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Water quality index as a tool for wetland restoration

Nitin Bassi[a] and M. Dinesh Kumar[b]

[a]*Corresponding author. Institute for Resource Analysis and Policy (IRAP), Liaison Office, New Delhi, India*
E-mail: nitinbassi@irapindia.org
[b]*Institute for Resource Analysis and Policy (IRAP), Head Office, Hyderabad, Telangana, India*

Abstract

Worldwide, wetlands are subjected to increasing anthropogenic pressures resulting in loss of their hydrological and ecological functions. Such impacts are more pronounced in the case of wetlands in urban areas which are exposed to land use changes and increased economic activities. In many Indian cities, natural water bodies such as lakes are heavily polluted due to runoff from farmlands in urban and peri-urban areas and discharge of untreated domestic and industrial wastewater. The major constraint for restoring such water bodies is difficulty in devising a concrete action plan for analysing different sets of water quality parameters. Hence, a water quality index (WQI), which is a tool to analyse large amounts of data on different water quality parameters, is computed for one of the biggest natural lakes in the metropolitan city of Delhi. The mean WQI of the lake was estimated to be 46.27, which indicates a high level of water pollution. The paper discusses how these findings can be used for informing policies on management of wetlands. The paper also suggests establishment of a community based water quality monitoring and surveillance system, backed by infrastructural support from the State, in order to restore the wetlands in urban areas.

Keywords: Anthropogenic pressures; Land use changes; Natural water bodies; Urban areas; Wastewater; Water quality monitoring and surveillance

1. Introduction

Wetlands are the most productive ecosystems which perform numerous ecological and physical functions and provide a number of goods and services (Birol & Cox, 2007; ten Brink *et al*., 2012). As per the Ramsar Convention on Wetlands, most of the natural water bodies (such as rivers, lakes, coastal lagoons, mangroves, peat land, coral reefs) and man-made wetlands (such as ponds, farm ponds, irrigated fields, sacred groves, salt pans, reservoirs, gravel pits, sewage farms and canals) constitute the wetland ecosystem. Major benefits provided by these wetlands are categorized into cultural, supporting, provisioning and regulatory goods and services (Ghermandi *et al*., 2008).

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Though wetlands perform many functions that are valuable, they continue to be ignored in the policy process (Turner *et al.*, 2000; Ghermandi *et al.*, 2008) and are threatened by increasing pollution as a manifestation of urbanization, population growth, land use changes and increased economic activities (Verma *et al.*, 2001; Chan, 2012). Urbanization exerts significant influences on the structure and function of natural wetlands, mainly through modifying the hydrological and sedimentation regimes, and the dynamics of nutrients and chemical pollutants (Faulkner, 2004; Lee *et al.*, 2006; Yuanbin *et al.*, 2012).

Water in most Asian wetlands (rivers, streams, tanks, lakes and ponds) is heavily degraded, mainly due to agricultural runoff containing pesticides and fertilizers, and industrial and municipal wastewater discharges, all of which cause widespread eutrophication (Prasad *et al.*, 2002; Liu & Diamond, 2005). The situation in India is no different. In particular, the contribution of urban domestic and industrial effluent to this menace is noteworthy. In India, less than 31% of the domestic wastewater from urban centres is treated. In the 35 metropolitan cities (population size of 0.4 million or more) put together, treatment capacity is only 51%. The condition in smaller urban centres is even worse as treatment capacity exists for only about 18% of the sewage generated in Class I cities (population size of 100,000 or more but other than metropolitan cities) and 9% of the sewage generated in Class II towns (population between 50,000 and 100,000) (Central Pollution Control Board (CPCB), 2009). Actual sewage treatment is lower due to inadequacy of the sewage collection system and non-functional treatment plants.

Given the insufficient capacity to treat industrial and municipal wastewater, the problem of water quality deterioration is alarming, particularly in the case of water bodies such as lakes and ponds in small urban centres (Bassi *et al.*, 2014). In the past, these water sources performed several economic (fisheries, livestock and forestry), social (water supply), and ecological functions (groundwater recharge, nutrient recycling, biodiversity maintenance, flood control, etc.). However, the public good character of many wetland services and goods leads decision makers to overlook many of their values (Ghermandi *et al.*, 2008). Further, as most of the wetlands are in the open access regime, every one claims a stake in them, but few are willing to pay for the extractive use (Verma *et al.*, 2001). Results from the Monitoring of Indian Aquatic Resources (MINARS) programme also show that water bodies, such as rivers and lakes, near to urban centres are becoming increasingly saprobic and eutrophicated due to contamination from partly treated or untreated wastewater (CPCB, 2010). Studies have also indicated that rising pollution of water bodies in metropolitan areas, such as in National Capital Territory of Delhi and Greater Bengaluru, are pushing these precious eco-balancers to extinction (Indian National Trust for Art and Cultural Heritage (INTACH), 1998; Ramachandra & Kumar, 2008).

