Environmentalist (2008) 28:217–221
DOI 10.1007/s10669-007-9130-8

Interaction of ions in water affects water quality of freshwater lake: a case study of major lakes of North India

Sarfraz A. Khan · Jatin Srivastava

Published online: 6 September 2007

Abstract The influence of ionic composition on the water chemistry and thereby on aquatic flora was investigated. Two major wetlands of North India were taken for the study. Quality parameters of the lakes showed the enrichment of the water especially in the month of September with higher values of P and BOD in almost all of the lakes viz., LSJ, LCH, LSN, and LHT as <5.0, 9.0, 1.0, 1.7 and <7.3, 6.0, 6.3, and 4.0, respectively. Statistically correlated values of the ions in the water quality showed an effect of one on another. An attempt has also been made to investigate if ionic constituent is one of the major causes affecting the aquatic floral diversity.

Keywords Ionic composition · Lakes · Wetlands · North India

1 Introduction

Wetlands are transition areas between land and water, characterized by shallow water overlying waterlogged soil as well as interspersed submerged or emergent vegetation. The main chemical composition of the freshwater lakes includes dissolved ions, such as cations like Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), and anions, such as bicarbonates (HCO_3^-), Sulfate (SO_4^{2-}), Chloride (Cl^-), Nitrate (NO_3^-) (Tchobanoglous and Schroeder 1985). The chemistry of surface waters is largely controlled by processes like rock weathering e.g., Ca/HCO_3, atmospheric precipitation e.g., Na/Cl and by evaporation/crystallization (Wu and Gibson 1996). The ionic species and their properties in water depend on the redox potential of water and topographical conditions (Yang and Williams 2003). Interactions of these ionic species affect the chemistry of water in a natural freshwater system (Srivastava et al. 2006). McGrath et al. (2001) has reported the phosphate uptake at lower pH from the water by the aquatic plants. Eutrophication increases the organic loading in the water and causes increased biological oxygen demand (BOD), which affects carbon and nitrogen transformation processes along with the production of CH_4 and N_2O (Liikanen and Martikainen 2003). Aquatic ecosystems are increasingly subjected to anthropogenic pollution. One of the most severe problems caused by eutrophication is the loss of submerged aquatic macrophytes (Nimptsch and Pflugmacher 2007). NH_3 in an unionized form is more toxic to the duckweeds as compared to the ionized NH_4^+ (Körner et al. 2003).

The Gangetic plane is a large area catchment fed by big rivers, such as the Ganges and the Yamuna and their tributaries to the Northern Indian state of Uttar Pradesh, Etawah, and Mainpuri are two closely located major districts of Uttar Pradesh (Plate 1), which is famous for its bird sanctuaries which lie entirely in the Gangetic plain. The water in the lakes nurtures many exotic as well as native birds, aquatic flora and fauna. The source of water to these lakes is the River Pandu a tributary of Ganges. The lakes under investigation are tropical shallow freshwater lakes (Latitude: 26 46′ 00″; Longitude: 79 02′ 00″) (mean depth < 3 m) and spread over 7 square km. In the recent past it was observed (Behl and Singh 2003) that the water

S. A. Khan
Department of Environmental Chemistry, Sagar Institute of Technology and Management, Barabanki, UP, India

J. Srivastava (✉)
Department of Environmental Sciences, Institute of Biosciences and Biotechnology, Chhatrapati Shahu Ji Maharaj University – Kanpur, Kalyanpur, Kanpur, UP 208024, India
e-mail: jks_345@rediffmail.com

and the land in the catchment are under severe threat of over exploitation. The catchments are being used by the local people for Paddy cultivation. The fertilizers and pesticides used for crop protection enter into the water of the lakes through the run-off. Enrichment of the lake water has been witnessed to be caused by the defecation, which is also one of the major sources of pathogens and organic loading. Aquatic vegetation, especially floating macrophytes has declined and even disappeared as a result of degraded water quality (Zhang and Forde 1998).

Current investigations are centralized on the ionic composition of the lake water especially those ions, which contribute to the enrichment of water, such as reactive phosphates (PO_4^{3-}–P), total kjheldhal nitrogen (TKN), chloride (Cl). The BOD has also been followed as an indicator of organic loading. Statistical analysis of the data of ionic constituent has also been made in the study to investigate the impact of one on another ion and the overall impact on the aquatic flora.

2 Materials and methods

2.1 Study area

The lakes coded as LSJ, LSN, LCH, and LHT are closely located at the boundaries of two North Indian districts Etawah and Mainpuri fed by the River Pandu a tributary of Ganga. The mean depth of the lakes is <3 m. The lakes cover around 7 square km of area.

