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Water quality assessment of the urban ponds in Chandannagar city, Hugli

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Abstract

In spite of serving the urban and peri-urban milieu in multifaceted way, the urban ponds have experienced massive decline in number and have degraded in quality in response to rapid and haphazard urban expansion. Along with landscape transformation, increasing water pollution has reduced the utility of the ponds. The study examines the water quality of selected urban ponds of Chandannagar city by using Weighted Arithmetic Water Quality Index (WAWQI). The result reveals that nearly 41% of the ponds are extremely polluted, unsuitable for survival of aquatic life and for human use, whereas another set of 15 Ponds report poor to very poor water quality. Such alarming state of contamination of the ponds is a threat to aquatic species and also has reduced future potentiality of resource generation and ecological services.

Keywords: *Surface water quality, Urban ponds, Weighted Arithmetic Water Quality Index, Water pollution*

Introduction

Ponds in urban and peri-urban areas play distinct ecological functions and help restrain the negative consequences of urbanization (Malgorzata *et al.* 2016). They cool the ambient environment, help recharge ground water by accommodating excess rain water and combat urban flooding through regulating surface run-off (Hassall, 2014). They help preserve freshwater ecology by provisioning a specific habitat favorable for urban biodiversity amidst the concrete landscapes. Diverse local flora and fauna, both aquatic and terrestrial, survive in and around these water pools and thus these ponds has become vital receptacle of urban biological resources. Several studies (Fuyuki *et al.* 2014; Hassall and Anderson 2015) during the past decades have attempted to assess the importance of urban ponds in sustaining the city's biodiversity.

Besides serving the physical environment multitudinously, these water bodies benefit the urbanites by extending diverse ecosystem services with immense cultural, aesthetic and civic values (Noble and Hassall, 2014). As an integral part of urban green space, they have substantially influenced the physical and psychological well being of the urban dwellers. Concurrently, they also act as a centre of various social, religious and cultural activities and a source of water supply for extinguishing fire in congested urban areas. A sizeable proportion of the urban poor community, living in slum areas without the access of fresh water, especially in the populous metros of the developing world, use these surface water sources for nearly all human requirements except drinking (Ray, 2010).

Despite their overriding importance, existence of these urban ponds has been recklessly exploited and threatened due largely to rapid urbanization. These interspersed 'blue spaces' in urban sphere have frequently been abolished to meet the growing demand of land for human establishments, without apt evaluation of its services. The existing ones are often used as the disposal pit of untreated litter and effluents of the urban areas, which has conspicuously contaminated the water stored in those ponds. Disposal of municipal waste, herbicides and insecticides applied, industrial effluent and atmospheric deposition are the chief sources of contaminants of surface water of the urban wetlands (Ali and Khairy, 2016). Moreover, those ponds are more susceptible to contamination than other flowing water masses as these stagnant water bodies cannot clean themselves (Dalakoti *et al.* 2017). Increasing accumulation of organic and inorganic pollutants deteriorate the quality of potable water, which disrupts the ecological balance, reduces the utility and significantly harms the public health (Tang *et al.* 2018). The potentiality of such small water bodies to provide provisioning, regulating, supportive and cultural ecosystem services has been properly recognized in many developed countries, whereas their importance is underestimated and often discarded in the unplanned older cities of the developing world. Even, the requirements satisfied by these water bodies are not usually reckoned within the account of the natural urban resources. Recently, an increasing trend has been observed to restore and even to excavate new water bodies in many European cities (Segaran *et al.* 2014).

Rampant harvest of surface and sub-surface water for life and economic purposes over the last two centuries have severe impact on the accessibility, availability, quality and quantity of water resources. Nearly half of the world's largest cities, both in developed and developing countries, now experience acute scarcity of clean water and more than 1.2 billion people lack access to clean drinking water (UNDP, 2006). The situation is worse in Indian metros (*NITI Aayog*, 2018). Hence there is an urgent need to find out new and sustainable sources to ensure water security not only for India, but also across the globe.

The principal objective of this study is to assess the present status of the water quality in the urban ponds of Chandannagar city of Hugli by computing WAWQI from human use and resource perspectives.

