar (2009) [6], while studying Dal lake ecology and its environment have reported through their research on the functioning of FAB based STP's, that these treatment plants are malfunctioning and according to authors, this situation will not only exacerbate the problem of pollution of Dal Lake but shall have catastrophic consequence, as the non- point sources of pollution are being made the point sources of pollution. A report on Dal Lake published by the Comptroller and Auditor General of India (2012) [2], also contained observation that the working of STP installed at Hazratbal, Habak and Laam are highly inefficient.

Table 1: Morphometric characteristics of Dal Lake of each basin

Parameters	Units	Hazratbal	Nishat	Nehru park	Nigeen
Max. water depth	m	3.0	2.8	2.5	5.7
Mean water depth	m	0.76	0.86	0.70	1.37
Open water area	Sq. m	4.50	5.70	1.3	0.89
Volume of water $\times 10^6$	m^3	2.76	4.92	0.93	1.22

Source: Abubakr & Kundangar, 2009) [6]

Table 2: Different land use in Dal Lake

S. No.	Land use class	Area (sq. km)	Percentage (%)
1.	Bare grounds	160.97	47.74
2.	Dense forests	52.02	15.42
3.	Built- up/ unclassified	45.44	13.47
4.	Open forest	34.15	10.12
5.	Lakes/ shadows	33.35	9.93
6.	Snow	9.25	2.74
7.	Degraded forest	1.85	0.54
8.	Total	337.17	

Source: Zutshi and Yousuf, 2014 [27]

Material and Methods

Study Area

Dal Lake, a typical example of an urban multi-utility lake, receives large quantities of untreated sewage from the point and non point sources. In order to arrest the point source of pollution, three STP's were installed at Hazratbal, Habak, and Laam areas with sewage treatment capacity of 7.5 MLD, 3.5 MLD and 4.5 MLD respectively. These 3 STP's are treating the wastewater on FAB technology and after treatment the waste water is being discharged directly into Dal Lake (Fig1.)

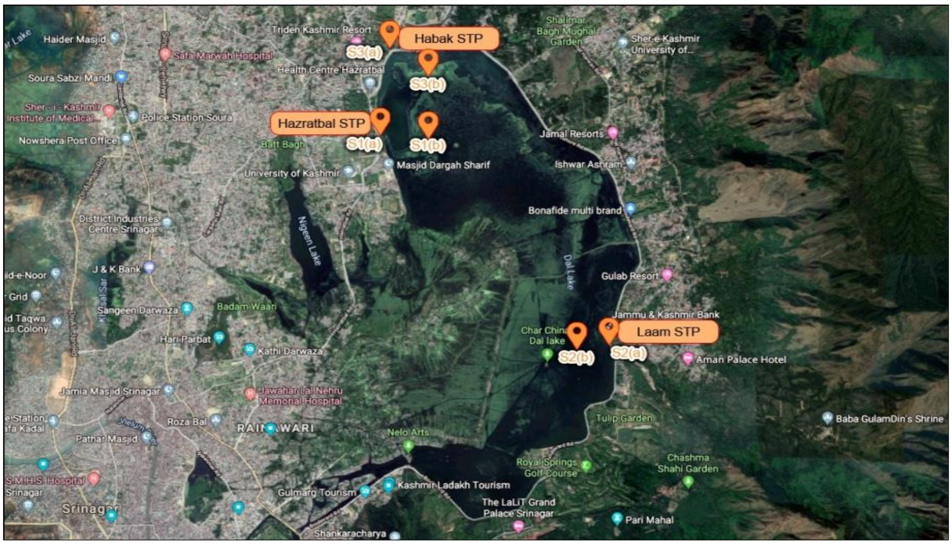

Fig. 1: Map showing location of STP and sampling sites within Dal Lake

In order to investigate the impact of treated sewage on water quality of Dal Lake, three sampling points were selected within the lake where STP's discharge treated sewage, viz., site 1(a) at Hazratbal, site 2 (a) at Laam and site 3 (a) at Habak. For each sampling point, a complementary site [site 1 (b); site 2(b) and site 3(b)], 500m away was selected which hardly affected by the influx of sewage discharged by STP's. Sites S1(a), S2(a) and S3(a) were hypothesized as polluted sites, while sites S1(b), S2(b) and S3(b) were hypothesized as unpolluted sites for the present work.

The water quality was monitored at all the six designated sites monthly from October 2018 to March 2019 covering autumn and winter seasons. The water samples were collected at a depth of 0.1m -0.3m below the water surface by hand in the polyethylene bottles. Air temperature (AT), Water temperature (WT), dissolved oxygen (D.O), depth, water transparency (SDT) were measured on site, whereas, electrical conductivity (EC), pH, orthophosphate (PO_4-P), total phosphorus (T.P), chloride (Cl^-), ammonia (NH_4-N), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N) and silicate (Si) were determined in laboratory, using standard methods as described in A.P.H.A (2012) [12] and Adoni *et al.* (1985) [9].

