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RESEARCH PAPER

Water Quality Assessment in Urban Wetlands and Suitability for Fish Habitat: A Case Study

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ABSTRACT
In this study, water from three urban wetlands of Gurugram – Sultanpur (WS), Damdama (WD), and Basai (WB), was studied for various physicochemical parameters to assess their suitability for the healthy survival of fishes and the results were compared with the limits of these parameters for fish farming. The parameters studied were colour, temperature, pH, alkalinity, hardness, Ca^{2+}- Mg^{2+} ratio, NO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}, and heavy metals (Fe, Mn, Cr, Cu, Zn, Ni and Pb). The results of the study indicate the majority of studied parameters are beyond the desirable limits in WB; thus, water is most unsuitable for fishes in WB. WB is unsuitable for parameters: colour, alkalinity, hardness, Ca -Mg ratio, NO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}, Cr, Cu, Fe, Mn, Ni and Zn. WS needs consideration for temperature, NO_3^-, Cu, Ni and Zn, whereas WD needs improvement in temperature, TDS, NO_3^-, Cr, Cu, Fe, Mn, Ni and Zn concentration for better fish growth. Most of the parameters are high in summer as compared to winter, which is due to the dilution after rainfall. Hence, we recommend timely action for effective measures to improve the water quality of wetlands and their regular monitoring for improved fish habitat.

KEYWORDS: Fish farming; Heavy metals; Wetlands; Surface Water

INTRODUCTION

Fishes are an integral part of any wetland ecosystems. In urban wetlands, they are reared either for visiting avian fauna or for commercial food. This makes the health of fishes a vital aspect of wetland management and a key factor in successful aquaculture (James, 2000). Since the entire life of a fish depends on the quality of the environment, the water quality of a wetland plays a significant role in the growth and survival of the fishes (Arulampalam et al., 1998; Thirupathaiah et al., 2012). Any deterioration in the quality of water may cause stress and associated disorders in them. Significant water quality parameters affecting the life cycle of fishes include colour, temperature, pH, dissolved oxygen, alkalinity, hardness, Ca-Mg ratio, NO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}, and heavy metals like (Fe, Mn, Cr, Cu, Zn, Ni, Pb etc.) (Boyd & Pillai, 1984; Kiran, 2010). In aquaculture, water is considered good for fishes when the color ranges between light green to light brown, whereas it creates a problem for fishes when water is clear and is lethal when water is dark green or dark brown in colour (Bhatnagar & Devi,

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2013). For the proper growth of the fish and their healthy survival, TDS in water should be < 400 mg/l (Bhatnagar et al., 2014). It is observed that with an increase in pH and alkalinity, growth, survival, and other physiological activities of fishes gets affected (Maoxiao, 2018). Utilization of CO_2 by macrophytes for photosynthesis regulates the pH of the water bodies (Nazneen et al., 2019). Total hardness has shown an impact on the size of the egg, which decreases with an increase in total hardness (Luo et al., 2016). A ratio of 10:1 of chloride to nitrate reduces this poisoning (Stone & Thomforde, 2004). Sewage is added traditionally to enhance aquaculture and is considered good for the growth of some fish species (Datta, 2006) however; nutrients and some heavy metals present in the sewage in high concentrations may create stress. Concentrations of heavy metals in water bodies are usually deficient, but despite their low concentration, they may create stress for fishes when exceeding even little from the desired level (Boyd, 2009). These parameters are contributed by either natural processes like weathering or anthropogenic activities like road and agricultural runoff, sewage, industrial effluents or garbage etc. (Ahamad et al., 2020; Madhav et al., 2018; 2020). Every organism has an optimum range for these parameters where maximum growth occurs, which is the desirable limit for that organism. Any sudden change above or below this limit may severely impact the growth and survival of the organism (Bhatnagar & Devi, 2013). This may cause physiological, structural or haematological changes like reduction in fertilization; increase in mortality rate; damage of gills and skin; and reduction in the growth of embryos (Alabaster & Lloyd, 2013; Luo et al., 2016; Maoxiao, 2018). Hence, regular monitoring, control of these parameters and application of appropriate amendment becomes a necessity. This study was conducted to assess the water quality of three urban wetlands in Gurugram to check their suitability for the survival of fishes to provide necessary measures for optimum growth.