The Study Area

Located on the western bank of Hooghly River, the Chandannagar city extends from 22°50′10″N to 22°53′13″N and 88°18′11″E to 88°22′58″E covering a total area of 22.03 km^2. The municipal corporation now comprises 33 administrative wards and accommodates nearly 170000 people with a density of 8800 persons/ km^2 (Census, 2011). 27 urban ponds ('*Pukurs*' in vernacular), dispersed within the city's administrative area have been randomly selected as sample sites for the present study (Fig 1). All these ponds, located within residential areas are comparatively small in size ranging from 0.10 ha (P21) to 1.85 hectares (P14) and are extensively used locally (Table 1)

Materials and Methods

Sample Collection: A sum of 135 water samples have been collected from the selected 27 ponds (5 samples from each) to analyze the magnitude of impurities of the water stored in those ponds. Each sample has been tested thrice and the mean value has been accepted for further assessment. The average value of the five samples has been considered as the representative value for each pond.

Selected Parameters: Ten physico-chemical parameters i.e. Chloride (Cl), Fluoride (F), Iron (Fe), Nitrate (NO_3), Total Hardness (TH), pH, Electrical Conductivity (EC), Turbidity, Dissolved Oxygen (DO) and Total Dissolved Solids (TDS) are selected as per the standard guidelines of American Public Health Association (APHA, 2012).

Computation of WAWQI: The Weighted Arithmetic Water Quality Index (WAWQI) has been computed by using the following equation.

$$WAWQI = \frac{\sum_{i=1}^{i=n} Q_i W_i}{\sum W_i}$$

[Where, Q_i = Quality Rating Scale of i*th* parameter determined by

$$Q_i = 100 \times \left(\frac{Q_a - Q_i}{Q_s - Q_i}\right)$$

Q_a = Concentration of the parameter in sampled water; Q_i = Ideal value of the parameter in pure water i.e. 0 (except pH = 7.0 and DO = 14.6 mg/l); Q_s = Recommended standard value of the parameters shown in table 2

W_i = Unit weight of i*th* parameter computed by the following equation

$$W_i = K/Q_s$$

[where, K = Proportionality constant, computed by:

$$K = \frac{1}{\sum \frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \cdots + \frac{1}{S_n}}$$

[where, $S_1, S_2, \ldots, S_n$ = Standard value of 1st, 2nd ….nth parameter]

The gradation of the obtained WAWQI score (Tyagi *et al.* 2013) of studied ponds has been shown in table 3.

Result and Discussion

Status of water Quality

The obtained result attests that all the ponds suffer from very less concentration of dissolved oxygen relative to the prescribed desirable limit of 5 mg/l. The value of DO ranges from 0.03 mg/l (P18) to 2.33 mg/l (P22) (Table: 4). The water of the ponds is highly deoxygenated, probably due to open sewerage and solid wastes leaching out of the dumps beside the ponds and excessive oxygen consumption during the decomposition of organic matter. Nearly 4-6 mg DO per liter of water ensures healthy environment for growth of aquatic biota, whereas lower proportion threatens their existence (Raveen and Daniel, 2010). Lower proportion of DO in the selected ponds indicates that the aquatic life in those ponds is in severe stress and the lentic ecosystem is on the verge of destruction. It has been empirically observed that fishes in every pond are gasping in the surface level for fresh oxygen.

The amount of dissolved particles both in organic and inorganic form in the water refers to the total dissolved solid, higher proportion of which reduces palatability of water and also causes gastrointestinal irritation in human body (BIS, 2005). There is a wide fluctuation in the TDS values of the samples. Lowest TDS value (311.39 mg/l) is found in Pond 15, whereas Pond 27 has recorded the highest value (652.44 mg/l), which has exceeded the BIS standard (300 mg/l). As many as 11 of the 27 ponds (40.74%) (P 4, 7, 8, 11, 17, 18,

