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Major ions chemistry of surface water in Bhindawas Wetland, Haryana

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Abstract

Water samples were taken from different locations in Bhindawas wetland during summer season for analyzing major ion chemistry of surface water and its suitability for irrigation and domestic purpose. Along with some major ions, other general water quality parameters like temperature, pH, TDS, EC and Total Hardness were also analyzed. Irrigation quality parameters Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Kelly's Ratio(KR) were also investigated. The study was carried out in the month of May, 2016. The results showed that majority of samples were suitable for domestic purpose due to low and medium hardness. Values of pH range from 6.5 to 7.4, indicating slightly acidic to alkaline nature of surface water. Total dissolved solids ranges from166 to 344 mg/l. All the sampling locations have SAR value and KR value below 10 and 2 respectively, which indicates excellent water quality of lake for irrigation purposes. Also the values of SSP at each sampling locations is below 50 indicating good water for irrigation. Also RSC value for all the samples range below 2.5 and also suitable for irrigation. According to present study it was found that all the parameters were found within the permissible range and suitable for irrigation and domestic purpose.

1. Introduction

A large number of problems are associated with occurrence, use and control of water resources in developed as well as in developing nations which may cause direct impact on the sustainable development of these resources. Although three fourth earth surfaces are covered with water even then we have only 1% usable water in rivers, lake and subsoil aquifers. A large number of people are dependent on freshwater aquatic ecosystems for their personal and domestic needs such as drinking water, washing, cooking, watering animals, and irrigating fields. At a global level 70% of water is used for agriculture about 25% for industry and only 5% for domestic use (Bharucha 2004). Industrialized countries consume greater percentage of water resources as compared to other countries.90% of water is used for agriculture in India and only 7% for industry and 3% for domestic use.

A high pressure on all water bodies have been exerted due to fast growth in industrialization, urbanization and agricultural revolution along with population growth, which is prime reason for all these developmental activities. And unfortunately all these developmental activities are responsible for fast depletion and deterioration of these available water resources (Gangwar 2013). Also point as well as nonpoint sources are responsible for impaired conditions of freshwater bodies. Pollutants from wastewater, municipal, domestic and industrial effluents are point sources which continuously add organic, inorganic and toxic pollutants respectively in surface water bodies. Pollutants from non-point sources are nutrients through fertilizers, toxic pesticides and other chemicals; mainly from agriculture runoff (Aenab and Singh 2013, Ravi kumar et al. 2013). Bhindawas lake is situated in between agricultural fields and surrounded by more than five villages so its water may be used for irrigation and domestic use. So it is necessary to check suitability of lake water for irrigation purpose. Major ions (cations and anions) Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Kelly's Ratio(KR) and some other physicochemical parameters like conductivity, temperature, total dissolved solids, alkalinity, acidity, and hardness of the water was determined. The main objective of present study is to assess the major ion chemistry and irrigation water quality parameters of water in Bhindawas lake for its suitability for irrigation and domestic purpose. Time to time water quality monitoring has a high priority for the determination of current status and long term trends for effective management of water resources.

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2. Site Selection for study:

The present study area is located from 80 kms west of Delhi and 20 km from Jhajjhar, on the Jhajjar-Kosli road. Bhindawas Lake is situated 28 37' 29" N and 76 40' 60" E coordinates and is at an altitude of 200 m. The lake is spread

Fig. 1: Sampling locations in Bhindawas Lake

over an area of 1074 acres and larger than the Sultanpur Bird Sanctuary. The peripheral embankment is man-made and basically constructed to store the escaped water of Jawaharlal Nehru canal through an escape channel at the time of power failure of Lift Canal System. The Bhindawas lake is being used by the migratory and resident birds of about 250 species. This sanctuary is situated in between a number of villages namely Kanwah, Bilochpura, Nawada, Redhuwas, Shanjhanpur and Chadwana. The periphery of the sanctuary is 12 km. Temperature varies between 14℃ in winter and 47 ℃ is summer. Average annual rainfall is 800 mm. Bhindawas Sanctuary is surrounded by agricultural crop fields.