MATERIAL & METHODS

The wetlands selected for the study lies in the Gurugram (earlier Gurgaon) district of Haryana and falls in the southernmost region of the state. The city, which is also called the cyber city - Gurugram, is also part of the National Capital Region. The city is situated between latitudes 27°39’ 58’ N to 28°32’ 30’ N and longitudes 76°39’ 10’ E to 77°20’ 27 E. The annual temperature range here is 5°C - 40°C, and it receives an average yearly rainfall of about 596 mm (Dixit et al., 2020).

The presence of both hills and depressions in the city leads to irregular and diverse topography. Geologically, a large part of this city comprises of Pre-Cambrian metasediments of Delhi Super Group and Quaternary alluvium. Delhi super-group is represented by Alwar quartzites, pegmatite intrusive of the Alwar series, slates of phyllites, mica schists and quartzites of the sub-recent alluvium and dunes (Malik et al., 2010). Low-grade haematite and jasperoid hematite occur in the Ferozpur-Jhirka area. Minerals other than haematite include china clay, arsenopyrite, feldspars, garnet, graphite, and quartz (Narain, 2009).

Among the different soil types found in Haryana, the Ustipsamment type is frequently distributed by aeolian activity. These types of soil are sandy and alkaline. Different types and textures of soils are found in different parts of the districts, like tropical and brown soils in northern parts while waterlogged and salt-affected soils in the southern parts (Chakrapany, 1981; Malik et al., 2010). The overall texture of the soils of Gurugram is medium-textured loamy sand (CGWB, 1995; Chaudhary et al., 1996; Mahmood, 2012).

Out of various struggling water bodies of Gurugram, three active wetlands selected for this study were: Sultanpur (WS), Damdama (WD), and Basai (WB). Sultanpur wetland lies in Farrukhnagar block and is a shallow lake situated inside Sultanpur national park in an area of

143 ha. The lake is rich in avian fauna. It is fed water from rainfall, irrigation canal, and runoff from agricultural land. Fishes are reared to feed visiting avian fauna. Damdama wetland is an artificial lake in the lap of Aravalli hills. It receives its input from precipitation, surface drainage and runoff from nearby village area (Laroia, 2015). It is used for tourism, irrigation, idol immersion and fish farming. Basai wetland is also situated in Farrukhnagar block and is a permanent, shallow, sewage fed, accidental wetland spread in an area of 100 ha in a depressional land. It also possesses rich avian visits like Sultanpur (Solanki & Joshi, 2017; SANDRP, 2018). A well-stabilized sewage fed aquaculture is prominent at one end of this wetland. The wetland is mainly surrounded by built-up area and agricultural land on one side and receives wastewater input from there. The study area map and locations of wetlands selected for the study are depicted in Fig. 1.

Water samples (n=55) were collected in separate polyethene bottles for different sets of parameters during November 2017 and May 2018. Water samples were filtered using a 0.45 µm syringe filter (Millipore), brought to the laboratory, and preserved at 4 ℃ for further analysis. Samples were analyzed for various Physico-chemical parameters such as pH, total dissolved solids (TDS), Hardness, Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}, PO_4^{3-}, NO_3^{-} and heavy metals (Cr, Cu, Fe, Mn,