A series of statistical method, including Correlation analysis (CA) and Principal Component Analysis (PCA) was employed to study and discuss the impact of STP effluents on water quality of Dal Lake. Statistical Analysis was performed for data generated using software programmes of SPSS (version 20.0) and PAST software. PCA was applied to determine the difference between sites as polluted and unpolluted and to explain the water quality variations with transformed data. For PCA, the transformed data for polluted sites were clubbed as a zone called polluted zone and the same was done for the unpolluted sites called unpolluted zone. Eigenvalue >1 was used as the criterion to determine the appropriate number of Principal Components (Ouyang *et. al.*, 2006) [22].

Results & Discussion

Analysis of water quality

The values of the assessed water quality parameters of Dal Lake are shown in Table 3. PCA analysis was used to determine and identify the important water quality parameters responsible for influencing water quality of Dal Lake. In the present study all the samples of polluted sites were clustered together irrespective of seasons and same was done for unpolluted sites. A scree plot for the eigenvalues obtained in this study showed a marked change of slope after the fifth eigenvalue, for both polluted and unpolluted sites (fig. 2 and 3).

Eigenvalues for polluted zone are displayed in Table (4). The five PCs together accounted for about 80.19% of the total variances and the rest of the 9 components only accounted for about 19.80%.The largest source of variation 29.45% in PC1 showed a strong positive loading of PO_4-P and EC, moderate positive loading of NO_3-N, NO_2-N, T.P, Si and positive weak loading by WT, Cl^- and NH_4-N and negative moderate loading of D.O. and pH. Positive loading of PO_4-P, EC, NO_3-N, NO_2-N, T.P and Si clearly indicate that all these three sites, where STP discharge treated effluents directly show higher concentration of nutrients. The concentration of nutrients, especially nitrogen increased significantly at sites with influx of STP effluents, indicating that STP effluent was the main source of NO_3-N and NO_2-N in Dal lake, and is responsible for changing its water chemistry rendering these sites as polluted / highly eutrophic. Similar results were reported by Vega *et al.* (1998) [25] and Al-Barzingy *et al.* (2010) [11] and they reported high levels of phosphate and organic matter may originate from municipal wastewaters discharges since it is an important component of detergents.

The second component of polluted zone PC2 with 22.11% variance explained a moderate positive loading of D.O, depth, SDT and Cl^- and positive weak loading of PO_4-P and Si and moderate negative loading is explained by WT and weak negative loading by NH_4-N. Jin *et al*. (2017) [16] also observed significant difference in D.O. after the influx of STP effluent indicating strong impact of STP effluent on receiving ecosystem. Abubakr *et al.* (2018) [8] have related low D.O state with high organic matter and sewage which consumes oxygen for decomposition in different lakes in Kashmir. The positive D.O. and negative water temperature loading is attributed to the capacity of water to hold more D.O at lower temperatures (Hutchinson, 1975) [15].