2. Materials and Methods

Surface water samples were collected in pre-cleaned polyethylene bottles from ten different locations in Bhindawas lake during summer (Post monsoon) season as per the standard procedures.(APHA 2005). The location of these samples is shown in Figure 1. The water samples were analyzed at Microbiology Lab, DTU, Delhi. Samples of post-monsoon were studied for various physico-chemical parameters which include pH, EC, TDS, TH, major ions, cations such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and anions Cl^{-}, $SO4^{2-}$, $PO4,^{-}NO3^{-}$ and $HCO3^{2-}$. The pH was measured using the digital pH meter, EC and TDS was determined on site with the help of multi meter and standard titration method was used for Total Hardness, $HCO3^{2-}$ and Cl^{-} .$Na^{+,}$ Ca^{2+}, and K^{+} were analyzed by flame photometry. Sulfate was estimated by the Barium chloride method, PO4,by Stannous chloride method and Nitrate was analyzed by Brucine method by using UV-visible spectrophotometer. Sodium Adsorption Ratio (SAR), the Soluble Sodium percentage (SSP), the Residual Sodium Carbonate (RSC) and Kelly's ratio were determined by the methods described by Richards (1954), Todd (1980), Eaton (1950) and Kelly (1953) respectively. The analytical data of surface water samples are presented in Table 1.

Table 1. Analytical data of surface water samples in Bhindawas lake during Summer season.

Sample no. → Parameters ▼	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Min	Max	Mean
pH	6.9	7.1	7.1	6.8	7.4	6.7	7	7.3	6.5	7.1	6.5	7.4	6.99
Temp (℃)	33.1	32	33.2	36.2	35.8	37.3	34.7	35.7	26.5	34.3	26.5	37.3	33.88
EC (ds/m)	0.338	0.337	0.341	0.348	0.700	0.353	0.353	0.343	0.416	0.347	0.337	0.700	0.388
TDS(mg/l)	166	166	168	171	344	173	176	169	204	170	166	344	190.7
TH(mg/l)	170	170	150	170	160	180	150	180	190	180	150	190	170
Cl^{-}(meq/l)	1.41	0.85	0.85	1.13	0.85	1.13	1.13	1.13	1.69	1.41	0.85	1.69	1.15
$SO4^{2}$(mg/l)	86.21	85.17	82.46	75.97	774.48	75.78	77.25	82.74	101.7	86.92	75.78	774.48	152.87
$PO4,^{-}$ (meq/l)	0.03	0.03	0.19	0.04	0.05	0.06	0.03	0.12	0.22	0.20	0.03	0.22	0.10
$NO3^{-}$(meq/l)	0.30	0.20	0.40	0.23	0.16	0.17	0.30	0.24	0.17	0.41	0.16	0.41	0.26
$HCO3^{2}$(meq/l)	2.4	2.6	4	4.2	2.2	2.2	2.6	2.2	3	2.6	2.2	4	2.8
Ca^{2+}(meq/l)	0.70	0.70	0.69	0.70	0.69	0.69	0.69	0.67	0.88	0.68	0.67	0.88	0.71
Mg^{2+}(meq/l)	1.40	1.40	1.60	1.40	1.40	1.40	1.20	2	1.20	2	1.20	2	1.50
Na^{+}(meq/l)	0.38	0.38	0.35	0.36	0.36	0.35	0.36	0.35	0.72	0.37	0.35	0.72	0.40
K^{+}(meq/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01

3. Results and Discussion

Analytical data of surface water samples in Bhindawas lake during Summer season is shown in Table no. 1.

3.1 Water Quality

3.1.1. Temperature, pH and EC

The temperature, pH and EC ranged from the highest of 37.3ºC,7.4 and 0.700ds/m to the lowest of 26.5ºC, 6.5 and 0.337ds/m respectively. According to UCCC (1974),all the parameters, temperature and EC and pH are within the acceptable range. Electrical Conductivity measures the capacity of a substance/solution to conduct electric current. Total dissolved salts are directly related to EC of water. (Hari lal et al. 2004) and is used as an index to represent the total concentration of soluble salts in water (Gupta et al. 2008). As the lake is surrounded by many villages and agricultural land so man made activities such as waste disposal, and agricultural runoff may be the cause for addition of organic and inorganic waste. (Pandit 2002). The irrigation water of the Bhindawas lake is suitable for domestic and irrigation purpose as it falls under category

'slight to moderate' in terms of degree of restriction on use of EC.