Considering the state of wetlands in urban areas, the foremost requirement is to determine the extent of water pollution and quality deterioration the wetlands have undergone. Thereafter, based on a correct assessment of water quality parameters, appropriate policy and management decisions can be taken for their restoration. However, arriving at any strategy on wetland restoration through analysis of different sets of water quality parameters is often difficult as it requires a multidisciplinary understanding of water pollution problems. The water quality index (WQI) can be an important tool for decision and policy makers to formulate wetland restoration and management strategies based on water quality parameters.

2. Water quality index

Water quality indices are a convenient means to analyse large amounts of water quality data, using various groups of analytes (Wills & Irvine, 1996; Bharti, 2011). Since, Horton (1965) proposed the first WQI, several other indices have been formulated. Some important ones include: National Sanitation Foundation (NSF) WQI (Brown *et al*., 1970); Oregon WQI (Dunnette, 1979); Bhargava method (Bhargava, 1983); British Columbia WQI (Rocchini & Swain, 1995); Canadian Council of Ministers of Environment (CCME) WQI (CCME, 2001); and Overall Index of Pollution (Sargaonkar & Deshpande, 2003). Every WQI gives a single value indicator that expresses overall water quality at a certain location based on several water quality parameters and turns complex water quality data into information that is understandable and useable by the concerned stakeholders (Chowdhury *et al*., 2012; Kankal *et al*., 2012).

Bharti (2011) established that NSF WQI and other indices based on it (such as overall index of pollution), provides the best results for the indexation of the general water quality. In India, the Central Pollution Control Board (CPCB) which is the country's foremost pollution control body and some State Pollution Control Boards also use NSF WQI, with a slight modification in weights, to classify only selected surface water bodies (mainly rivers) based on their pollution loads (Maharashtra Pollution Control Board (MPCB) & The Energy and Resources Institute (TERI), 2014).

NSF WQI consists of nine analytes which include: dissolved oxygen (DO); faecal coliform (FC); pH; biochemical oxygen demand (BOD); temperature change; total phosphate; nitrates; turbidity; and total solids (TS). Results obtained from tests on these nine analytes are transferred to a weighting curve chart where a numerical value (Q-value) is obtained. Then for each analyte, the Q-value is multiplied by a weighting factor which is based on the significance of the particular analyte in determining the water quality (Table 1). The sum of all weights used for determining the WQI is 1. The nine resulting values are then added to arrive at an overall WQI. The highest score a water body can receive is 100. Quality of water in a surface water body is categorized from bad to excellent depending on the WQI score. Mathematically NSF WQI can be represented as:

$$\text{NSF WQI} = \sum_{i=1}^{p} WiIi$$

where, Ii is the subindex (Q-value) for the ith water quality analyte; Wi is the weight (in terms of importance) associated with the water quality analyte; and p is the number of water quality parameters.

Table 1. NSF WQI analytes and assigned weights.

Serial number	Analyte considered	Desirable unit	Weight assigned
1	DO	% saturation	0.17
2	FC	colonies/100 ml	0.16
3	pH	Units	0.11
4	BOD	mg/L or ppm	0.11
5	Temperature change	°C	0.10
6	Total phosphates	mg/L or ppm	0.10
7	Nitrates	mg/L or ppm	0.10
8	Turbidity	NTU	0.08
9	TS	mg/L or ppm	0.07
	Overall weight		1.00

Source: Brown *et al*. (1970).

The main objective of this study is to compute the WQI for a lake situated in an urban area and highlight its importance as a tool to assist policy makers, natural resource managers and conservationists to strategize actions which can lead to improvements in environmental conditions of the lakes, particularly the quality of their water.

3. Application of WQI: methodology and results

WQI was computed for Lake Bhalswa which is an important freshwater wetland of the Yamuna river basin in Delhi and is under threat mainly due to anthropogenic pressures.

3.1. Study area

Bhalswa lake is a natural freshwater oxbow lake situated in the north-western district of Delhi metropolitan area (Figure 1). This district occupies an area of 440 square kilometres and receives an average annual rainfall of around 700 mm. The lake is located in the floodplain of the river Yamuna which flows about 8 to 9 km east of the lake in a north-south direction (Bhattacharya *et al.*, 2011). Geo-hydrologically, the area is underlain by alluvium with a groundwater yield potential varying from 100 to 280 cubic metres per hour.