Table 3: Water quality parameters of Dal Lake

Parameters	unit	Hazratbal basin		Laam basin		Habak basin	
		STP 1(a) min. – max. mean± S.E	**O.W 1(b) min.– max. mean± S.E**	**STP 2(a) min.– max. mean± S.E**	**O.W 2(b) min.– max mean± S.E**	**STP 3(a) min. – max. mean± S.E**	**O.W 3(b) min. – max. mean± S.E**
A.T	°C	5.8(jan) – 10.5 (mar) 7.8 ± 0.6	5.5(jan)-10 (mar) 7.4 ± 0.6	5.8(jan)-11.7(mar) 8.3 ± 0.8	5.6(jan)-11(mar) 8.1 ± 0.8	6 (jan) – 11(mar) 8.0 ± 0.7	5.9 (jan)–10.6 (mar) 7.8 ± 0.7
W.T	°C	6.5(jan)- 11.2(mar) 8.5 ± 0.6	5.2(jan)-9.1(mar) 7.0±0.5	6.1(jan)-12.1(mar) 9.0±0.9	5(jan)-10(mar) 7.7±0.6	7.8(jan)-12.8(mar) 9.7±0.7	5.7(jan)-10.1(mar) 7.5±0.7
pH	-	7.1(oct,mar)-7.9(dec) 7.4±0.1	7.3(oct)-8.1(dec) 7.7±0.1	7.4(jan)-8(dec) 7.7±0.1	7.4(jan)-8(mar) 7.6±0.1	7.3(jan)-7.8(feb) 7.5±0.08	7.3(jan)-8(mar) 7.6±0.1
EC	Scm^{-1}	508(feb)-642(nov) 566.1±20.6	326(jan)-402(oct) 364.6±11.4	404(dec)-486(nov) 454.8±13.9	255(mar)-344(nov) 306.8±18.9	440(jan)-814(mar) 576.5±58.0	322(jan)-396(nov) 362±13.5
Depth	m	0.9(mar)-1.2(dec) 1.08±0.04	3.9(mar)-4.2(jan) 4.0 ±0.04	0.5(feb,mar) -0.6(oct,jan) 0.56±0.02	1.3(oct,dec,jan)-1.5(nov,mar) 1.7 ±0.36	0.5(dec,jan)-0.70(nov) 0.57±0.03	1.4(dec-mar)-1.5(oct,nov) 1.4 ±0.02
SDT	m	0.3(nov)-0.5(oct,jan,mar) 0.43 ±0.03	0.9(dec,jan)-1.2(feb) 1±0.04	0.3(oct-feb)-0.4(jan,mar) 0.33±0.02	0.8(oct-feb)-0.9(jan,mar) 0.85 ±0.02	0.2(nov)-0.5(feb) 0.37±0.04	0.75(jan)-0.8(oct-dec,feb,mar) 0.79±0.008
D.O	mg/l	3.2(nov)-6.7(jan) 4.6 ±0.5	10(nov)-11.6(mar) 11.0 ±0.3	3.2(mar)-5.3(jan) 4.05±0.32	8.1(mar)-12.2(jan) 9.65±0.7	2.9(mar)-4.1(jan) 3.5±0.1	8(mar)-9.6(jan) 8.61 ±0.24
Cl^-	mg/l	20(nov)-41(mar) 28.3±3.4	11(oct,nov)-19(dec) 14.5±1.2	18(feb,mar)-29(dec) 20.3±1.7	10(nov)-17(dec) 13.2±0.9	28(jan)-37(dec) 31.3±1.72	12(jan)-26(mar) 17±2.46
NO_2-N	µg/l	40(feb)-53(oct) 45.3±2.2	15(nov)-28(mar) 23±1.8	32(dec)-50(jan) 39.8 ±2.3	13(dec)-31(jan) 23.28±2.2	44(feb)-53(mar) 47.1±1.37	15(dec)-28(feb) 19.8±2.04
NO_3-N	µg/l	435(jan)-686(oct) 569±46.7	305(nov)-377(mar) 345±11	424(jan)-492(dec) 454.6±11.8	161(jan)-388(mar) 287.5±30.1	485(nov)-831(dec) 599.3±50.4	290(nov)-493(mar) 409.6±28.6
NH_4-N	µg/l	719(jan)-1189(oct) 923 ±79.9	101(jan)-150(nov) 117.3±6.9	862(oct)-1216(nov) 983.8±57.4	105(oct)-191(mar) 143.1±11.7	817(mar)-1185(oct) 956.1±76.1	98(dec)-139(mar) 114.1±5.9
PO_4-P	µg/l	433(feb)-785(nov) 582.1±48.6	216(oct)-396(mar) 287.3± 26	348(oct,feb)-385(nov) 360.6 ±5.7	101(jan)-182(feb) 188.2± 36	446(jan)-684(oct) 526.5±35.30	123(dec)-190(mar) 145±10.6
T.P	µg/l	1028(oct)-1253(jan) 1111.6 ± 39.7	627(jan)-672(oct) 639 ± 15	857(dec)-1717(nov) 1114.3±130	420(jan)-598(nov) 545.5±34.1	1031(dec)-1663(oct) 1322.1±96.5	502(feb)-611(mar) 552±18.0
Si	mg/l	3.0(feb)-5.0(dec) 3.8± 0.27	1.2(dec)-1.8(nov,mar) 1.56± 0.09	2.3(feb)-2.8(mar) 3.0± 0.2	1.5(oct,dec,mar)-1.9(feb) 1.6±0.06	3.3(feb,mar)-4.8(jan) 3.88±0.27	1.3(jan)-2.4(oct) 1.95± 0.16