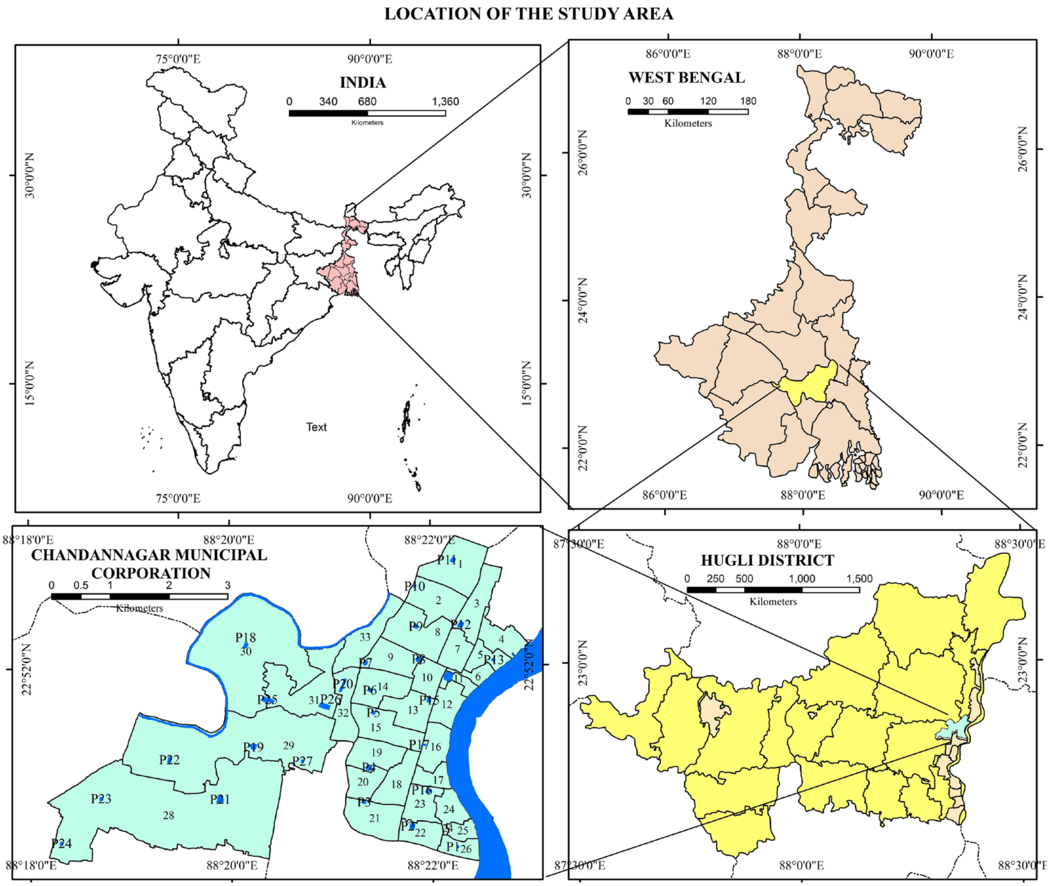

Fig. 1: The Study area

19, 21, 22, 25 and 27) (Table: 4) exceeded the desirable limit with excessive concentration of particle owing to the discharge of rubbish and sewerage from domestic and municipal sources. In addition, cleaning of vehicle in and around the ponds increases the proportion of solids in the water.

Higher accumulation of dissolved or suspended solids enhances the turbidity, which deteriorates the water quality by retarding penetration of light. Consequently, the photosynthesis rate of the phytoplankton and the hydrophytes has been reduced (De, 2003). The turbidity level of all the ponds has exceeded the standard limit with a wide variation from 6 NTU (P 8, 10 and 21) to 13 NTU (P 16, 18 and 25) (Table: 4). Such higher turbidity disrupts the ecological balance of the fresh water ecosystem of the ponds to a massive extent. Huge influx of various organic/inorganic suspended solids of diverse sources through surface run-off from the adjacent areas increases the turbidity of water, which touches its peak in rainy season.

Electrical conductivity (EC) refers to the rate at which electric current can pass through the water and is proportional to the dissolved ion present in water. Higher quantity of dissolved solids and turbidity has enhanced the EC of water of those ponds. It is alarming that all the 27 sample urban ponds have shown higher EC value, exceeding the desirable limit of 300 µ mhos/cm (Table: 4). The resulted values fluctuate from 435.67 µ mhos/cm (P 21) and 1012.10 µ mhos/cm (P 18). Values above the desirable limit for all the sampled ponds indicate severe contamination of water.

pH, the degree of acidity or alkalinity of water, needs to be kept between 6.5 and 8.5 as the value beyond these limits makes water unsuitable for food production as well as human consumption (BIS, 2005). pH less than 6.5 terminates the production of vitamins and minerals in human body, while pH more than 8.5 makes the taste of water bitter. The observed value of pH of the water samples fluctuates between 6.34 (P 6) to 8.06 pH (P13) (Table: 4). Two sample ponds (P6 and 7) show less pH values than 6.5 which are