Table 2: Irrigation Water quality parameters

Sample no													
Parameters	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**Min**	**Max**	**Mean**
SAR	0.135	0.134	0.107	0.123	0.123	0.118	0.137	0.092	0.492	0.102	0.092	0.137	0.156
SSP(%)	15.17	15.08	13.21	14.58	14.58	14.34	15.92	11.56	25.41	12.08	11.56	25.41	15.19
RSC(meq/l)	0.30	0.50	1.71	2.10	0.11	0.11	0.71	-0.47	0.92	-0.08	-0.08	2.10	0.59
KR	0.18	0.18	0.15	0.17	0.17	0.17	0.19	0.13	0.34	0.14	0.13	0.34	0.18

Table 3 Guidelines for Interpretations of Water Quality for Irrigation (UCCC, 1974)

Potential Irrigation Problem		Units	Degree of restrictions on use		Severe
			None	Slight to moderate	
Salinity (affect crop water availability)					
EC_w		ds/m	< 0.7	0.7-3.0	> 3.0
Or					
TDS		mg/l	< 450	450-2000	> 2000
Infiltration (affect infiltration of water into the soil Evaluate using EC_w and SAR together)					
SAR	0-3	EC_w	0.7	0.7-0.2	<0.2
	3-6		> 1.2	1.2-0.3	<0.3
	6-12		> 1.9	1.9-0.5	<0.5
	12-20		> 2.9	2.9-1.3	<1.3
	20-40		> 5.0	5.0-2.9	<1.9
Specific Ion Toxicity					
Sodium		meq/l	< 3.0	3.0-9.0	>9.0
Chloride		meq/l	< 4.0	4.0-10.0	>10.0
Boron		meq/l	< 0.7	0.7-3.0	>3.0
Miscellaneous effect					
Nitrogen(NO_3-N)		meq/l	< 5	5-30	>30
Bicarbonate (HCO_3^2)		meq/l	0-120	120-180	180-600
Carbonarte(CO_3^2)		meq/l			
pH		Normal Range		6.5 – 8.4	

3.1.2 Total Hardness and Total Dissolved Solids

Total Hardness in water is due to presence of carbonates and bicarbonates of calcium and magnesium ions. Total hardness values of surface water in lake were investigated from 150 mg/l to 190 mg/l with average value of 170 mg/l. According to WHO standards the water of Bhindawas lake is very hard and unsuitable for domestic use. Total Dissolved Solids(TDS) is most important parameter which plays major role in the determination of irrigation water quality, because many of the toxic(organic or inorganic solids) substances may be found in the water, Matthess, 1982 investigated that presence of toxic substances dissolved in water may affect the plants.TDS and EC are indicative of saline water (Michael 1992).TDS values ranged from 166mg/l to 344mg/l with average value of 190.7mg/l at sample locationsS1,S2(166mg/l),S5(344 mg/l). This indicates the category of none' according to the degree of restriction on use (Table 3).An adequate amount of salinity is required by plants for their growth. Very high acidic and very high saline, both these conditions affects the productivity as well as survivality of plants. Irrigation water with high sodium (Na^+) can bring about a displacement of exchangeable cation Ca^{2+} and Mg^{2+} from the clay minerals of the soil.

3.1.3 Alkalinity and Chlorides

Alkalinity is a measure of the ability of water to neutralize acids. Bicarbonates, carbonates and hydroxide of calcium, magnesium, sodium, potassium and salts of weak acids and strong bases as borates, silicates, phosphates, etc are responsible for alkalinity of surface water. Alkalinity of surface water of Bhindawas lake is mainly due to presence of bicarbonates which ranged from 2.2 meq/l to 4 meq/l which falls in none category according to degree of restriction on use by guidelines from UCCC, 1974. Due to presence of excess alkalinity in water a bitter taste was felt. Excess amount of Alkalinity is harmful for irrigation as it damages soil and hence reduces crop yields (Sundar and Saseetharan 2008). In terms of degree of restriction on use of $HCO3^-$ and $CO3^{2-}$ they fall under category 'none'. High chloride content indicates heavy pollution. It can be due to the uses of inorganic fertilizer, leachates from landfills, industrial and irrigation drainage. Chloride concentrations in the study area have a range from 0.85meq/l to 1.69 meq/l in the surface water samples during post-monsoon periods at sampling locations S2 and S9 respectively. The value of chlorides is below the range and have no harmful impact and suitable for domestic and irrigation use.