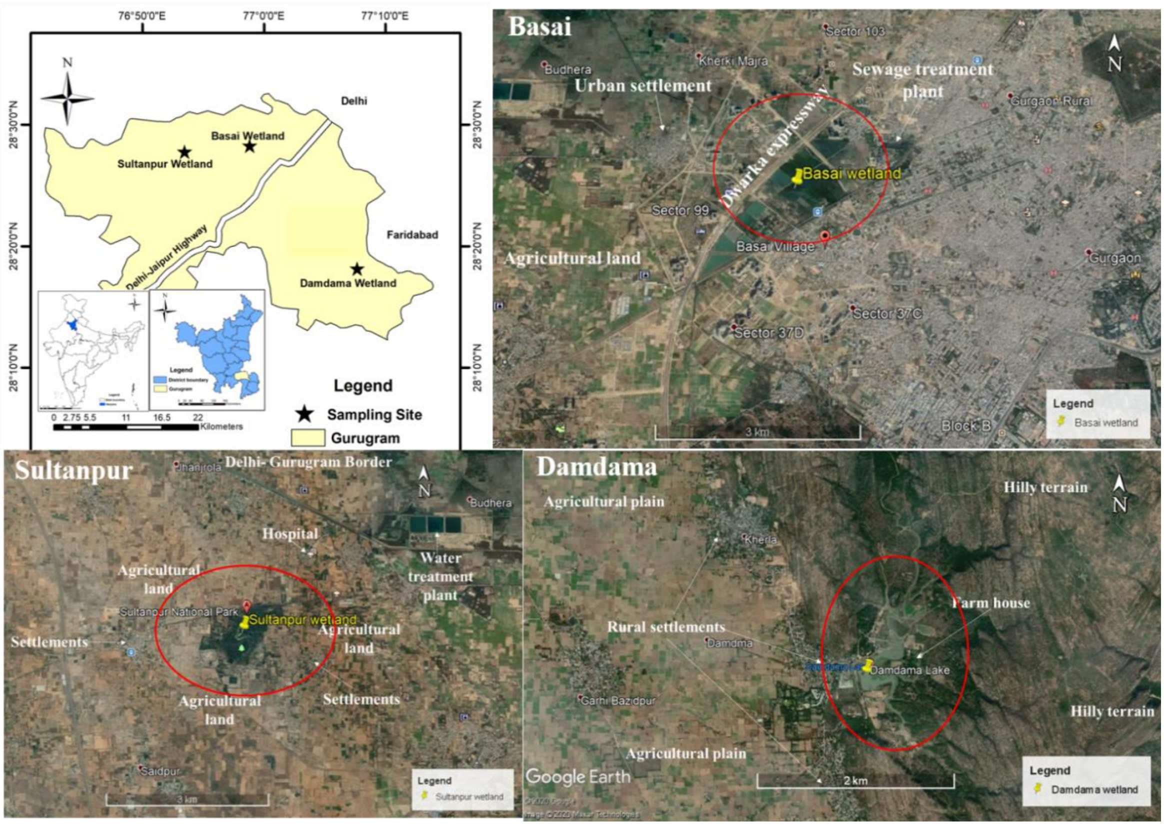

Figure 1. Study area map and locations of selected wetlands (Basai, Sultanpur and Damdama) for the study and images describing shape of the lakes and its catchment activities.

Ni, Pb and Zn. The pH, EC, and TDS were measured on-site with the help of a portable pH meter (Hanna instrument, H196107) and multimeter (Aquapro water tester, model AP-2), respectively. DO was analysed using Winkler's method. Alkalinity was calculated using the titration method using phenolphthalein and methyl indicator. For determination of Cl^{-} argentometric method was used. NO_3^{-}, PO_4^{3-} and SO_4^{2-} were analysed using the

Spectrophotometer method using TRI solution, ascorbic acid method and Barium chloride turbidimetric method, respectively. Hardness was calculated from Ca^{2+} and Mg^{2+} through calculation which was analysed through atomic adsorption spectrophotometer (Thermo Scientific, M series). Heavy metals were also analysed using AAS. All the parameters were analyzed according to the standard methods of APHA (2005). Accuracy and precision were checked by analyzing the reagent blanks at each step. Standards of E-Merck single element were used for calibration of Ca^{2+} and Mg^{2+}. The range of relative standard deviation for sample replicates was within 5 %. All statistical analyses were carried out using Sigma Plot 11.0.

RESULTS AND DISCUSSION

The average values of different parameters and their ranges in water samples of studied wetlands are given in Table I.