2.2 Water sampling & analysis

Water quality of the lakes was analyzed only in one quarter of the year and the sampling was done in the months of July, August, and September. Samples of lake water were collected from the surface from various locations in lakes. Amber colored pre sterilized glass bottles were used to take the sample with the help of an adjustable shaft of 300 cm length provided with the clamp at the other end of the shaft to hold the sample bottle. The water quality parameters such as turbidity, TKN, chloride (Cl^{1-}), and BOD were analyzed as per (Standard Methods 1992). Phosphates (PO_4^{3-}) ion concentration was measured by the blue phosphomolybdate method (EPA 1979). pH and electrical conductivity were measured by a digital potentiometer model Cyber Scan 2000 provided by Thermo Orion Inc. USA, with the help of specific glass electrodes.

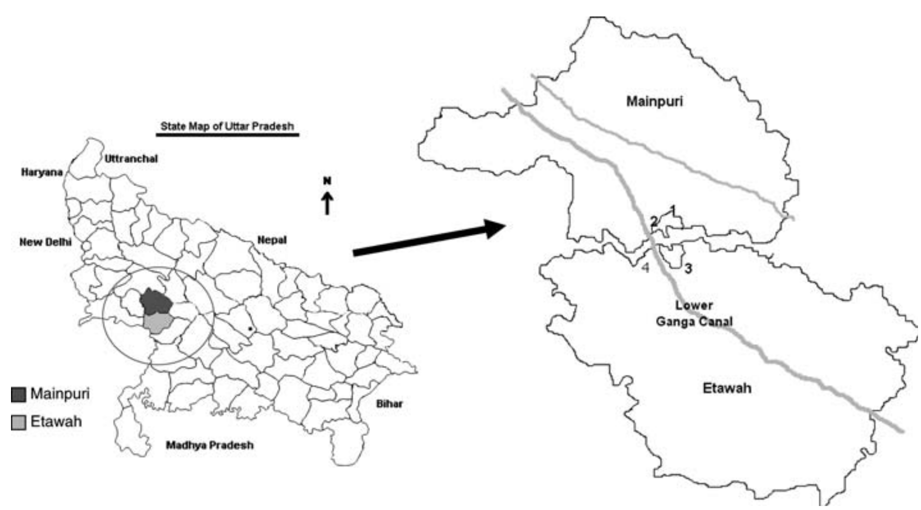
2.3 Defining the statistical procedure

The standard deviation is measure of dispersion, however; the coefficient of variance among the sets of mean values of water quality parameters in different months of different lakes was calculated to measure the consistency of the lake water. The correlation between variables would be expressible by the coefficient of correlation, which is a single number that tells the extent by which two variables are related and to what extent variations are associated with each other. Karl Pearson's coefficient of correlation is the closeness of relationship between two variables and also describes the dependency of one on another.

2.4 Data analysis

The data of water quality was analyzed statistically with the help of Computer aided software SPSS 13.0 version (SPSS 1997).

Plate 1 The lakes of Mainpuri & Etawah Districts



3 Results

The results are based on the quarterly analysis of lake water collected in the same season from the lakes of Etawah and Mainpuri district of northern Gangetic plane in Uttar Pradesh of India. Table 1 refer to the results of water quality of lakes where the pH, EC, turbidity, P, N, and BOD was determined quarterly after a rainy spell in the area. In September when there is no or very little (12–20 mm) of precipitation, the values of P and BOD in almost all the lakes viz., LSJ, LCH, LSN, and LHT was found at maximum 5.06 ± 0.13, 9.20 ± 0.36, 1.00 ± 0.03, 1.71 ± 0.25 and 7.36 ± 0.03, 6.01 ± 0.04, 6.37 ± 0.25, and 4.42 ± 0.47, respectively, where nitrogen was found at its lowest value in the same month 0.77 ± 0.13, 0.95 ± 0.06, 0.02 ± 0.02 and 0.03 ± 0.02, respectively. Based on the water quality (Table 1) Table 2 shows the coefficient of variation (CV) in the cumulative water quality. In the experiment the least values of CV were found in a scattered manner. The CV for pH is least in the lake coded as LSJ > 1.0 and maximum in LHT < 6.0. For the electrical conductivity the CV found least <14.0 in LSJ and maximum in LSN < 21. For the parameters, such as P, N, and BOD the CV values were found least in LSN < 85.0, LSJ < 42.0, and LHT < 39.0. From the results it is clear that the lakes LSJ and LHT are consistent as compared to the other water bodies.