The lake was originally shaped like a horseshoe. Over the years, due to large-scale encroachments in its surroundings (as confirmed by satellite images of different time periods and field survey), the lake

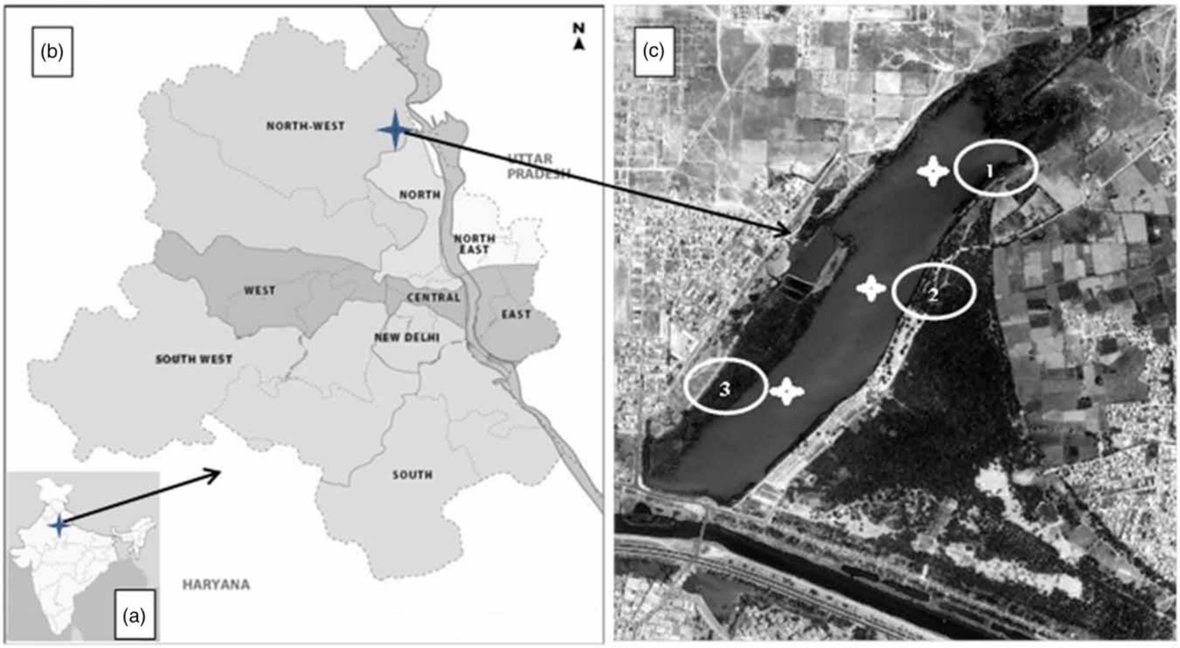

Fig. 1. (a) India map showing location of Delhi, (b) Delhi district map showing location of Bhalswa lake, and (c) satellite image of lake with sampling sites (marked in asterisks).

area has decreased by almost half. Presently, the lake is 1.5 kilometres long with a water spread area of about 22 hectares and is one of the three largest lakes in Delhi. The other two being Sanjay lake and Najafgarh lake.

In the catchment area along the west bank of the lake, there is a resettlement colony having inadequate sanitation and sewerage facilities and thus is the main source of most of the wastewater being discharged into the lake. The majority of the households in this colony have dairy as their main occupation. One of the three major landfill sites of Delhi is also situated about 600 metres from the western side of the lake. On the eastern side, Delhi Development Authority (DDA), an autonomous body under the Ministry of Urban Development of the Government of India, has developed a golf course and water sports facilities and has also undertaken some plantation activities. Some plants (such as *Prosopis* sp. and grasses) suitable for semi-arid areas were found to be growing naturally on the western side of the lake.

Apart from its use as a tourism and recreational site, the lake provides water for outdoor bathing, meeting the drinking and bathing needs of cattle, and for the commercial fisheries activities. Further, it contributes to groundwater recharge which is indicated by shallow groundwater depth and greater rise in water levels post monsoon (in proportion to depth to groundwater level) in wells located near to lake than in those located away from it but tapping the same aquifer (Figure 2). Also, it attracts plenty of waterfowl (such as storks, stilts, herons) in winter. In the past, the lake was connected to the river Yamuna but due to large-scale land use changes in the Yamuna flood plains and the change of river course over the years that hydraulic interconnectedness no longer exists. At present, the lake stands as an independent wetland providing the discussed benefits and services to the community and environment.