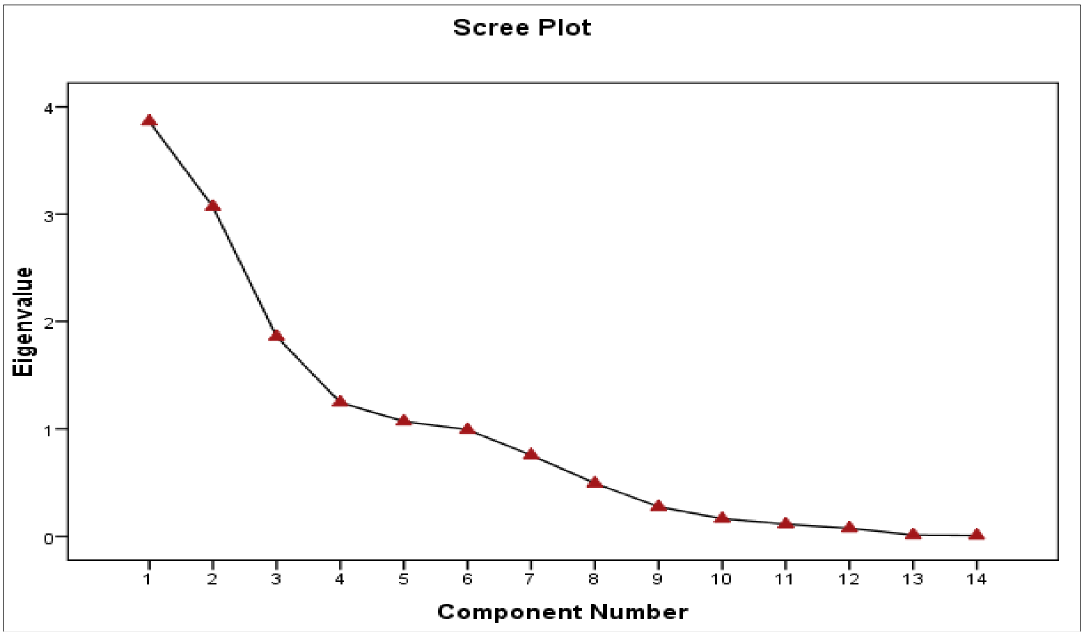

Fig. 2: Scree plot of the eigenvalue of principal component of the polluted zone variables

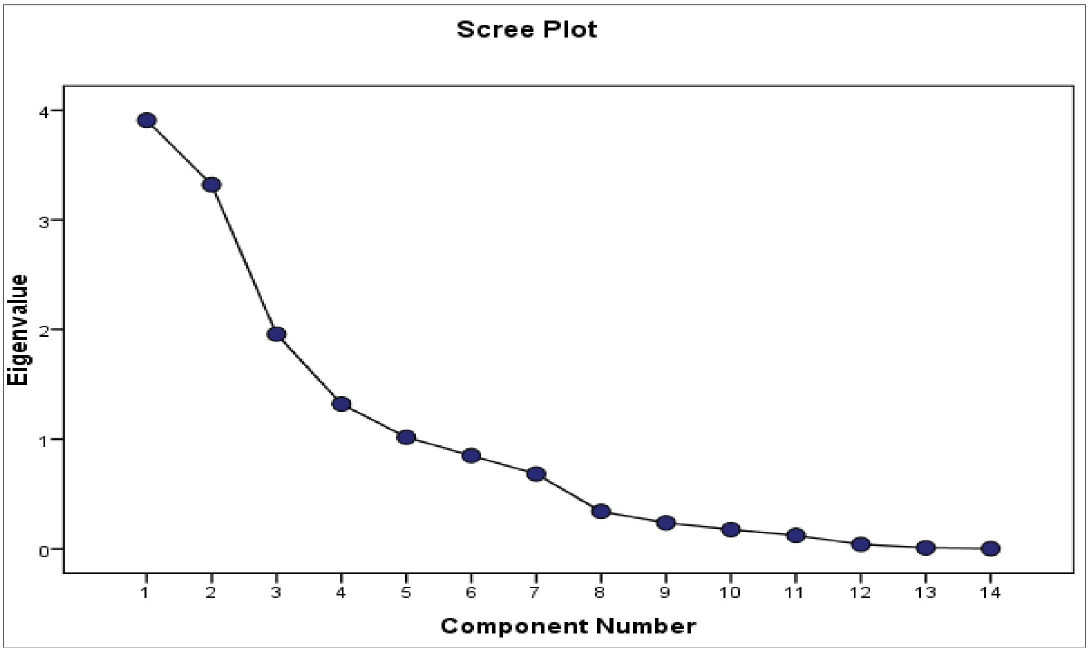

Fig. 3: Scree plot of the eigenvalue of principal component of the unpolluted zone variables

The third component, PC3 of polluted zone accounted for 12.36% of total variance explained strong negative loading of NH_4-N and moderate negative loading of Si. PC3 showed an additional input of organic related parameter (NH_4) which may be due direct discharge of partially treated effluent from STPs. Vega *et al.* (1998) [25] explained the origin of high levels of ammonia-nitrogen from decomposition of nitrogen-containing organic compounds such as proteins and urea occurring in the municipal wastewater discharges. Further, the increase in NH_4 can also be related to the process of de-nitrification with the reduction of D.O content (Kiely, 1997) [17].

