Ground Water Quality Assessment for Agricultural and Domestic Purposes in Hindustan College of Science and Technology Campus Farah Mathura, India

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Abstract

Ground and surface water in the Hindustan College of Science and Technology Campus Mathura, India has been analyzed to assess its suitability for, irrigation, domestic and drinking purposes. Different indices for irrigation uses such as Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Electrical Conductivity (EC), Magnesium Adsorption Ratio (MAR), Kellys Ratio (KR), Total Dissolved Solids (TDS) and Permeability Index (PI) were calculated from standard equations and employed to assess the suitability of groundwater for irrigation purposes in the study area. Water quality parameters such as pH, Hardness, Sulphate (SO4), Bicarbonate (HCO3), Chloride (Cl), Total Dissolved Solid (TDS), Electrical conductivity were experimentally determined and used to assess the suitability of water for domestic and drinking by comparing their values with WHO guidelines. Results indicate that although most of the standard are met for water to be suitable for irrigation purpose but the values of MAR and TDS limits the applicability of water except for raw water to RO for irrigation purpose. The results also indicate that that only treated RO water meets the standard of water to be suitable for drinking and raw water to RO can be suitable for other domestic uses. None of other water source is suitable either for domestic or drinking purpose.

Key Words: Irrigation, Domestic, Drinking, WHO, Indices

1. Introduction

Groundwater resources play a major role in ensuring livelihood security across the world, especially in economies that depend on agriculture. India has emerged as one of the largest users of groundwater particularly in irrigation and drinking purposes in the world (Shah 2009). The share of groundwater in the net irrigated area has also been on the rise. Of the addition to net irrigated area of about 29.75 million hectares between 1970 and 2007, groundwater accounted for 24.02 million hectares (80%), (Shankar et al.,2011). The problem needs urgent attention because groundwater is the major source of drinking water especially in rural areas. According to the latest available data from the National Sample Survey, 56% of the rural households get drinking water from hand pumps or tube wells, 14% from open wells and 25% from piped water systems based on groundwater (NSSO 2006). According to the department of drinking water supply (DDWS), GOI, nearly 90% of the rural water supply currently is sourced from groundwater. Though the share of drinking water in total water use is about 7% while irrigation accounts for over 80%, rapid expansion of groundwater irrigation can threaten drinking water security in the long run, since the resource for both uses is common. There is extreme overexploitation of the resource in some parts of the country coexisting with relatively low levels of extraction in others. Thus, the stage of groundwater development in Punjab (145%), Rajasthan (125%) and Haryana (109%) have reached unsustainable levels while Tamil Nadu (85%), Gujarat (76%) and UP (75%) are fast approaching that threshold (Shankar et al.,2011).

Besides the problem of over exploitation of ground water, there is also a severe problem with the ground water quality used for different purposes in India. Even while a district may be "safe" in terms of quantitative availability of groundwater, it is possible that it also has a high incidence of water quality problems. Official figures from department of drinking water supply (DDWS) state that out of 593 districts from which data is available, we have problems from high fluoride (203 districts), iron (206 districts), salinity (137 districts), nitrate (109 districts) and arsenic (35 districts) (DDWS 2006). Biological contamination problems causing enteric disorders are present throughout the country and probably constitute the problem of major concern, being linked with infant mortality, maternal health and related issues such as loss of valuable "work time". However, no clear estimates are available on the impact of this problem. It must be noted, however, that this summary is based on a sketchy nation-wide data and represents only the tip of the iceberg of water quality problems. The reality could be much grimmer than what is apparent here (Shankar et al.,2011). Therefore assessing the quality of ground water in different part of the country is essential to find its suitability for different use in India.

The definition of water quality is very much dependent on the desired use of water. Therefore different uses require different criteria of water quality as well as standard methods for reporting and comparing results of water analysis (Babiker 2007). Major chemical elements including Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, and SO_4^{2-} play a significant role in classifying and assessing groundwater quality. A few number of literatures are available regarding the assessment of groundwater quality data based on different irrigation indices in different areas of the world (Quddus and Zaman, 1996; Talukder *et al*., 1998; Shahidullah *et al*., 2000; Sarkar and Hassan, 2006; Raihan and Alam, 2008). Quddus and Zaman (1996) studied the irrigation water quality of some selected villages of Meherpur district of Bangladesh and argued that some of the following ions such as calcium, magnesium, sodium, bicarbonate, sulphate, chloride, potassium, boron and silica are more or less beneficial for crop growth and soil properties in little quantities.