Colour in a water body is provided by the presence of planktons, organic and clay particles, dissolved matters and suspended materials (Mane et al., 2017). The presence of algae in a water body provides it with greenish or brown colouration. Also, with runoff from the watershed, a water body receives a lot of vegetative matter and other products. Presence of hamates in this matter imparts a brown colour to the water body. As such no direct effect of colour on fishes is found, but it reduces the plant growth by affecting the light penetrating the water body, which is available for fish food (Boyd & Pillai, 1984). Mortality and growth rate are affected by undesirable colouration. The colour of water in WS is light green in winter, whereas light green to brown in summer. In WD, the colour ranges from clear to light green and light green to brown in winter and summer, respectively. This suggests the suitability of water in WS and WD, for the survival of fishes. In WB, water is light green to brown in colour in winter, whereas; in summer, the colour is dark green in colour. This suggests the unsuitability of water for fishes in summer.

Temperature is an important parameter defining wellbeing of poikilotherms like fishes which cannot regulate their body temperature on their own. Fishes have different temperature optimum ranges depending on the type of fishes they are, i.e. cold water, warm water or tropical fishes. Temperature above 20 – 25 ˚C effect cold water fishes, whereas temperate water fishes face difficulty in survival at a temperature below 10 ˚C. Death of tropical fishes is reported at 10 – 20˚C (Boyd, 2018). Temperature also has a role in day-night stratification in shallow wetlands, with a brief stratification in the day time and mixing at night. Temperature also regulates DO concentration in water body which affects fishes (Roy, 2015). The temperature of the water is > 12 and < 35 in all the studied wetlands, which is the permissible limit for temperature for fish production (Bhatnagar & Devi, 2013). Water quality of WS and WD in winter is below desirable limits of 20 – 30 ˚C for fish survival. But overall, the temperature in all the wetlands is suitable for fishes.

pH range 6.5 - 9 is the desirable range for fish production whereas, range 9 - 11 causes slow growth of fishes. Geogenic sources are the crucial sources defining pH of water in a region. Other than that addition of sewage, agricultural waste, road runoff and other wastes may increase or decrease the pH in natural waters (Madhav et al., 2018). Decomposition of allochthonous organic matter may be one of the primary reasons for the increase in pH (Jiwyam & Chareontesprasit, 2001). Lowering in pH may interfere with the reproductive cycle and calcium levels of fish whereas a high pH may destroy slimy coating, gills, eyes and toxin releasing capacity in fishes (Alabaster & Lloyd, 2013). pH in the studied wetlands WS, WD and WB in summer and winter is 8.5 and 8.6; 8.6 and 8.6; and 8.8 and 8.7, respectively. The pH of water in all the selected wetlands is within the desirable range of 6.5 – 9 for fish production, as given in Table II. Hence water is suitable for fishes in all the wetlands with respect to pH. However, a few points have pH > 9, which suggests water may interfere with the growth of fishes.

High TDS in the water body leads to delayed hatching and fertilization and increased mortalities (Weber-Scannell & Duffy, 2007). In this study, the average TDS values in winter and summer in WS (225 and 314 mg/l) and WD (157 and 326 mg/l) is under the acceptable limit. In contrast, the average TDS in WB (1393 and 2233 mg/l) is much higher than the compared acceptable limit. It is 3 times the acceptable limit in winter and 5 times the limit in summer. Hence, water in WB is not suitable for fishes with respect to TDS.

DO concentration of 5 mg/l is found good for fish production and growth, which is also the permissible limit of DO in water (Amankwaah et al., 2014). DO content below 2 mg/l may cause death. In some fishes like striped bass and yellow perch, even 3 mg/l may cause life threat Bhatnagar & Jain, 2013). It is also referred to as an indicator of eutrophication and the availability of organisms in water (Boyd & Pillai, 1984). Higher is the number of organisms present in the waterbody; more is the consumption of DO (Yee et al., 2012), which gives rise to a hypoxic condition in water. The addition of organic matter in the water body through sewage and other wastewater sources or runoff may lead to a decrease of DO. However, during the rainy season, the mixing of water increases its dissolved oxygen content. Average DO content in winter and summer, respectively, is 6.8 and 7.1 in WS; 7.1 and 8.8 in WD; 5.9 and 5.1 in WB.

Table 1. Average concentrations of physico-chemical parameters, nutrients and heavy metals in wetlands of Gurugram and their permissible limits in water for fish suitability.