Table 1: Ward-wise Location of the Selected Urban Ponds

Pond Id.	Ward	Area(Ha.)	Pond Id.	Ward	Area(Ha.)	Pond Id.	Ward	Area(Ha.)
P1	26	0.12	P10	2	0.18	P19	29	0.83
P2	22	0.72	P11	1	0. 55	P20	32	0. 93
P3	21	0.28	P12	3	0. 81	P21	28	0.10
P4	19	0.78	P13	5	0. 23	P22	29	0.54
P5	15	0.31	P14	11	1.85	P23	28	0.30
P6	14	0.41	P15	13	0.47	P24	28	0.29
P7	9	0.50	P16	23	0.55	P25	31	1.37
P8	9	0.73	P17	16	0.17	P26	31	1.42
P9	8	0.42	P18	30	0.52	P27	29	0.25

Table 2: BIS Standard of desirable limit, 2005

Parameters	Desirable Limit
Dissolved Oxygen (DO)	5 mg/l
Total Dissolved Solids (TDS)	500 mg/l
Electrical Conductivity	300 µ mhos/cm
pH	6.5 - 8.5
Turbidity	5 NTU
Total Hardness	300 mg/l
Fluoride	1 mg/l
Chloride	250 mg/l
Nitrate	45 mg/l
Iron	0.3 mg/l

Table 3: Water Quality Rating as per WAWQI

Grading	Score	Water Quality Status (WQS)	Possible Usage
A	0 - 25	Excellent	Drinking, Irrigation and Industrial uses
B	26 - 50	Good	
C	51 - 75	Poor	Irrigation and Industrial
D	76 - 100	Very Poor	Irrigation
E	Above 100	Unsuitable for Drinking	Proper Treatment required before any sort of human use

Table 4: Tested/ Observed Values of Water Quality Parameters

Pond ID.	Dissolved Oxygen (mg/l)	TDS (mg/l)	EC (µ mhos/ cm)	pH	Turbidity (NTU)	Total Hardness (mg/l)	Fluoride (mg/l)	Chloride (mg/l)	Nitrate (mg/l)	Iron (mg/l)
P1	0.13	322.67	**536.00**	7.48	**8.00**	**92.33**	1.00	74.67	3.67	0.09
P2	1.03	421.40	**668.00**	7.55	**7.00**	**95.33**	1.00	64.00	7.17	**0.31**
P3	1.10	371.99	**591.00**	7.86	**8.00**	**116.49**	1.00	67.38	1.17*	0.22
P4	0.07	**522.16**	**806.67**	7.87	**7.00**	**121.67**	1.00	116.67	1.83	**0.32**
P5	0.13	381.32	**587.89**	7.30	**8.00**	**88.67**	1.00	123.67**	10.67	0.24
P6	0.87	430.63	**682.67**	**6.36***	**6.00***	**125.33****	1.00	85.00	7.17	**0.42**
P7	0.17	**501.08**	**778.67**	**6.42**	**9.00**	**103.67**	1.00	79.33	1.33	0.13
P8	0.23	**520.93**	**817.00**	7.13	**6.00***	**105.67**	1.00	84.83	21.00	0.19
P9	0.17	421.69	**667.63**	7.22	**8.00**	**102.00**	1.00	113.67	3.33	0.24
P10	0.30	361.39	**577.07**	7.36	**7.00**	**82.33**	1.00	54.67*	2.17	**0.33**
P11	0.27	**651.11**	**1007.67**	6.52	**11.00**	**76.33**	1.00	117.67	7.67	**0.37**
P12	0.10	311.72	**541.33**	7.32	**11.00**	**95.67**	1.00	114.83	11.33	**0.46****
P13	0.33	481.75	**743.67**	8.06**	**10.00**	**103.50**	1.00	109.83	5.50	**0.37**
P14	0.57	461.41	**766.33**	7.83	**11.00**	**112.67**	1.00	96.67	1.67	**0.37**
P15	0.27	311.39*	**486.67**	7.33	**12.00**	**124.33**	1.00	107.00	1.33	0.29
P16	0.67	431.25	**678.33**	7.57	**13.00****	**102.00**	1.00	87.67	11.33	0.08
P17	0.33	**621.10**	**963.67**	8.00	**12.00**	**86.33**	1.00	83.33	10.83	0.04*
P18	0.03*	**650.78**	**1012.10****	7.56	**13.00****	**103.67**	1.00	97.33	21.67**	0.08
P19	0.43	**521.54**	**788.67**	7.64	**10.00**	**75.67***	1.00	105.83	7.67	0.24
P20	0.83	421.85	**623.33**	7.63	**7.00**	**106.33**	1.00	65.33	7.33	0.18
P21	2.13	**621.10**	**435.67***	7.88	**6.00***	**106.33**	1.00	87.67	4.33	0.16
P22	2.33**	**511.75**	**678.67**	7.19	**8.00**	**85.67**	1.00	83.67	2.33	0.15
P23	1.73	321.39	**726.67**	7.33	**11.00**	**106.33**	1.00	104.33	11.00	**0.43**
P24	1.27	421.07	**678.67**	7.43	**10.00**	**102.00**	1.00	105.33	10.50	**0.32**
P25	0.27	**562.09**	**986.33**	7.67	**13.00****	**98.67**	1.00	86.67	7.50	0.23
P26	0.67	452.08	**767.66**	7.52	**12.00**	**86.67**	1.00	95.00	7.83	0.26
P27	0.87	**652.44****	**687.33**	7.78	**9.00**	**101.67**	1.00	104.33	4.67	0.23