3.2. Sampling and analytical procedures

Water samples were collected from a depth of 45 cm from three sites located near to the northern end (site 1), middle (site 2) and southern end (site 3) of the lake during monsoon, winter and summer seasons, to capture both spatial and temporal variability in the water quality. For bacteriological (FC) analysis, glass bottles were used to collect water samples. Parameters such as pH, DO, FC, turbidity

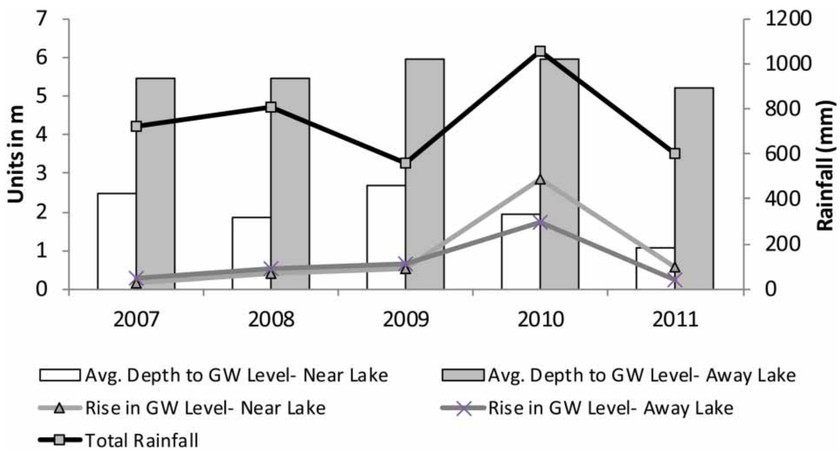

Fig. 2. Groundwater behaviour in wells located near and away from the lake.

and total dissolved solids (TDS) were measured within 24 hours of water sample collection. For analysis of BOD and FC, samples were stored at a temperature below 4°C in the refrigerator and for nitrates, water samples were preserved below pH 2 by adding concentrated sulphuric acid (CPCB, 2007).

Temperature was measured by dipping the thermometer at the selected sites in the lake; pH, DO, TDS and turbidity were measured by placing electrodes from the calibrated water testing kit in the water sample. The colorimetry method was followed for measuring total phosphates and nitrates in the water sample. For BOD, stored water samples were measured for DO and difference in DO values over three days. For measuring FC, the most probable number method was followed (CPCB, 2007).

3.3. Assumptions

Measurement of TS (dissolved and suspended) is necessary for calculating NSF WQI. However, only dissolved solids in water samples were measured. As per the NSF WQI manual, the Q-value is fixed and does not respond to changes in TS concentration beyond 500 ppm. Since the measured dissolved solids concentration was above 500 ppm for all the water samples, measurement for suspended solids was not carried out as it would not have affected the Q-value.

Similarly, DO was measured as units of concentration (mg/L). However, the NSF WQI requires DO to be reported as % saturation. Thus, DO values were converted to % saturation using standard conversion tables, which consider the measured temperature and assume chloride concentrations to be near zero.

3.4. Results from water quality assessment of the lake

Results from the laboratory analysis of water samples are presented in Figure 3 and discussed in detail in the following sub-sections.

3.4.1. Temperature and pH. Mean temperature of the lake water ranged from 32°C in monsoon to 31°C in summer and 10.33°C in the winter season. However, no major intra-seasonal difference in temperature was found across the three selected sites. Mean value of pH ranged from minimum of 7.82 in winter to maximum of 8.77 in summer season. In monsoon season, it was 8.39. Except for summer, pH was found to be within the permissible limit (which is 6.5–8.5) as per the Indian Standard (IS) for the surface water bodies in India (IS: 2296). Higher alkalinity in summer can be due to increased concentration of carbonate salts as a consequence of greater evaporation and reduced inflow of freshwater in the lake. In fact, mean concentration of carbonate (52.43 mg/L) was found to be highest during the summer season. As is the case with temperature, no major intra-seasonal variation in pH was observed across the three selected sites.

3.4.2. Dissolved oxygen. Mean concentration of DO was 4.83 mg/L in monsoon and 4.67 mg/L in both winter and summer seasons. These concentrations are above 4 mg/L which is considered to be the minimum for fish culture and wildlife propagation but below the range of 5–6 mg/L which is considered ideal for drinking water and outdoor bathing use (as per IS: 2296). Intra-seasonal comparison in the DO concentration showed no significant difference across the three selected sites.