3.1.4 Sulphate, Phosphate and Nitrates

$SO4^{2-}$ concentration is possibly contributed by the type of precipitation and excess use of fertilizers in paddy cultivation. The sulphate in the surface water ranged from 75.78 mg/l to 774.48 mg/l with a mean of 152.87 mg/l during the post-monsoon season. Similar results were observed by Deepika and Singh, 2015 in Bhalswa lake during premonsoon season. The maximum permissible limit $SO4^{2-}$ was 250 mg/l. The highest (774.48mg/l) value was observed at sample location S5.This could be due to high microbial degradation in summer season. Phosphate and nitrate are major anions, which are very important water quality parameters of lake water. Their excess concentration can have harmful impact on flora and fauna of lake ecosystem. Excess runoff of phosphates and nitrates cause eutrophication of lake. (Vyas et al. 2006). The phosphate in surface water found in range between 0.03meq/l to 0.22 meq/l with mean valueo.10 meq/l and value of nitrates were observed in range between0.16meq/l to 0.41meq/l with mean value0.26meq/l.The permissible limit of phosphate is 0.3 mg/l(0.01meq/l) in water.And all of sampling locations have value beyond this limit, which indicates the eutrophic nature of lake.But the values of nitrates are below permissible limits.

3.1.5 Calcium and Magnesium

All the surface water samples have lower Ca^{2+} than permissible limits of < 200 mg/l as per standards WHO standards. The S8 sampling station have minimum value, 0.67meq/l and high value Ca^{2+} was observed at sample locationS9 of Bhindawas lake. Mg^{2+} in surface water for post-monsoon periods varies from 2 to 1.20 meq/l . The average amount of magnesium present in water samples of the post-monsoon season is 1.50 meq/l. It seems that the average values of Ca^{2+}& Mg^{2+} are within the permissible limits as per WHO. All the analyzed water samples at each sampling locations have values suitable for drinking purposes, since the values of Mg^{2+} are within the permissible limits (<150 mg/l) as per the BIS standards.

3.2 Irrigational quality parameters

Base criteria for evaluating the irrigation water quality are calculations of SAR (Sodium Absorption Ratio), which is the measure of solidity of the water, SSP (sodium soluble percentage), RSC (Residual sodium carbonate), KR (Kelly ratio), cations and anions.

3.2.1. Sodium absorption ratio

If the SAR ratio of the water samples in the study area is less than 10, it is excellent for irrigation purposes. The SAR values for each water sample were calculated using the following equation (Richards 1954).

$$SAR = \frac{Na}{\frac{Ca + Mg}{2}} \quad (1)$$

Sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). A significant relationship between SAR values of irrigation water and extent to sodium adsorbed by the soil. High sodium and low calcium in water raises the cation exchange between water and soil and is responsible for saturated sodium in an irrigated area. The values of SAR of the water samples from the study area ranged from 0.092 to 0.137 with an average value of 0.156. According to Richards (1954), for salinity classification, all the irrigation water samples fell under no sodium hazard and no salinity hazard.

Table 4 Classification of irrigation water based on SAR

S No	Types of water and SAR value	Quality	Suitability for irrigation
1	Low sodium water (S1) SAR value: 0-10	Excellent	Suitable for all types of crops and all types of soils, except for those crops which are sensitive to Sodium
2	Medium sodium water(S2) SAR Value: 10-18	Good	Suitable for coarse textured or organic soil with good permeability Relatively unsuitable in fine textured soils
3	High sodium water(S3) SAR Value: 18-29	Fair	Harmful for almost all types of soil, Requires good drainage, high leaching gypsum addition
4	Very High sodium water(S4) SAR value >26	Poor	Unusable for irrigation

Table 5 Sodium percent water class (Wilcox 1995)

Sodium Percentage	Water Class
20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
>80	Unsuitable

Irrigation water rich in $HCO3^-$ tends to precipitate insoluble Ca^{2+} and Mg^{2+} in the soil which ultimately leaves higher proportion of Na^+ and increase the SAR value (Michael, 1992) as shown in eq. (2):

$$2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + H_2O + CO_2 \uparrow \quad (2)$$

3.2.2. Percent Sodium

It has been recommended that percentage of sodium in irrigation water should not exceed 50–60, this is in order to avoid its harmful effects on soil. When the percent sodium exceeds 60, the water is considered to be unsuitable for irrigation purposes. It is considered, that water is of excellent quality if the % sodium is less than 20 % and beyond 80% water is of poorest quality.

SSP = Na x 100/(Ca + Mg + Na) (3)

All values of Na, Ca and Mg is in meq/l.