The fourth component, PC4 with 8.73% of total variance explained moderate positive loading of Cl^- and pH with weak positive loading of Si and weak negative loading of NO_2-N and depth. This can be ascribed to direct discharge of effluent from the STPs which contain high concentration of chloride in it. Dwivedi & Odi, 2003 [13] while working on Dickrong river and Sanap *et al.* (2006) [23] also suggested that the increased chloride values were due to sewage and domestic waste contamination in Godavari river. Mathew & Vasudavan (2000) [21] related the elevated chloride to the flow of sewage in river Pamba while Abubakr & Kundangar (2008) [26] worked on number of Kashmir Lakes and reported higher values of chloride and attribute it to the presence of organic matter originated from sewage.

Therefore, at polluted zone, water quality parameters were dominated by the presence of higher concentration of EC, PO_4-P, NO_3-N, NO_2-N while D.O recorded low values. The first changes resulting from discharge of effluents/pollution are decrease in the concentration of D.O. or increase in the oxygen consumption, with rise in the concentration of electrolytes including chlorides. In addition to it, decrease in transparency with increase in pH, phosphorus and nitrogen were observed during the study. All these changes are because of influence of partially treated effluents from STP. These results are graphically represented in Figure 4.

Table 4: Eigen value and percentage of variance explained by each of the five principal components (PC's) for polluted zone for studied variables

Principal Component	PC_1	PC_2	PC_3	PC_4	PC_5
Eigenvalue	4.123	3.097	1.731	1.223	1.054
% total variance explained	29.451	22.119	12.361	8.733	7.531
% cumulative variance	29.451	51.57	63.931	72.664	80.194

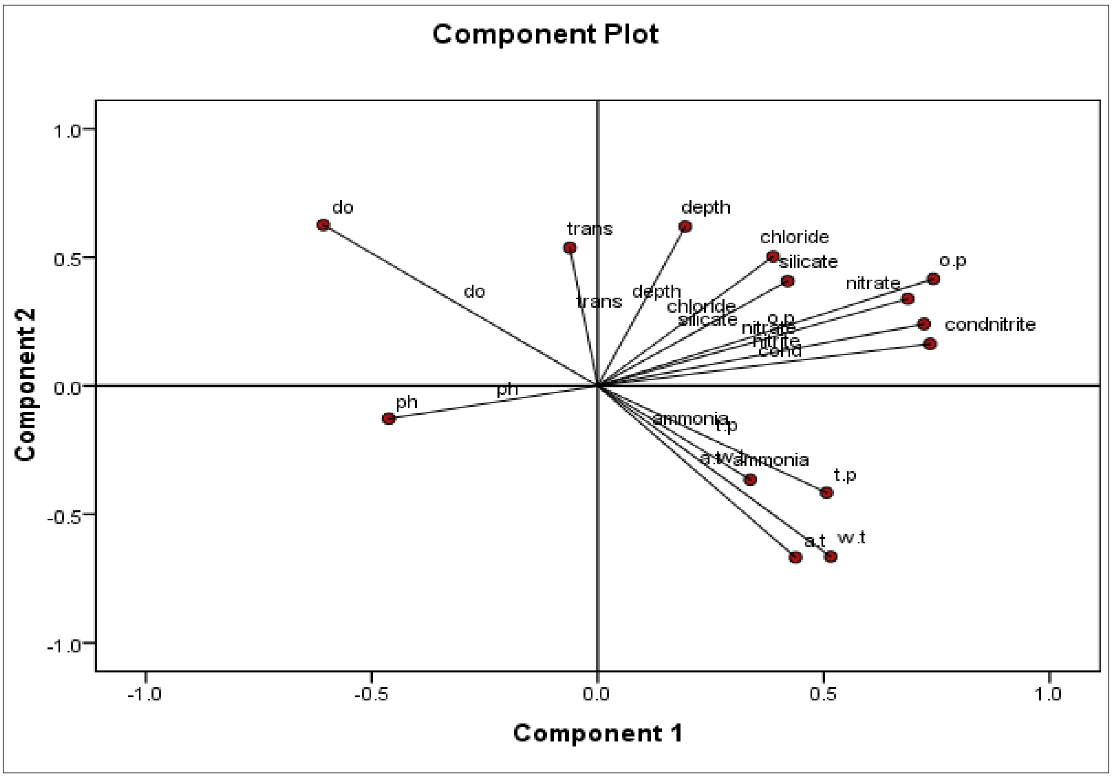

Fig. 4: Principal component analysis (PCA) scatter plot for polluted zone water samples on the basis of studied water variable characteristics

Eigenvalues for unpolluted zone are displayed in Table (5), the first component, PC1, with 27.42% variation showed positive strong loading of depth, PO_4-P, water transparency, T.P, and moderate positive loading for D.O and E.C. These characteristics of water quality are attributed to cleaner water a condition which is characterized by increased depth, high transparency and high D.O. content. Although phosphorus concentration was found to be high at all the three unpolluted sites but the concentration was much lower than polluted zone. The higher values of phosphorous shows sign of nutrient enrichment of waters on account of eutrophication as suggested by various authors (Sawyer, 1947 [24], Welch and Lindell, 1980 [26]).