Wetland	Season		Water color	Temperature	pH	TDS	DO	Alk	Ca-Mg ratio	Hardness	NO_3^-	Cl^-	SO_4^{2-}	PO_4^{3-}
code				(°C)		mg/l	mg/l	mg/l as $CaCO_3$		mg/l	mg/l			
WS	Winter	Range	LG	19 - 20	7.8 - 9.5	199-283	3.5 - 9.5	72.1 - 104.9	1.50 - 4.56	97.5 - 172.5	11.0 - 24.4	22-Jun	32.6 - 49.0	0.1 - 0.2
	(n =14)	Mean			8.5	225	6.8	86.9	3.4	120.9	15	9.4	39.8	0.2
		Std			0.5	23	2.2	10.4	1	18.2	3.6	3.8	5	0
	Summer	Range	LG - LB	25 - 26	8.0- 9.3	251 - 378	6.0 - 7.8	88.5 - 160.7	3.07 - 5.71	156.6 - 197.6	17 - 22	5.6 - 15.1	49.0 - 61.5	0.04 - 0.45
	(n=6)	Mean			8.6	314	7.1	125.7	4	179.1	20.4	8.5	55.6	0.3
		Std			0.5	56	0.8	31	1	19.4	1.8	3.5	4.2	0.2
WD	Winter	Range	CW - LG	18 - 20	8.4 - 8.8	145-164	5.0 - 8.4	52.4 - 59.0	6.99 - 9.32	61.4 - 84.7	16.2 - 23.6	4.0 - 14.0	15.9 - 28.1	0.19 - 0.24
	n=10	Mean			8.6	157	7.1	55.8	8.1	74.4	20.1	6.4	24	0.2
		Std			0.1	5	1.1	2.7	0.8	6.5	2.3	2.8	4	0
	Summer	Range	LG - B	26 - 27	7.6 - 9.1	303-341	8.0 - 9.2	72.1 - 91.8	6.42 - 10.10	113.3 - 141.2	22.1 - 30.4	20.0 - 24.0	63.8 - 82.3	0.2 - 0.3
	n=4	Mean			8.6	326	8.8	82.8	8.9	128.7	27.9	21.5	70.1	0.2
		Std			0.7	17	0.5	9	1.7	12.8	3.9	1.9	8.6	0
WB	Winter	Range	LG - B	20 - 21	7.9 - 9.4	1006 - 2181	3.0 - 8.0	186.9 - 649.4	1.25 - 2.22	231.4 - 468.2	14.8 - 37.3	380 - 840	34.7 - 81.2	2.3 - 5.2
	n=9	Mean			8.8	1393	5.9	310.1	1.7	297.7	21.5	522.2	49	3.2
		Std			0.5	398	1.7	161.3	0.4	77.8	6.7	166.6	14.7	0.9
	Summer	Range	DG	27 - 29	8.1 - 9.5	1945 - 2477	4.2 - 5.8	360.8 - 478.9	1.44 - 3.41	282.8 - 535.1	28.4 - 58.2	650 - 1000	60.8 - 69.7	5.3 - 10.2
	n=4	Mean			8.7	2233	5.1	428.9	2.1	407.3	41.9	837.5	65.5	7.1
		Std			0.6	229	0.7	59.6	0.9	103.4	12.3	165.2	4.4	2.2
A L			CW, DB and B	> 12 and < 35 [a]	> 4 and <11 [a]	< 400 [b]	>5 and <8 [a]	> 20 and < 300 [a]	>0.05 and <8	>20 and <300 [a]	> 0.01 and <100 [a]	>60 and <100	> 5 - < 100 [c]	> 3 [a]
D L			LG to LB	20 - 30 [a]	6.5 - 9 [a]	-		25 - 100 [a]		75 - 150 [c]	0.1 - 4.5 [a]	> 60 [a]	-	0.01 - 3 [a]

AL = Acceptable water quality limit for fish survival
DL = Desirable water quality limit for fish survival
a = Bhatnagar and Devi, 2013
b =James, 2000
c = Boyd, 1998
d = Boyd 2009