4 Discussion

Environmental factors, such as lateral diffusion of the ions such as P and N into the water surface at soil water interface (Serra et al. 2004), precipitation (Srivastava et al. 2006) bring the changes in the chemistry of water. Pearson's coefficient of correlation between the ions has been given in the Tables 3–6. Results of coefficient correlation analysis show a pattern of common distribution where pH values have been found to be in positive correlation with nitrogen indicating that increase in pH with increase of the nitrogen content in water. The increase in pH value is associated with increase in dissolved oxygen (DO) and the disappearance of NO_3^{1-} from the water (Ii et al. 1997). This finding is in the agreement with our findings, where the BOD is negatively correlated with pH and nitrogen in lakes LSJ, LSN, and LHT. This is explained on the basis of the findings of (Ii et al. 1997; Taebi et al. 2004), where pH increases and N rich conditions promote the growth of algae that photosythetically produce oxygen in the water and decrease the BOD level of water. The increased DO causes the disappearance of NO_3^{1-}, as it is consumed by the aerobic bacteria. As per the results, P has a negative correlation with N, which may be because of higher

Table 1 Water quality of lakes in one quarter of year

Parameters	LSJ			LCH			LSN			LHT		
	Jul.	Aug.	Sep.	Jul.	Aug.	Sep.	Jul.	Aug.	Sep.	Jul.	Aug.	Sep.
pH	7.38 (0.32)	7.33 (0.37)	7.33 (0.03)	6.56 (0.09)	7.45 (0.32)	7.27 (0.10)	8.15 (0.17)	7.78 (0.16)	7.53 (0.02)	7.53 (0.12)	7.91 (0.22)	7.26 (0.10)
EC	372.4 (20.7)	428.5 (9.45)	318.7 (9.20)	347.3 (40.4)	407.5 (9.79)	482.1 (19.21)	522.3 (31.7)	549.6 (8.50)	356.1 (14.5)	678.2 (47.6)	794.0 (37.2)	963.6 (62.4)
Turbidity	11.73 (1.58)	8.20 (0.36)	25.79 (4.57)	2.08 (0.81)	18.03 (0.06)	2.40 (0.30)	11.73 (0.76)	5.13 (0.32)	76.07 (3.91)	5.15 (0.07)	4.47 (0.42)	8.19 (0.16)
PO_4–P	0.74 (0.06)	0.85 (0.06)	5.06 (0.13)	0.01 (0.01)	0.67 (0.05)	9.20 (0.36)	0.03 (0.00)	0.73 (0.07)	1.00 (0.03)	0.09 (0.01)	0.01 (0.01)	1.71 (0.25)
TKN	1.91 (0.22)	1.87 (0.24)	0.77 (0.13)	2.56 (0.32)	1.77 (0.09)	0.95 (0.06)	2.59 (0.36)	2.83 (0.05)	0.02 (0.02)	1.29 (0.24)	1.07 (0.01)	0.03 (0.02)
Cl	7.58 (0.51)	54.73 (9.16)	21.60 (0.96)	2.04 (0.06)	11.63 (0.95)	126.1 (3.99)	9.54 (0.76)	125.2 (4.57)	41.69 (0.92)	14.20 (0.20)	68.01 (0.04)	53.50 (0.63)
BOD	2.63 (0.85)	3.63 (0.55)	7.36 (0.03)	2.00 (0.02)	2.37 (0.38)	6.01 (0.04)	3.23 (0.49)	1.87 (0.85)	6.37 (0.25)	2.39 (0.08)	2.30 (0.44)	4.42 (0.47)

EC, Electrical conductivity in µs/cm; BOD, Biological oxygen demand in mg/l; Turbidity, In NTU; PO_4, Phosphate in mg/l; TKN, Total Kjheldhal nitrogen mg/l; Cl, Chlorides in mg/l

Values in parenthesis are std. dev

Table 2 Coefficient of variance in the collective quarterly observations of water quality

Observations	LSJ	LCH	LSN	LHT
pH	7.35 (0.42)	7.09 (6.63)	7.82 (4.03)	7.57 (4.36)
EC	373.2 (14.71)	412.31 (16.38)	476.01 (21.99)	811.94 (17.68)
Turbidity	15.24 (61.07)	7.50 (121.56)	30.98 (126.50)	5.93 (33.37)
PO_4–P	2.22 (111.25)	3.29 (155.95)	0.59 (85.21)	0.61 (158.35)
TKN	1.52 (42.53)	1.76 (45.80)	1.81 (86.06)	0.794 (84.87)
Cl	27.97 (86.55)	46.58 (148.14)	58.80 (101.51)	45.24 (61.55)
BOD	4.54 (54.84)	3.46 (64.11)	3.82 (60.42)	3.04 (39.57)