The second component, PC2, accounted for 23.57% of total variance and explained strong positive loading for NO_3-N and WT. This may be attributed to the organic matter decomposition along with the reduction in D.O. The higher nitrate loading showed the signs of enrichment of waters of Dal. Goreski *et al.* (2019) [14] reported that nitrate values are higher in autumn and winter due to limited biological activities. Moderate positive loading is explained for pH and E.C and weak positive loading for Si.

Release of treated STP effluent directly into Dal Lake resulted in bringing a marked change in the water chemistry of Dal Lake near the outfall. No such change was observed in the water quality at other locations/ stations. These results are statistically confirmed and shown through graphical representation in Fig. 5.

Dal Lake has been bifurcated into two distinct zones, based on the water quality parameters, one polluted and other unpolluted. The main reason behind this is the release of partially treated effluent from STP's. At polluted zone, water quality parameters were dominated by the presence of higher concentration of EC, PO_4-P, NO_3-N, NO_2-N while low concentration of D.O. Thus, confirming the reduced water quality at this zone. At unpolluted zone, dominant parameters were depth, transparency and D.O. These results were statistically substantiated by the use of bi-variate plot of PC1 and PC2 extracted from PCA, which clearly showed 2 distinct plots as depicted in Figure 6.

Table 5: Eigen value and percentage of variance explained by each of the five principal components (PC's) for unpolluted zone for studied variables

Principal Component	PC_1	PC_2	PC_3	PC_4	PC_5
Eigenvalue	3.84	3.3	1.999	1.334	1.053
% total variance explained	27.429	23.573	14.281	9.529	7.518
% cumulative variance	27.429	51.002	65.283	74.812	82.331

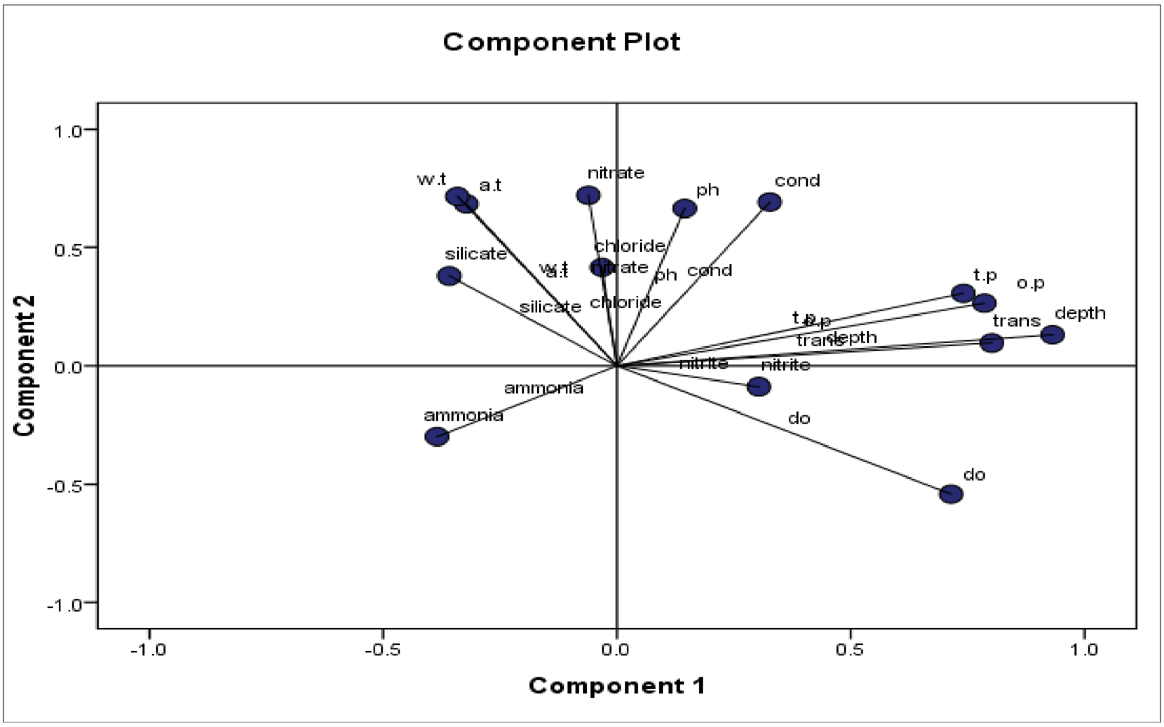

Fig. 5: Principal component analysis (PCA) scatter plot for unpolluted zone water samples on the basis of studied water variable characteristics