The average Soluble Sodium Percentage (SSP) value was found to be 15.19% with minimum value,11.56% at sampling station S8 and maximum value,25.41% at sampling station S9 indicating that all the sapling stations have percentage value excellent except sampling station S9.Based on water class we concluded lake water is highly suitable for domestic as well as irrigation use.

3.2.3. Residual sodium carbonate

If the water contains a high concentration of bicarbonate ion, then it is responsible for increase in sodium hazard . As the soil solution becomes more concentrated, there is a tendency for calcium and magnesium to precipitate as carbonates thus, increasing the relative proportion of sodium . RSC can be calculated using the equation below employing data of alkalinity, calcium and magnesium.

$$RSC = (CO_3 + HCO_3 - (Ca + Mg))$$

Where all ionic concentrations are expressed in meq/L.

The mean RSC concentration in Bhindawas lake water was 0.59 meq/l with minimum value of -0.08 meq/l at sampling location S10 and maximum, 2.10meq/l at sampling location S4.Lake water showed maximum RSC value 2.10 at sampling location S4, illustrating that these waters are marginal/Doubtful for irrigation purpose. A positive RSC value indicates that the contents of dissolved Ca^{2+} and Mg^{2+} ions is less that of CO 3^{2-} and HCO 3^{-} (Raihan and Alam, 2008). RSC is not satisfied in the study area. To be considered satisfactory, irrigation water should have RSC value <5 meq/l (Gupta and Gupta, 1987).

Table 6: Water quality based on RSC (after Richards 1954)

RSC(meq/l)	Water Quality
<1.25	Safe/good
1.25-2.50	Marginal/Doubtful
>2.50	Unsuitable

Table 7: Water quality based on Kelly's Ratio

Range of Kelly's ratio	Category
<1	Suitable
1-2	Marginal
>2	Unsuitable

3.2.4. Kelly's Ratio (KR)

The concentration of Na^{+} measured against Ca^{2+} and Mg^{2+} is known as Kelly's ratio, based on which irrigation water can be rated(Kelly 1946 and Paliwal 1967). The concentration of Na^{+} is considered to be one of the prime concern in making the water unsuitable if Kelly's ratio is >1. As per the Kelly's ratio water from the study area are categorized into suitable if KR is <1, marginal, when KR is 1-2 and unsuitable if KR is >2. The majority of surface water samples were suitable for irrigation (Table 7) with average value of 0.156 indicated suitable water for irrigation.

4. Conclusions

The quality of surface water in the present study area has been assessed for domestic and irrigation purposes using varies hydro chemical parameters and irrigation quality parameters that are suited for domestic and irrigation applications. The surface water from the study area has pH slightly acidic to alkaline in nature and are within permissible limits for drinking purposes. The EC values of the surface water in the study area reveal that the low sodium and low salinity hence the surface water is suitable for irrigation. In context of TDS value, concentration of dissolved solids is below permissible limits and quality of water is suitable for domestic and irrigation use but the range of Total hardness (TH) of the Bhindawas lake water is beyond permissible values and water is denoted very hard water and unfit for domestic use.water indicates that the majority of samples are unsuitable for domestic purposes due to high hardness; and therefore these are described as very hard and unsuitable for domestic, drinking and irrigation purposes. Major cations (Ca^{2+}, Mg^{2+}) from the surface water samples showed considerable variation during post monsoon season. In spite of the variation in their concentration during study period, the majority of samples have values within the permissible limits. The major cations in surface water distinctly exhibit decreasing order of their averages abundance as Mg^{2+}>Ca^{2+}>Na^{2+}.>K Similarly anions also have varying concentrations in decreasing order of their mean values as HCO3- > $SO4^{2-}$ > Cl > NO3 > PO4 during post-monsoon periods. The anionic concentration of Chloride is different from other anionic groups, since it is coherent with Na ion in the study area. Nitrates and phosphates are due to excess uses of fertilizers and organic material. The surface water of the study area are classified on the basis of Irrigation quality parameters like SAR, KR, RSC, SSP. The different physico-chemical parameters suggest that surface water in Bhindawas lake is good for irrigation use. But due to very high values of hardness at some sampling stations, restricts its use for domestic purpose. All the sampling locations have SAR value and KR value below 10 and below 2 respectively, which indicates excellent water quality of lake for irrigation. Also the values of SSP at each sampling locations is below 50 indicating good and safe water for irrigation. Also RSC value for all the samples range below 2.5 and also suitable for irrigation. According to present study it was found that all the parameters were found within the permissible range and suitable for irrigation and domestic purpose.

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