EC, Electrical conductivity in µs/cm; BOD, Biological oxygen demand in mg/l; Turbidity, In NTU; PO_4, Phosphate in mg/l; TKN, Total Kjheldhal nitrogen mg/l; Cl, Chlorides in mg/l

CV is significant at 0.05 level

concentration increase active nitrogen assimilation (Schindler et al. 1985). P ions have been found to be correlated positively with BOD level that agrees with the reports (Srivastava et al. 2006) where by a negative correlation with the DO was shown. Oxygen production is more at higher pH levels because of the algal growth. In the correlation matrix (Tables 3, 5, 6) the P content is negatively correlated with the pH of water. At lower pH, microbial uptake is enhanced (McGrath et al. 2001) causing a decrease of reactive phosphorous in the water. The nutrient status of a water body affects the floral composition of aquatic ecosystem as nutrient heterogeneity in fresh water systems largely influence aquatic flora (Xie et al. 2007). The increased DO causes the disappearance ofNO_3^{1-}, which significantly influences the floating aquatic macrophytes such as *Pistia stratiotes* that utilize ammonium ions from the water prior to the use of nitrate (Aoi and Hayashi 1996). Absence of NO_3^{1-} may consequently decrease the population of this floating aquatic macrophyte. Increase in dissolved oxygen is associated with the aeration of water that supports the growth of microbes such as *Escherichia coli* one of the members of phosphate accumulating family Enterobacteriaceae (Vassilev et al. 1999) depending upon the availability of phosphate and nitrogen ion richness in the medium (Rao et al. 1998). Lateral roots

Table 3 Correlation coefficient (*r*) between observations of water quality of LSJ Lake

	pH	EC	Turbidity	P	N	Cl	BOD
pH		–0.01	–0.33	–0.52	0.53	–0.73	–0.66
EC			–0.94	–0.85	0.85	0.69	–0.74
Turbidity				0.98	–0.98	–0.41	0.92
P					–0.99	–0.21	0.98
N						0.20	–0.99
Cl							–0.03
BOD							

Value of "*r*" is significant at 0.5 level

Table 4 Correlation coefficient (*r*) between observations of water quality of LCH Lake

	pH	EC	Turbidity	P	N	Cl	BOD
pH		0.71	0.65	–0.39	–0.75	0.39	0.41
EC			–0.04	0.92	–0.99	0.92	0.93
Turbidity				–0.43	–0.01	–0.42	–0.41
P					–0.90	0.99	0.99
N						–0.90	–0.91
Cl							0.99
BOD							

Value of "*r*" is significant at 0.5 level

Table 5 Correlation coefficient (*r*) between observations of water quality of LSN Lake

	pH	EC	Turbidity	P	N	Cl	BOD
pH		0.73	–0.75	–0.99	0.76	–0.37	–0.59
EC			–0.99	–0.62	0.99	0.37	–0.99
Turbidity				0.65	–0.99	–0.33	0.97
P					–0.66	0.50	0.48
N						0.32	–0.98
Cl							–0.52
BOD							

Value of "*r*" is significant at 0.5 level

Table 6 Correlation coefficient (*r*) between observations of water quality of LHT Lake

	pH	EC	Turbidity	P	N	Cl	BOD
pH		–0.51	–0.90	–0.84	0.71	0.35	–0.83
EC			0.83	0.89	–0.97	0.63	–0.84
Turbidity				0.99	–0.94	0.09	0.99
P					–0.98	0.22	0.99
N						–0.41	–0.98
Cl							0.22
BOD							

Value of "*r*" is significant at 0.5 level of *Eichhornia crassipes* are longer and denser at low-P than at high-P while the diameter decreased when grow in condition with low-P availability (Xie et al. 2003). Organic matter turnover in freshwater ecosystem is a link among macrophyte production, decomposition, nutrient limitation, and rate of nutrient cycling.

5 Conclusion

The lake water is a natural medium for the growth of aquatic flora and the fluxing of the ions by natural or anthropogenic factors cause a disturbance in its composition. This causes the change in the optimum conditions favorable for the growth of the aquatic flora. The correlation matrix shows the dependency of the ions on each other. The change in ionic composition of water brings the changes in water chemistry and the aquatic flora accordingly.