CW- Clear water
LG - Light green; LB - light brown
DG - Dark green; DB - Dark brown

Table 1. Continued…

Wetlands code			Cr	Cu	Fe	Mn	Ni	Zn	Pb
			µg/l						
WS	Winter	Range	1.1 - 7.9	0.5 - 10.2	23.1 - 317.3	0.9 - 184.2	0.1 - 1.1	0.3 - 16.6	
	(n =14)	Mean	3.1	4.8	90.1	55.3	0.5	5.6	bdl
		Std	2.2	3.7	88.1	57	0.3	4.9	
	Summer	Range	16.1 - 22.3	8.9 - 10.2	100.4 - 405.1	90.4 - 251.6	1.10 - 3.3	31.1 - 67.1	
	(n=6)	Mean	19.7	9.7	345.4	168.9	2.5	47.6	bdl
		Std	2.1	0.6	120.5	71.1	0.8	12.1	
WD	Winter	Range	1.1 - 6.7	0.7 - 7.1	10.5 - 568.4	47.2 - 92.7	2.3 - 13.2	0.6 - 9.4	
	n=10	Mean	2.4	4	119.2	63.1	6.4	3.5	bdl
		Std	1.6	2.4	162.7	14.9	3.5	2.9	
	Summer	Range	21.3 - 115.0	4.4 - 43.2	2719.9 - 2947.9	197.5 - 498.2	42.9 - 63.2	46.3 - 203.6	
	n=4	Mean	54.6	23.8	2819.1	370.2	54.9	118	bdl
		Std	41.9	19.3	94.7	126.1	8.7	68	
WB	Winter	Range	11.1 - 23.7	2.0 - 11.3	11.3 - 89.1	7.7 - 296.1	1.2 - 9.9	1.9 - 78.0	
	n=9	Mean	15.6	5.4	56.3	168.4	6	16.8	bdl
		Std	4.3	2.9	31.1	79.3	3.3	25.5	
	Summer	Range	22.8 - 127.1	22.6 - 49.1	196.9 - 983.8	109.4 - 549.4	61.4 - 170.9	116.9 - 264.8	
	n=4	Mean	90.2	35.1	549.7	342.5	117.9	160	bdl
		Std	47.7	10.9	324.7	201	54.4	70.1	
A L			**1 - 50** [d]	**5 - 50** [d]	**Trace - 500** [d]	**Trace - 250** [d]	**5 - 25** [d]	**10 - 100** [d]	**1 - 20** [d]
D L			-	-	-	-	-	-	-

The average DO content in all the wetlands is within the desirable range. Hence all the wetlands have water suitable for fishes concerning DO concentration.

Alkalinity is the total concentration of bases in water. Processes that increase alkalinity include photosynthesis, sulphate reduction and denitrification, whereas those processes which decrease alkalinity are respiration and nitrification (Cook et al., 1986). Also, humates coming to the water body along with runoff lowers the alkalinity (Boyd & Pillai, 1984). The alkalinity of water should be > 20 and < 300 mg/l as $CaCO_3$, which is the acceptable limit for fishes. Alkalinity < 20 mg/l as $CaCO_3$ is reported as a death point for fishes in various studies (Bhatnagar et al., 2004; Stone & Thomforde, 2004). Average alkalinity in WS in summer (125.7 mg/l as $CaCO_3$) is beyond the desirable limit, whereas in winter (86.9 mg/l as $CaCO_3$) it is within the limit. In WD, average alkalinity is within the desirable limit in both winters (55.8 mg/l as $CaCO_3$) and summer (82.8 mg/l as $CaCO_3$). No sample in WS and WD has crossed the acceptable limits. In WB, average alkalinity is beyond the desirable and acceptable limit in both winters (310 mg/l as $CaCO_3$) and summer (428 mg/l as $CaCO_3$).