***highest concentration, *lowest concentration; Bold represent values exceeding the desirable limit* unsuitable for aquatic life form and functions.

Hardness of water refers to the presence of milligrams of calcium carbonate equivalent per liter. Dissolved polyvalent metallic ions from sedimentary rocks, seepage and runoff from soils are the major natural sources of hardness in water (WHO, 2011). The value of total hardness of the sampled water ranges from 75.67 mg/l (P19) to 125.33 mg/l (P6). All the samples have recorded TH level less than the desirable limit of 300 mg/l (Table: 4). According to McGowan classification (2000) water quality of three urban water bodies are hard and rest 24 samples are moderately hard in nature (McGowan, 2000).

Generally, agricultural effluents from the neighbouring croplands increase the nitrate accumulation in water, which has declined the oxygen level and affected the diverse varieties of aquatic species (Nas and Berktay, 2016). The nitrate concentration in the tested samples varies widely from 1.17 mg/l (P 3) to 21.67 mg/l (P 18) and all the samples have recorded far less value than the desirable limit of 45 mg/l (Table: 4).

Chloride is available in water in the form of different salts (like $NaCl$, KCl and $CaCl_2$), higher concentration of which indicates higher density of organic pollutants (Munawar, 1970). Irrigation discharge, run off from fertilizer enriched agricultural fields, leaching of weathered materials from different rocks/ minerals and animal nourishing are the major sources of chloride in water (Bora and Goswami, 2016). All the selected ponds have recorded much lower concentration of Chloride than the stipulated level. The mean chloride concentration in the sampled water ranges between 54.67 mg/l (P10) and 123.67 mg/l (P5) (Table: 4). It is observed that the ponds, which have directly received domestic sewerage and agricultural runoff show higher chloride concentration above 100 mg/l. As all the selected ponds have received insignificant amount of agrarian effluent, due to their inner urban location amidst the built up space, both the nitrate and chloride concentration in surface water is comparatively much less.

Higher concentration of iron in water has provided a suitable environment for germination and proliferation of iron bacteria, which adversely alters the taste and appearance of water and puts negative impact on domestic usage and water supply system (BIS, 2005). Iron concentration in the sample waters ranges between 0.04 mg/l (P17) and 0.46 mg/l (P1l). Nearly 10 out of the 27 sample ponds show higher density of iron particles beyond the recommended limit of 0.3 mg/l (Table: 4).

High concentration of fluoride causes fluorosis which imparts adverse effects on human health (BIS, 2005). But it is heartening that all the selected urban water bodies show similar level of fluoride concentration of 1 mg/l which is exactly equal to the BIS standard (Table: 4). So, essential measures need to be taken to check further increase of fluoride.