Acknowledgments The work was sponsored & supported by National Botanical Research Institute Lucknow. Special thanks are due to Dr. H. M. Behl for providing the best of the lab facilities. We acknowledge the reviewers for their suggestions in the making the work presentable.

References

Aoi, T., & Hayashi, T. (1996). Nutrient removal by water lettuce (*Pistia stratiotes*). *Water Science Technology, 34*(7–8), 407–412.

Behl, H. M., & Singh, N. (2003). *Evaluation of biodiversity in Mainpuri and Etawah Wetlands of U.P.' Final report*. Lucknow, UP, India: Remote Sensing Application Centre.

Environmental Protection Agency (EPA) (1979). Methods for the chemical analysis of water and wastes. EPA-600/4-79-020, Washington, DC.

Ii, H., Hirata, T., Matsuo, H., Nishikawa, M., & Tase, N. (1997). Surface water chemistry, particularly concentrations of NO_3^- and DO and δ^{15}N values, near a tea plantation in Kyushu, Japan. *Journal of Hydrology, 202*, 341–352.

Körner, S., Vermaat, J. E., & Veenstra, S. (2003). The capacity of duckweeds to treat wastewater: Ecological considerations for a sound design. *Journal of Environmental Quality, 32*, 1583–1590.

Liikanen, A., & Martikainen, P. J. (2003). Effect of ammonium and oxygen on methane and nitrous oxide fluxes across sediment–water interface in a eutrophic lake. *Chemosphere, 52*, 1287–1293.

McGrath, J. W., Cleary, S., Mullan, A., & Quinn, J. P. (2001). Acid-stimulated phosphate uptake by activated sludge microorganisms under aerobic laboratory conditions. *Water Resource, 35*(18), 4317–4322.

Nimptsch, J., & Pflugmacher, S. (2007). Ammonia triggers the promotion of oxidative stress in the aquatic macrophyte *Myriophyllum mattagrossense*. *Chemosphere, 66*, 708–714.

Rao, N. N., Liu, S., & Kornberg, A. (1998). Inorganic polyphosphate in *Escherichia coli*. *Journal of Bacteriology, 178*, 1394–1400.

SPSS Inc. (1997). SPSS base statistics, version 13.0. Chicago, USA: SPSS Inc.

Schindler, D. W., Turner, M. A., & Hesslein, R. H. (1985). Acidification and alkalization of lakes by experimental addition of nitrogen compounds. *Biogeochemistry, 1*, 117–133.

Serra, T., Fernando, H. J. S., & Rodriguez, R. V. (2004). Effects of emergent vegetation on lateral diffusion in wetlands. *Water Resource, 38*, 139–147.

Srivastava, J., Chandra, H., & Singh, N. (2006). Seasonal variation in ionic fluxing in the fresh water bodies of Lucknow city of UP (India). *Environmental Conservation Journal, 7*(1–2), 59–63.

Standard Methods for the Examination of Water and Wastewater (1992). 16th ed. Washington D.C: American Public Health Association.

Taebi, A., & Droste, R. L. (2004). Pollution loads in urban runoff and sanitary wastewater. *Science of the Total Environment, 327*, 175–184.

Tchobanoglous, G., & Schroeder, E. D. (1985). *Water quality*. USA: Addison-Wesley Publishing Company.

Vassilev, M., Azcon, R., Barea, J., & Vassilev, N. (1999). Effect of encapsulated cells of Enterobacter spp. On plant growth and phosphate uptake. *Bioresource Technology, 67*, 229–232.

Wu, Y., & Gibson, C. E. (1996). Mechanical controlling the water chemistry of small lakes in Northern Ireland. *Water Resource, 30*(1), 178–182.

Xie, Y., Deng, W., & Wang, J. (2007). Growth and root distribution of *Vallisneria natans*to sediment type and water column nutrient. *Aquatic Botany, 81*, 85–96.

Xie, Y., & Yu, D. (2003). The significance of lateral roots in phosphorus (P) acquisition of water hyacinth (*Eichhornia crassipes*). *Aquatic Botany, 75*, 311–321.

Yang, X., & Williams, M. A. J. (2003). The ion chemistry of lakes and late Holocene desiccation in the Badain Jaran Desert, Inner Mongolia, China. *Catena, 51*, 45–60.

Zhang, H., & Forde, B. G. (1998). An Arabidopsis MANS box gene that controls nutrient induced changes in root architecture. *Science, 279*, 407–409.