Ca:Mg ratios also influence fish's development. A ratio of < 1:20 or > 8:1 interferes with larval growth, development, survival and hatching. Also, Mg and Ca deficiency increases the mortality rate in embryos and larvae. Average hardness in WS in summer (179.1 mg/l) is beyond the desirable limit set for suitability for aquaculture, which is 75 – 150 mg/l. Whereas in winter (120.9 mg/l) it is within the limit. In WD, average alkalinity is within the desirable limit in both winters (74.4 mg/l) and summer (128.7 mg/l). No sample in WS and WD has crossed the acceptable limits. In WB, average hardness is beyond the desirable limit in summer (407.1 mg/l), and few samples are above acceptable limits also. Whereas in winter (297.7 mg/l) average hardness of water is within the desirable limits with few samples exceeding the acceptable level. Ca – Mg ratio in WD was > 8 in both seasons, which indicate its unsuitability for fishes. In all other wetlands, it is within limits.

Nitrate in wetlands may come from natural sources like igneous rock or anthropogenic sources like sewage or agricultural inputs (Azam et al., 2018; Madhav et al., 2020b). High concentrations of NO_3^- (above 500 mg/l) may affect the development and performance of fish juveniles (Monsees et al., 2017). Average NO_3^- concentration in summer and winter, respectively is, WS: 15.0 and 20.4 mg/l; WD: 20.1 and 27.9 mg/l and WB: 21.5 and 41.9 mg/l. In all the wetlands average NO_3^- value is beyond the desirable limit of 0.1 – 4.5 mg/l but well below an acceptable level. A high level of PO_4^{3-} may lead to the growth of weeds and pond scum in still water (Azam et al., 2015). Hence PO_4^{3-} may indirectly affect fishes through eutrophication (James, 2000). Average PO_4^{3-} concentration in WS is 0.2 and 0.3 mg/l in winter and summer. In WD, 0.2 mg/l of PO_4^{3-} is found in both summer and winter. In both the wetlands, PO_4^{3-} concentration is below the acceptable level and within the desirable range. In WB, however, PO_4^{3-} is 3.2 and 7.2 mg/l, which is higher than the acceptable level of 3 mg/l.

Cl^- content above 60 mg/l is suitable for the growth of catfishes, and the acceptable limit is 10 times the concentration of nitrite. Cl^- is added to water to reduce nitrate poisoning in freshwater as fishes are susceptible to brown blood disease caused by high nitrate poisoning in water. Average Cl^- concentration in summer and winter, respectively is, WS: 9.4 and 8.5 mg/l; WD: 6.4 and 21.5 mg/l and WB: 522.2 and 837.5 mg/l. The average concentration of Cl^- in WS and WD is well below the concentration which is desirable, whereas in WB it is much higher than the acceptable limit of 100 mg/l and is dangerous for fish survival. Catfishes can tolerate SO_4^{2-} concentrations up to 500 mg/l (Bhatnagar & Jain, 2013). The optimum growth range for SO_4^{2-} is 5–100 mg/l. Average SO_4^{2-} concentration in winter and summer, respectively, is 39.8 and 55.6 mg/l in WS; 24.0 and 70.1 mg/l in WD; 49.0 and 65.5 mg/l in WB. Average SO_4^{2-} concentration in all the wetlands is well within the desirable limits.