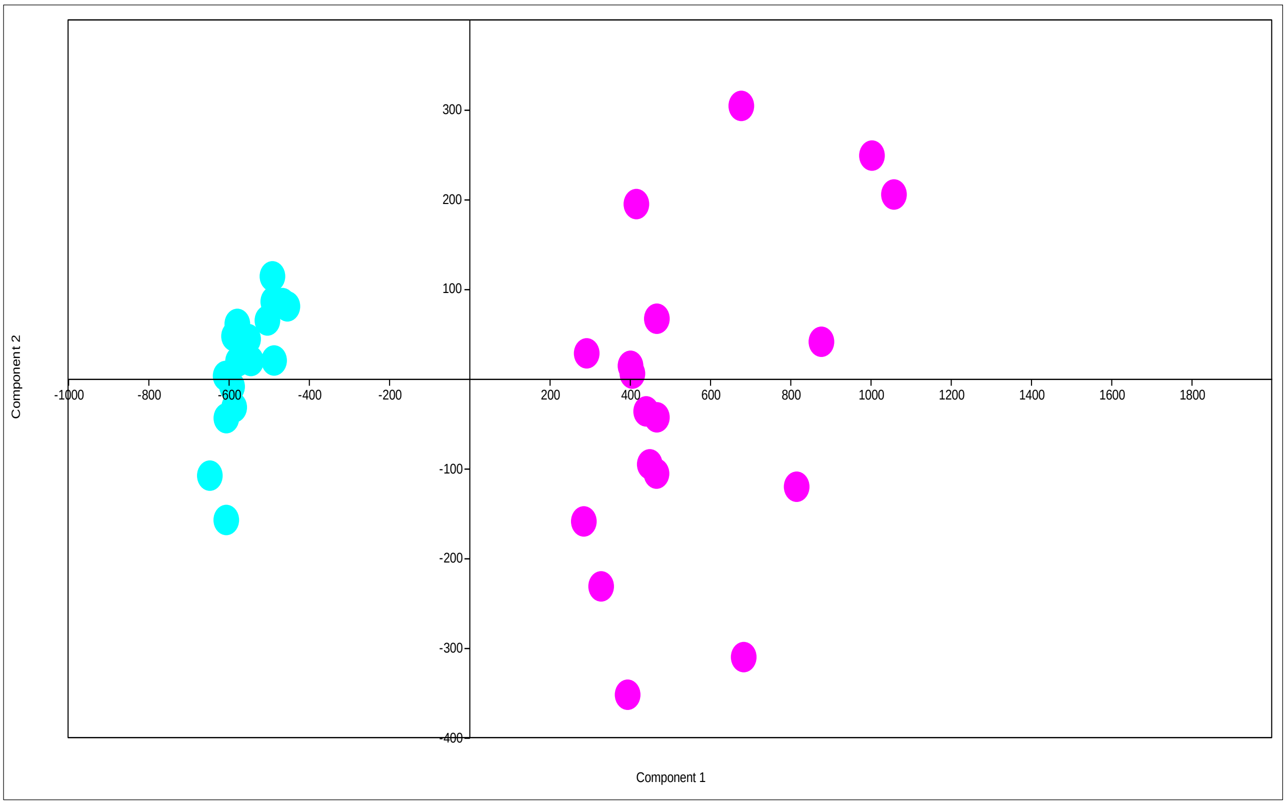

Fig. 6: Bi-variate plot differentiating sites into polluted and unpolluted zones

Conclusion

From the present study, it is clear that functioning of FAB based Sewage treatment plants installed to treat and improve wastewaters around Dal Lake is improper. STPs are not only malfunctioning but are exacerbating the problem of Dal lake pollution by bringing a catastrophic consequence as non-point sources of pollution are being made the point source of pollution. This has also manifested by an increase in the oxygen consumption in the hypolimnion, rise in the BOD, COD and the concentration of chlorides, sulphides, phosphorus and nitrogen. The same has also reported by Abubakr & Kundangar (2009) [7].

Thus, there is an urgent need to upgrade these FAB based STPs so that they are able to reduce N & P concentrations more efficiently. The long term solution in our opinion to this problem under Kashmir conditions (where there is already energy crisis and severe winter) is the adoption of proven Root Zone technology/ artificial wetland technology for waste water treatment. The same has been emphasized by Abubakr and Kundangar (2004) [4] and Abubakr and Kundangar (2009) [7].