Talukder *et al*. (1998) reported that poor quality irrigation water reduces soil productivity, changes soil physical and chemical properties, creates crop toxicity and ultimately reduces yield. Shahidullah *et al*. (2000) assessed the groundwater quality in Mymensigh district of Bangladesh and observed a linear relationship between SAR and SSP. They also discovered that the groundwater can safely be used for long-term irrigation. Sarkar and Hassan (2006) investigated the water quality of a roundwater basin in Bangladesh for irrigation purposes and observed that standard water quality indices like pH, EC, SAR, RSBC, MAR, PI, KR, and TDS are within the acceptable range for crop production. Raihan and Alam (2008) presented a pictorial representation of groundwater quality throughout the Sunamganj district that allowed for delineation of groundwater based on its suitability for irrigation purposes. Khodapanah et al., 2009 evaluateed suitability of water for drinking, domestic use and irrigation in Eshtehard District, Tehran, Iran**.** Finally Obiefuna and Orazulike (2010) carried out similar work in Yola area of Northeast Nigeria which indicated that the groundwater of the area is largely suitable for irrigation purposes.

In the present study hydro chemical assessment of the of ground and surface water in the Hindustan College of Science and Technology Campus Mathura, India was conducted by analyzing different water samples collected from different sources of ground and surface water .in the campus to assess chemical groundwater compositions and its suitability for different uses (i.e. domestic, irrigation and drinking purposes). Different indices for irrigation uses such as Sodium Adsorption Ratio (Sar), Soluble Sodium Percentage (SSP), Electrical Conductivity (EC), Magnesium Adsorption Ratio (MAR), Kellys Ratio (KR), Total Dissolved Solids (TDS) and Permeability Index (PI) were calculated from standard equations and employed to assess the suitability of groundwater for irrigation purposes in the study area. Drinking water quality parameters were compared with the WHO guidelines to assess its suitability for drinking purpose.

2. Data and Methods

2.1. Location and Hydrogeology of the Study Area

Hindustan College of Science and Technology campus is located near Farah town in Mathura district of Uttar Pradesh, India which is 27 km from Mathura City on Delhi-Agra Highway i.e. NH2. Area is spread across 34 acres land, The campus has a total built up area of 6,00,000 sq. ft. It is bordered by three cities namely Agra, Mathura, Bharatpur and it location is at 27°17'47"N 77°47'11"E . Yamuna River is the major perennial river in the area. Ground water occurs under unconfined and semi-confined condition. The depth to water table varies from 1.8 meter below ground level to 17.47 meter below ground level (mbgl) during pre-monsoon period and from 1.39 mbgl to 17.18 mbgl during post monsoon. The general direction of flow of ground water is from NNW to SSE (Rawat et al 2012). Water logging and salinity in ground water is a major problem in the area. The large quantity of ground water is of no use due to its high salinity.

2.2. Sampling and Analytical Procedure

Available sources of water in the campus are (i) Three sources of ground water (three bore well) (ii) Pond water, (iii) raw water which is imported from elsewhere through tankers and used in water treatment plant for drinking purpose and (iv) Rejected water from water treatment plant (hereafter referred to as RO reject) (v) Treated water from RO plant being used for drinking purpose. Sample collected from first 6 sources of water in the campus have been analyzed for assessing suitability for irrigation purpose. For assessing the suitability for domestic and drinking purpose one additional sample i.e. the treated water from RO apart from six previous samples has also been analyzed. The collected samples were analyzed for major ions such as Ca2+, Mg2+, Na+, K+, HCO3 $^{-}$, Cl $^{-}$ and SO4 $^{2-}$. Chemical analysis were performed in the environmental engineering laboratory of the college employing standard methods, The obtained chemical data was evaluated in terms of its suitability for agriculture, domestic and drinking purposes. Indices such as (i) Sodium adsorption Ratio (SAR) (ii) Soluble Sodium Percentage (SSP) (iii) Permeability Index (PI), magnesium Absorption Ratios (MAR) and (v) Kelley Ratios (KR) were calculated from the methods available in literature (Richards., 195; Todd., 1995; Khodapanah et al., 2009; Obiefuna and Orazulike (2010)) to assess the suitability of different sources of water for irrigation purposes. In addition drinking water quality parameters such as pH, Hardness, Sulphate , Bicarbonate , Chloride, Total Dissolved Solid (TDS), Electrical conductivity were evaluated and compared with the WHO guidelines to assess the suitability for domestic and drinking purposes.