Acceptable ranges for various heavy metals for suitability of various freshwater fishes (Boyd, 2009) are given in Table I. Naturally; these metals are present in water due to the dissolution of rocks which is favoured by low pH. They have also added anthropogenically in the water system through the various point (sewage and other direct effluents), and non-point sources (road or agriculture runoff) (Gall et al., 2015; Nazneen, 2019). Cr directly affects the skin and gills. A high concentration of Cr may reduce protein level in fishes and hence interferes with various enzyme activities. Cr toxicity may also cause behavioural changes in fishes (Aslam & Yousafzai, 2017). The average concentration of chromium in water from WS is 3.1 and 19.7 µg/l in winter and summer, respectively, which is within the acceptable limit of 1 – 50 µg/l. Cr concentration exceeds the limit of 50 µg/l in WD (54.6 µg/l) and WB (90.2 µg/l) in summer. Cu adversely affects fishes by creating slimy mucus on the body surface. Reduced growth, uncoordinated swimming and reduced odour perception are some other effects (Mustapha & Agunloye, 2016). Average Cu concentration in summer and winter respectively is WS: 4.8 and 9.7 µg/l; WD: 4.0 and 23.8 µg/l and WB: 5.4 and 35.1 µg/l. Cu concentration is within the acceptable level of 5 – 50 µg/l in WB, whereas it is less than 5 µg/l in WS and WD in winter. High iron may lead to enhanced transaminase activity in blood and damage to the spleen, liver and kidney (Slaninova et al., 2014). A concentration of Fe above 0.1 µg/l may damage gills. Average Fe concentration in summer and winter respectively is, WS: 90.1 and 345.4 µg/l; WD: 119.2 and 2819.1 µg/l and WB: 56.3 and 549.7 µg/l. Fe concentration is below the acceptable level of 500 µg/l in WS in both winter and summer. In WD and WB, Fe concentration exceeds the permissible limit in summer and is below this limit in winter. The average Mn concentration in WS is 55.3 and 168.9 µg/l in summer and winter, respectively, which is below the acceptable level of 250 µg/l. In WD and WB, Mn concentration (370.2 and 342.5 µg/l, respectively) exceeds the permissible limit in summer. In winter, concentration is below the limit in these wetlands. The desirable limit for Ni in aquaculture is 5 – 50 µg/l. Any value higher or lower than this limit is harmful to fishes. The high value of Ni in water may damage erythrocytes and cause depression in haemoglobin values (Ololade & Oginni, 2010). Average Ni concentration is above acceptable limits in WD (54.9 µg/l) and WB (117.9 µg/l) in summer. In winter, Ni concentration is within the desirable range. In WS, Ni concentration in water is less than the lower limit in both seasons, which suggests its water is not suitable for fishes. Sources of Zinc in natural waters may be weathering of rocks or road and agricultural runoff and industrial and municipal discharges

(Boyd, 2009). High levels of Zn in fishes may cause hypoxia, improper growth, structural damages and lack of balance (Afshan et al., 2014). The acceptable range for fish rearing is 10 – 100 µg/l. Water from WS with an average Zn concentration (5.6 µg/l) below the desirable limit in winter is unsuitable for fishes. Whereas that of WD, with an average concentration of 3.5 and 118.0 µg/l in winter and summer, respectively, is found unfit in both the seasons. The average concentration of WB is unsuitable in summer with an average Zn concentration of 160 µg/l, which is above the desirable range.

CONCLUSIONS

Based on the study on physicochemical parameters of waters of urban wetland aimed to assess their quality and, in turn, their suitability for fish habitat, the following conclusions are drawn. From the study, it is observed that the concentrations of NO_3^-, Zn and Ni are beyond the desirable range in water from all the wetlands and are found unsuitable for fishes. The major sources of these elements are geogenic. It is also found that the suitability of the concentrations of some parameters are season dependent and needs attention only in a particular season. These parameters of concern are colour in WB in summer; temperature in WS and WD in winter; hardness in WB in summer; Cr in WD and WB in summer; Cu in WS and WD in winter; Fe and Mn in WD and WB, respectively, in summer. Most of the parameters show unsuitability in summer as compared to winter, which is due to a dilution effect in winter. TDS in WD, alkalinity in WB and concentrations of Cl^- and PO_4^{3-} in WB were unsuitable in both the seasons. This is due to the addition of toxicants from sewage and wastewater from nearby areas. The concentrations of DO and SO_4^{2-} are within the desirable limit and thus are of little concern. The study indicates that WB is most unsuitable for fish habitat as the concentrations of the majority of is parameters are beyond the desirable limit. High concentrations of these parameters in wetlands can be improved by adopting appropriate amendments. Mechanical aeration can be provided as a remedy to maintain optimum temperature. The addition of fertilizers and other organic materials from nearby agricultural land should be controlled to manage productivity which affects the majority of the parameters. Although average pH is within the desirable limits, points of high pH can be supplemented with gypsum and organic matter, which will be helpful. Hardness can be controlled by adding quicklime and controlling silt. Hence, we recommend timely action for effective measures to improve the water quality of wetlands and their regular monitoring for improved fish habitat.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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