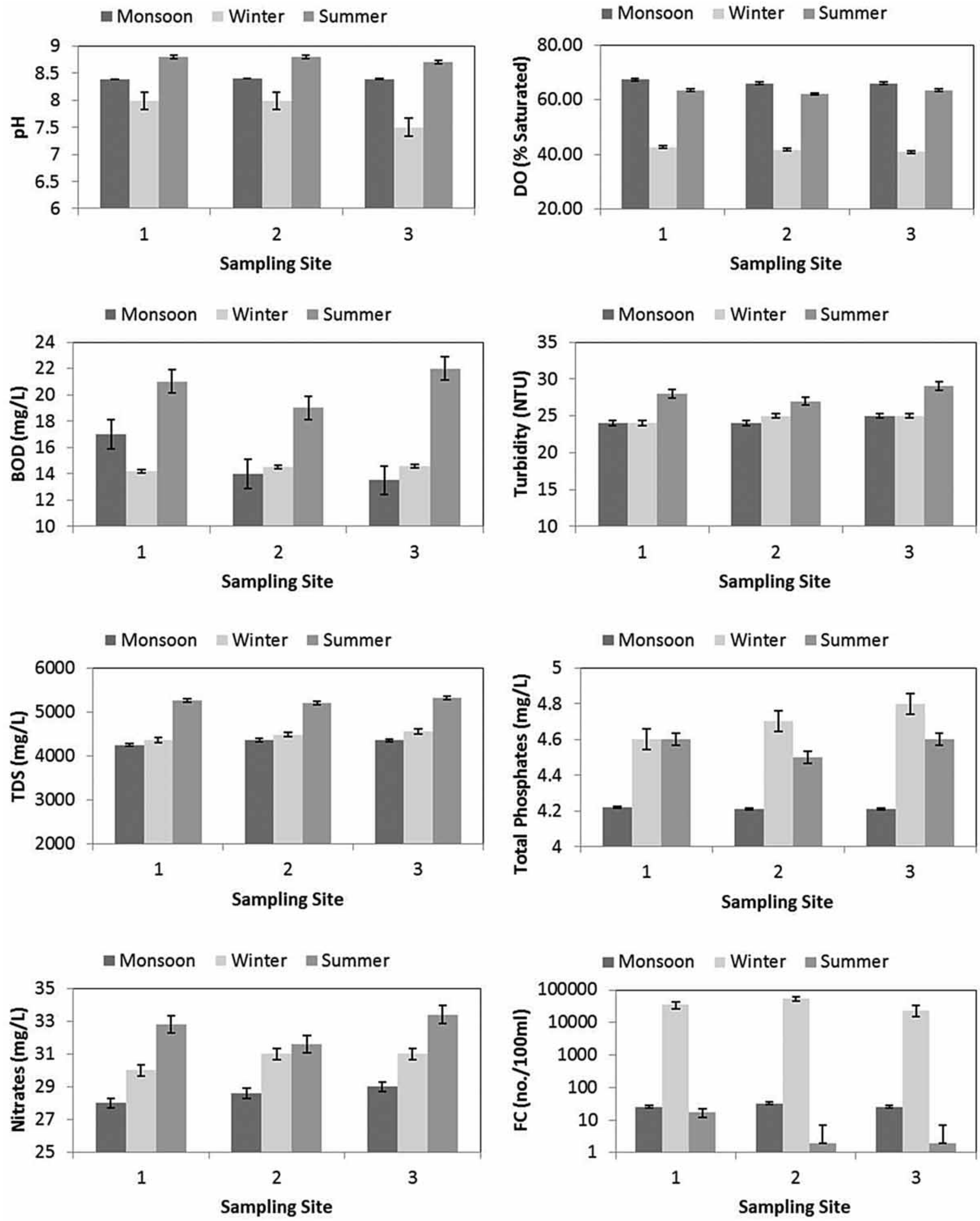

Fig. 3. Seasonal and temporal variation in analytes.

3.4.3. Biochemical oxygen demand. Mean BOD concentrations were 14.83 mg/L in monsoon, 14.43 mg/L in winter and 20.67 mg/L in summer season. As per IS: 2296, these concentrations are much above the permissible range of 2–3 mg/L, thus making the lake water unsuitable for any kind of domestic use including outdoor bathing. High BOD concentration can mainly be attributed to high level of organic matter in the lake water which is due to discharge of untreated domestic wastewater from the habitations in its surrounding area. Large quantities of organic matter act as substrate for micro-organisms and during its decomposition, DO in the receiving water is used up at a greater rate than it can be replenished causing oxygen depletion and increase in BOD concentration.