WAWQI Analysis

The WAWQI value has shown a wide variation

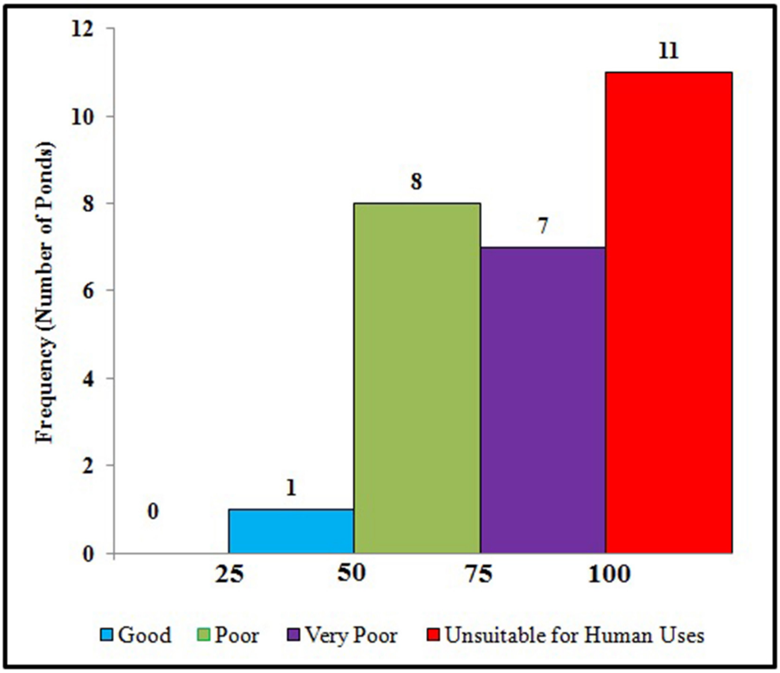

Fig. 2: Frequency Distribution of WAWQI value

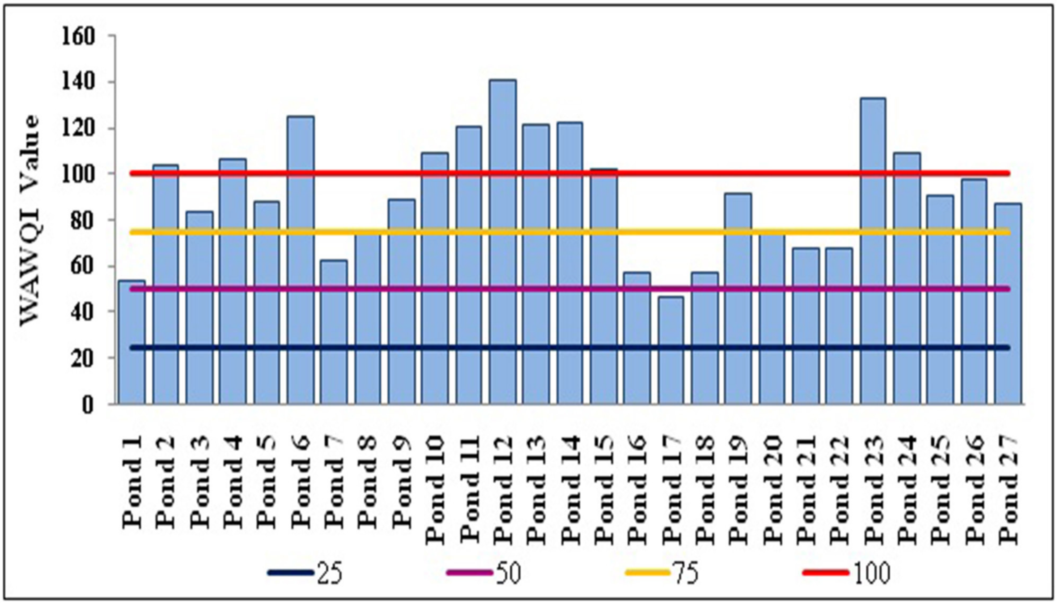

Fig. 3: Spatial Distribution of WAWQI value

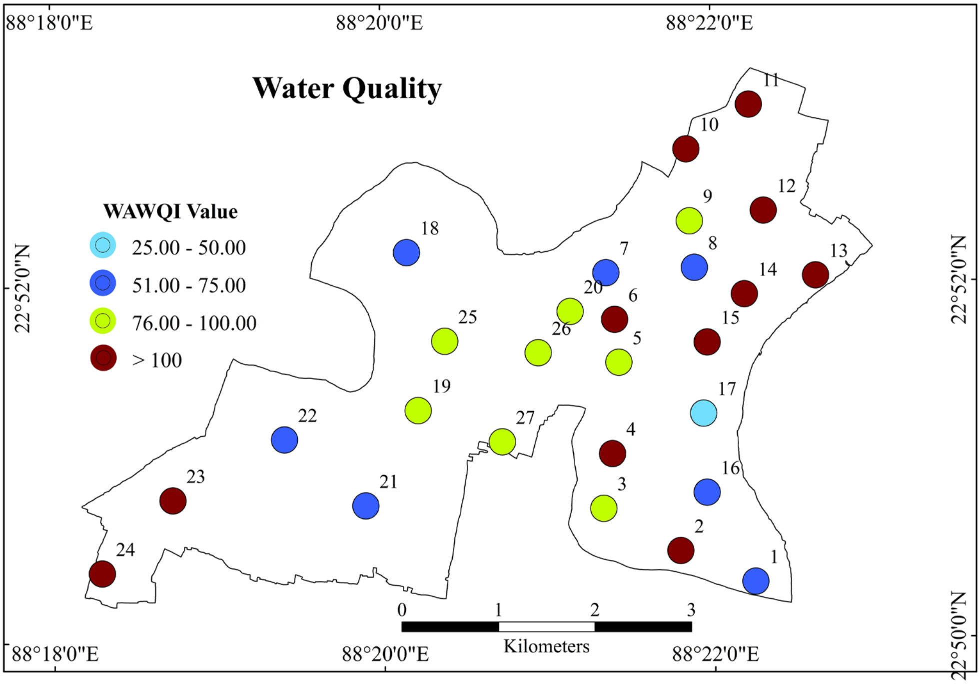

Fig. 4: WAWQI value of the sample water bodies

ranging from 46.69 in Pond 17 to 140.34 in Pond 12. None of the surveyed ponds posses excellent quality of water except one (P17) (3.70%) which has moderately good quality of water (WQI= 26 - 50). Located within the CBD region, Pond 17 contains good water quality due to better maintenance and absence of open sewerage. On the contrary, pond 12 shows the maximum index value due to heavy discharge of domestic waste throughout the year without any regulating mechanism. Eight Ponds (P 1, 7, 8, 16, 18, 20, 21 and 22) (29.63%) contain poor quality of water and another seven ponds (P 3, 5, 9, 19, 25, 26 and 27) (25.93%) contain very poor quality of water unsuitable for drinking but can be used for different cultural (like recreational fishing, pisciculture, religious use etc.) and domestic purposes (like bathing, washing the cloths, utensils and two/four wheelers etc.) (Figure 2, 3 and 4). The rest eleven ponds (P 2, 4, 6, 10, 11, 12, 13, 14, 15, 23 and 24) (40.74%) contain severely contaminated water (WQI= >100), unsuitable to meet any of the human needs (Figure 2, 3 and 4). Since a bulk of the urban poor regularly uses the pond water for domestic purposes, especially for bathing, they are more vulnerable to water borne diseases. The fresh water ecosystem of these ponds has become partially to utterly destabilized and they need immediate action of waste treatment, water purification and management.

Conclusion

The analysis clearly reveals very poor to severely deteriorated state of surface water in majority of the urban ponds in Chandannagar city. Located within congested residential areas, many of them (P 2, 4, 6, 10, 11, 12, 13, 14 and 15) are directly connected with the domestic sewerage lines constructed illegally. In addition, many of them have disappeared or have shrunk in size due to land conversion to fulfill the infrastructural requisition. Besides, concretization of the banks of the ponds for city's beautification has restricted the ground water flow and lowered down the water level. Application of chemical fertilizers for pisciculture and use of detergents for washing clothes in ponds increase accumulation of nutrient which lead to eutrophication and propagation of water hyacinth at its maximum density, which has also disturbed the stability of the pond ecosystems.

Proper and scientific management of those urban water storages may help combat with several environmental evils like water logging, urban flooding and especially the urban water crisis in near future. In this present era, when various urban centers are facing severe water crisis, the urban wetlands/ ponds may become an effective measure to mitigate the adverse situation to a large extent.

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