References

1. Abubakr A. Sanative variations in physico-chemical characteristics of Rudrasagar wetland – a Ramsar Site, Tripura, North East, India. Research Journal of Chemical Sciences 2010; 4(1):31-40.
2. Anonymous. A report on Dal Lake: Comptroller and Auditor General of India, 2012.
3. Abubakr A, Kundangar MRD. Bacteriological studies and trophic status of Himalayan lake- Dal. Journal of research and development. 2004; 4:45-57.
4. Abubakr A, Kundangar MRD. Bacterial dynamics of Dal Lake, a Himalayan temperate freshwater lake. Nature Environment and Pollution Technology. 2005; 4:291-298.
5. Abubakr A, Kundangar MRD. Ecological status of some Floodplain Lakes within Jhelum river basin, Kashmir. Nature Environment and Pollution Technology. 2008; 7(4):791-728.
6. Abubakr A, Kundangar MRD. Three decades of Dal Lake pollution-Restoration. Eco. Env. & Cons., 2009; 15(4):825-833.
7. Abubakr A, Gojar AA, Balkhi MH, Malik R. Macro-invertebrates (Annelida; Oligochaeta) as bio-indicator of water quality under temperate climatic conditions. International Journal of Pure and applied Bioscience. 2018; 6(1):726-737.
8. Adoni AD, Joshi G, Ghosh K, Chourasia SK, Vaishya AK, Yadav M *et al*. Workbook on Limnology, Sagar Publishers, Sagar Madhya Pradesh, 1985.
9. AHEC. Conservation and Management of Dal-Nigeen Lake; Detailed Project Report submitted to Ministry of Environment and Forests, GOI and Government of J&K, 2000, 1-5.
10. Al-Barzingy YOM, Haydar NH, Shekha YA. The effect of wastewater disposal on the water quality and phytoplankton in Erbil wastewater channel. Baghdad Science Journal. 2010; 7(2):984-993.
11. American Public Health Association (APHA). Standard methods for examination of water and wastewater. 22st Edn. Washington DC, USA, 2012.
12. Dwivedi P, Odi P. Evaluatation of potable water quality in streams and the Dickrongriver in the district Papum Pore, Arunachal Pradesh. Indian Journal of Ecology, Environment and Conservation. 2003; 9(4):437-440.
13. Gorski J, Dragon K, Kaczmarek PMJ. Nitrate pollution in the Warta River (Poland) between 1958 and 2016: trends and causes. Environmental Science and Pollution Research. 2019; 26(3):2038-2046.
14. Hutchinson GE. A treatise on limnology chemistry of lakes.John Wiley & Sons Inc., New York. 1975, I-II.
15. Jin Z, Zhang X, Li J, Yang F, Kong D, Wei R, Huang K, Zhou B. Impact of wastewater treatment plant effluent on an urban river. Journal of Freshwater Ecology. 2017; 32(1):697-710.
16. Kiely G. Environmental engineering. Irwin McGraw-Hill. UK, 1997, 979p.
17. Kundangar MRD. Towards restoration of Dal Lake Kashmir, Abstract submitted to international conference on Eco-restoration, Dehradun and New Delhi, 14-21, October 2003, organized by National institute of ecology and ICFRE, Dehradun, 2003.
18. Kundangar MRD, Abubakr A. Post dredging changes and comparative limnology of Dal Lake. Poll. Res. 2001; 20(4):539-547.
19. Kundangar MRD, Abubakr A. Thirty years of ecological research on Dal Lake Kashmir. J Res. Dev. 2004; 4:45-57.
20. Mathew K, Vasudavan NT. Water quality of river Pamba at Kozhencherry. Poll. Res. 2000; 19(4):665-668.
21. Ouyang Y, Nkedi-Kizza P, Wu QT, Shinde D, Huang CH. Assessment of seasonal variations in surface water quality. Water Res. 2006; 40:3800-3810.
22. Sanap RR, Mohite AK, Pingle SD, Gunale VR. Evaluation of water qualities of Godavari river with reference to physico-chemical parameters, district Nasik (M.S.), India. Pollution Research. 2006; 25(4):775-778.
23. Sawyer CN. Fertilization of lakes by agricultural and urban drainage. Journal of New Water Lakes Association. 1947; 51:109-127.
24. Vega M, Pardo R, Barrado E, Deban L. Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. Water Research. 1998; 32:3581-3592.
25. Welch EB, Lindell T. Ecological effects of waste water. Cambridge University Press. Cambridge, U.K, 1980
26. Zutshi DP, Yousuf AR. Morphometry and Physical Characteristics In: Lakes and Wetlands of Kashmir Himalaya: Ecology, Conservation and Management, Heritage Publishers, 2014, 34-65.