3.4.4. Turbidity. The water samples showed a high turbidity with a mean of 28 NTU in summer, 24.67 NTU in winter and 24.33 NTU in monsoon. The major reason for high turbidity in lake water is due to high storm-water discharge from the surrounding built up area as it makes the surface less impervious, reduces water retention and thereby increases runoff loaded with sediments. One of the major effects of high turbidity in water is that it reduces the light available to photosynthetic organisms which can have severe consequences on lake biota. In fact, no major aquatic plants (submerged, floating or emergent) were seen in the lake.

3.4.5. Total dissolved solids. Mean TDS concentration was found to be highest during summer (5259.67 mg/L) followed by winter (4463.33 mg/L) and monsoon (4318.67 mg/L) seasons. TDS concentrations were found to be above the permissible range of 500–2,100 mg/L as prescribed under IS: 2296 which makes the lake water not only unsuitable for domestic use but also for irrigation, industrial cooling and controlled waste disposal purposes. High TDS concentrations indicate presence of a greater amount of dissolved solids which are due to high discharge of surface runoff containing sediments and untreated wastewater from the surrounding urban area.

3.4.6. Total phosphates. Average concentration of total phosphates (soluble phosphorus and the phosphorus in plant and animal fragments suspended in lake water) varied from a lowest value of 4.21 mg/L in monsoon to a highest of 4.7 mg/L in winter season. In summer season, it was 4.57 mg/L. The concentration is sufficient to promote algal blooms (Shaw *et al.*, 2004) which can interfere with the functioning of other productive systems in the lake.

3.4.7. Nitrates. Mean amount of nitrates (NO_3) varied from a lowest value of 28.53 mg/L in monsoon to a highest of 32.60 mg/L in summer. In winter, it was 30.67 mg/L. All observed concentrations of NO_3 were below the permissible limit of 50 mg/L which makes the lake water suitable for drinking purposes but with conventional treatment and disinfection. However, due to high BOD and TDS concentrations, it is not suitable for domestic uses. The main source of nitrates is the animal waste which enters from the west bank of the lake.

3.4.8. Faecal coliforms. FC were found in all seasons, indicating unsuitability of water for drinking and other domestic uses. In terms of mean concentration, the highest FC count was in winter (about 37,667 per 100 ml) followed by monsoon (only 28 per 100 ml) and summer (7 per 100 ml) seasons. The prevalence of open defecation around the lake is one of the major reasons for the presence of FC in the lake water. In the winter season, the FC count was found to be abnormally high. This may be due to the fact that millions of people took a holy bath in the lake during a religious ceremony in winter and thereby may have contributed to its abnormally high FC count. Also, many migratory birds visit the lake during winters which might have also played a role in increasing the faecal content in the lake water.

3.5. Overall quality of the lake water

With the results obtained from the water quality testing, it is difficult to arrive at any conclusion on the overall quality of the lake water and its suitability for various uses. Concentrations of some water quality parameters make use of the lake water unsafe for municipal purposes, whereas others make it difficult for wildlife to be sustained. For instance, concentrations of DO, BOD, TDS and FC in the lake water were found to be above permissible limits for its use for drinking or outdoor bathing purposes and those of turbidity and phosphates makes it difficult for various aquatic flora and fauna to be sustained. Thus, for better understanding of the overall health of the lake (in terms of its water quality) and to take measures for its effective restoration, the results obtained from the water quality analysis need to be summarized. WQI plays an important role in achieving this.

3.6. WQI assessment

Based on the observed concentrations of the water quality analytes, the NSF WQI index (as explained in section 2) was computed for Lake Bhalswa. Table 2 presents the site wise and season wise Q or Quality value range of the analytes. These Q-values were estimated by converting the observed concentration value of each analyte using the online tool developed by NSF. The Q-values were then multiplied by a weighting factor (please refer to Table 1) to get the WQI for a particular analyte. The WQI for each analyte was then summed up to get the overall WQI for Lake Bhalswa which is presented in Table 3.

Based on the index value, water quality is categorized as: excellent (90–100), good (70–90), medium (50–70), bad (25–50) and very bad (0–25). The highest WQI value was obtained for site 3 during the summer season and the lowest for site 2 during the winter season. Subsequently, independent sample t-test results showed that there is a significant difference between WQI in winter as compared to the other two seasons (Table 4). However, WQI across sites does not vary significantly. Nevertheless, in winter, the lake water quality falls into the bad category and in summer and monsoon water quality was just above the range of being bad. Overall, water quality of the lake was found to be bad with a mean WQI value of 46.27. These results point to a high level of pollution in Lake Bhalswa.

Table 2. Summary of Q-value for each analyte.

	Q-value range					
	Site			Season		
Analytes	1	2	3	Monsoon	Winter	Summer
DO (% Saturated)	34–71	32–68	31–68	68–71	31–34	60–63
FC (no/100 ml)	7–65	6–91	8–91	57–60	6–8	65–91
pH	56–85	56–84	59–93	70–70	84–93	56–59
BOD (mg/L)	11–22	13–23	10–24	16–24	21–22	10–13
Temp change	89–93	89–93	93–93	93–93	89–93	93–93
Total phosphates (mg/L)	15–16	14–16	14–16	16–16	14–15	15–15
Nitrates (mg/L)	24–29	25–28	24–28	28–29	26–27	24–25
Turbidity (NTU)	55–58	55–58	54–57	57–58	57–58	54–55
TDS (mg/L)	20–20	20–20	20–20	20–20	20–20	20–20

Table 3. Summary of WQI of selected lake.

Site	WQI			
	Monsoon	Winter	Summer	Mean Site
1	50.97	37.81	47.48	45.42
2	50.65	36.81	51.45	46.30
3	51.16	38.35	51.78	47.10
Mean season	50.93	37.66	50.24	–

Table 4. Results of independent sample t-test.

	WQI groups compared	t statistics	Probability (p)	Mean difference	Result*
Site of water sample collection	1 and 2	−0.127	0.905	−0.78	NS
	2 and 3	−0.123	0.908	−0.79	NS
	1 and 3	−0.267	0.803	−1.58	NS
Season during which water sample is collected	Monsoon and Winter	27.935	0.000	13.27	S
	Winter and Summer	−9.331	0.005	−12.68	S
	Monsoon and Summer	0.457	0.691	0.59	NS

*S stands for significant result and NS stands for non-significant result.

4. Discussions

Wetlands in urban areas are under threat from the anthropogenic influences in their catchment and also from climate induced environmental stresses. These influences have led to a reduction in their areal extent and have also resulted in a decline in the hydrological and ecological functions they used to perform (Bassi *et al.*, 2014). As indicated by the WQI assessment of Lake Bhalswa, the water quality has deteriorated to the extent that it is no longer useful for most domestic, economic and environmental uses. It was found that water quality at all the sampling locations was poor. Further, lack of concrete legislation and poor implementation of existing policies on wetland conservation and regulating land use changes have hastened their degradation. These factors are further discussed in the subsequent sub-sections.

4.1. Anthropogenic influences on water quality

The main reasons identified for the high degree of pollution in the lake water were discharge of stormwater loaded with sediments during monsoon months and untreated sewage from the surrounding habitations. As a result, the lake water was found to have high BOD, turbidity, TDS, and phosphates concentrations. The situation is not so different for wetlands in other urban areas. It is estimated that in India about 38,000 million litres per day (mld) of municipal wastewater is generated in the urban centres having a population more than 50,000 (which encompass 70% of the urban population). However, treatment capacity exists for only about 29% (CPCB, 2013). The untreated wastewater is discharged into water bodies such as rivers and lakes which increases their pollution load.

4.2. Absence of institutional effort

Another major reason for the poor state of wetlands in urban areas is the lack of government effort in prevention of water pollution. For instance, though Lake Bhalswa was selected as one of the lakes for restoration by DDA, most of the works which were undertaken relate to the creation of water sports facilities, de-silting and afforestation activities. No effort was made to restrict indiscriminate land use changes and real estate development in the catchment area of the lake. Neither was any effort made to control discharge of untreated wastewater into the lake. In fact, DDA has proposed buildings, hotels and high-end housing on the eastern edge of the lake. Such a proposal would further alter the lake catchment hydrological regime and lead to more pollution of this already degraded water body. The situation is similar for most of the wetlands in and around major metropolitan cities of India.

4.3. Impact of climate variability

Climate variability influences the hydrological characteristics of the wetlands to a great extent. In India, there is a high degree of spatial and temporal variability in rainfall which greatly influences the inflows into wetlands. Such variability during years of low rainfall can affect the pollution assimilation capacity of those wetlands, like that of Lake Bhalswa, which are fed by rainfall and runoff generated thereof.

Further, in the majority of wetlands, water inflow is mostly during monsoon months which significantly reduces their capacity to retain and treat pollutants during non-monsoon months. As a result, water quality deteriorates significantly in the non-monsoon months. Even in the case of Lake Bhalswa, WQI was lowest during winter and summer months.

4.4. Lack of legal framework and policy support

As per the most recent wetland inventory (mapped on 1:50,000 scale), India has about 757 thousand wetlands with a total wetland area of 15.3 million hectares (Space Applications Centre (SAC), 2011). Though India is signatory to the Ramsar Convention on Wetlands, their conservation and management is not given due importance in the country. Since 1981, when the treaty was signed by India, only 26 wetlands have been designated as Ramsar Sites. Apart from some stand-alone instances of wetland restoration works on these sites, most of the efforts have only been on a few other important wetlands and remained mostly in silos. Except for a few States where wetlands offer tremendous tourism potential, they rarely figure in the government priority list. Further, ineffective implementation of pollution control programmes has led to discharge of untreated domestic wastewater and industrial effluent into wetlands, affecting their hydrological and ecological integrity (Bassi, 2016).

Still, there is no legal instrument which directly relates to wetlands. However, they are indirectly influenced by a number of other legal instruments which include: Water (Prevention and Control of Pollution) Act, 1974; Forest (Conservation) Act, 1980; Environmental (Protection) Act, 1986; Wildlife (Protection) Amendment Act, 1991; Biodiversity Act, 2002; and Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (Prasad *et al*., 2002; Bassi *et al*., 2014).

Even the policy support for wetland conservation until 2010 was governed mainly by the programmes initiated as per the international commitment such as National Wetland Conservation Programme

(NWCP), National Lake Conservation Plan (NLCP) and National River Conservation Plan (NRCP). In 2013, NWCP and NLCP were merged into the National Plan for Conservation of Aquatic Eco-systems (NPCA) to avoid overlaps and promote better synergies. Post 2010, the Central Government also notified the Wetlands (Conservation and Management) Rules, 2010. But these rules seem to have narrow objectives as they regulate only some selected wetlands (such as those under the Ramsar Convention and UNESCO World Heritage sites) and completely ignore a large number of smaller wetlands such as lakes, tanks and ponds which play an important role in urban and peri-urban landscapes (Bassi, 2016). This clearly shows the lack of interdisciplinary expertise and understanding in dealing with issues related to wetland conservation. Further, policies governing land use planning are also flawed, as in many cases the wetland catchment area has been altered leading to reduced or no water inflows.

5. Conclusion and policy implications

Wetlands in urban areas are undergoing large-scale deterioration in terms of both water availability and quality. As indicated by WQI assessment for Lake Bhalswa, the main reasons for the high pollution loads in the wetlands are discharge of storm-water loaded with sediments and untreated municipal wastewater. It has been also found that the Governments have failed in protecting wetlands water quality from large-scale pollution and land use changes in their catchments across many river basins in India. Further, inadequate legislative support and poor design and implementation of policies on wetland conservation and management have resulted in their further degradation. Given the state of affairs, WQI can be an important tool for policy makers, natural resource managers and concerned agencies to develop plans which can reflect the extent of effort required to restore the wetlands in urban areas. However, at present, water quality assessments are undertaken randomly and only for a few large wetlands. For instance, under NLCP (which is now merged into NPCA), only 61 major lakes in the urban areas of the entire country were selected for pollution prevention and restoration works (Bassi *et al.*, 2014). To put this figure into perspective, Chennai metropolitan city alone has around 79 lakes (SAC, 2011).

There is definitely a need for developing an effective and proper water quality monitoring and surveillance strategy for all wetlands, taking into consideration the ecological, economic and social benefits they generate. Further, as a community is often dependent on the wetlands for various domestic and economic purposes, including them in the water quality monitoring and surveillance exercise as an important stakeholder can bring about remarkable results. Selected community members can be given responsibility for water sample collection and its transfer to the designated scientific laboratory of testing. In fact, the community can also be given a portable water quality testing kit which can give instant results for temperature, pH, turbidity, TDS and DO. The results obtained from water quality testing need to be properly documented and any spatial and temporal changes of water pollutants should be determined in order to take proper remedial measures and regulatory decisions. However, relevant training and capacity building activities need be designed and undertaken for these selected community members. Necessary government support in terms of laboratory infrastructure and scientific manpower will also be required. Funds available under the NPCA can be utilized for the purpose. Based on the results of water quality monitoring and surveillance (in terms of concentrations of analytes and WQI values over different time periods), appropriate measures for regulating land use changes and treating wastewater can be adopted. This will also generate reliable data on the present condition of wetlands water quality which can be used for further planning.

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