3. Results and Discussion

3.1. Assessment of physicochemical qualities of groundwater:

Table 1 shows the variation in physiochemical parameters across different sources of water in the campus. Among major cations, Mg was generally dominant and ranges from 58.55% for pond water to 72.6 % for Borewell 2 warer respectively. Calcium ions were of secondary importance, ranging between 26.4 % for borewell 2 water to 39.4% for pond water respectively. Sodium ions was of even more secondary importance ranging from 2.9% for borewell 3 water to 8.4 % for pond water respectively. Potassium ion was almost absent with a minimum and maximum of 0.12% for borewell 3 water and 0.4% for raw water to RO plant. Among the major anions, the concentrations of chloride, sulfate and bicarbonate ions were determined. Chloride was ranging between 362 mg/l for raw water to RO to 3860.5mg/l for-Pond water. HCO3 ranges from 55.76 mg/l for raw water to RO and 1250 mg/l for Borewell 2 water. SO4 was found to lie between 28.55mg/l for raw water to RO to 830mg/l for pond. The order of their abundance is Cl-> HCO3>SO4. The electric conductivity (EC) varies from 1.8 Mhos for raw water to RO to 9.55 Mhos/cm for pond water. Total dissolved solids ranges from 1420 mg/l for raw water to RO to 6740 mg/l for pond water. The pH value of the study area water found to vary between 6.9 for borewell 2 water to a maximum of 8.2 for reject to RO indicating an alkaline nature. Turbidity varies between 0 NTU for borewell 1 water to 13.4 NTU for borewell 3 water. Total hardness was found to vary between 238 mg/l for raw water to RO and 6250 mg/l for borewell 2 water.

Table 1: **physicochemical parameters of ground water**

Parameter/Source	Borewell 1.	Borewell 2.	Borewell 3.	Pond	Raw to R.O.	Drinking	Reject R.O.
Temp 0c	22	22	22	21.5	20.5	20	20.5
pH	7.27	6.9	7.1	8.03	8.2	7.8	7.9
EC (Mhos/cm)	7.12	9.27	7.85	9.55	1.8	0.38	5.78
TDS (mg/L)	5010	6580	5550	6740	1420	280	3750
Turbidity (NTU)	0	0.4	13.4	3.4	3	1	2
Mg (mg/l)	2437.5	4543.7	3425	2781.2	157	20	501
Ca (mg/L)	1312.5	1706.2	1575	1968.7	81	5	300
Na (mg/L)	159.75	199.6	149.1	231.6	21.72	4.194	54.72
K (mg/L)	6.92	8.65	6.35	10.03	0.94	0.18	2.37
TH (mg/l)	3570	6250	5000	4750	238	20	801
Cl (mg/l)	2662.5	3328	2485	3860.5	362	69.9	912
HCO3 (mg/L)	642.6	1250	850	760	55.76	2.2	99.2
SO4 (mg/L)	210	670	650	830	28.55	5.45	71.13
% Mg	68.27	72.6	68.5	58.55	65.96	25	62.54
%Na	4.28	3.09	2.89	4.64	8.36	17.32	6.39
% Ca	33.51	26.41	30.55	39.44	31.07	17.021	34.9
% K	0.17	0.13	0.12	0.2	0.36	0.61	0.28

3.2. Assessment of Suitability of water for agricultural purpose

Salinity, sodicity and toxicity generally need to be considered for evaluation of the suitable quality of water for irrigation (Shainberg and Oster 1976). Good quality of waters for irrigation are therefore characterized by acceptable range of the indices like such as the Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR), Kellys Ratio (KR), Total Dissolved Solids (TDS) and the Permeability Index (PI). The sodium adsorption ratio (SAR) is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop. High Soluble Sodium Percentage (SSP) water for irrigation purpose may stunt the plant growth and reduces soil permeability (Joshi *et al*., 2009). More Magnesium Adsorption Ratio (MAR) in water will adversely affect crop yields as the soils become more saline (Joshi *et al*., 2009) because high magnesium adsorption ratio causes a harmful effect to soil when it exceeds 50%. Salts of calcium, magnesium, sodium, potassium when present in excessive quantities, reduce the osmotic activities of the plants and may prevent adequate aeration. The soil permeability is affected by the long-term use of irrigated water and the influencing constituents are the total dissolved solids, sodium bicarbonate and the soil type.

The results of the different irrigation indices for rating irrigation water quality are presented in Table 2 and compared with standard used for irrigation in Table 3 and Table 4. Values of SAR , SSP and KR are within the prescribed limit of water to be suitable for irrigation purpose (Table 3). However values of MAR and TDS are beyond the acceptable limit to be suitable for irrigation except for raw water to RO. Value of SAR obtained in the present study are generally less than 5 and fall under the category of C4SI (US Salinity Laboratory Staff, 1954), indicating low alkali hazards and suitability for irrigation. The SSP values water samples in the study area ranges between 3.01% for borewell 3 to 8.69 for raw to RO, indicating low alkali hazards (Class I) and therefore suitable for irrigation (Wilcox, 1950). Kellys Ratio (KR) values of the study area ranged between 0 and 0.029 for borewell 3 to 0.068 for reject to RO water. These indicate that all of the KR values for the water samples however fall within the permissible limit of 1.0 and are considered suitable for irrigation purposes. The values of The magnesium adsorption ratio of water sample in the present study varies from 58.54 % for pond water and 72.68 % for Borewell 2, indicating that they are above the acceptable limit of 50% (Ayers and Westcot, 1985). The waters are therefore, unsuitable for irrigation. The TDS value of the water sample in the study area ranges from 1420 for raw water to RO to 6740 for pond water indicating that only raw water to RO can be used for irrigation purposes (Robinove *et al*. 1958) (Table 4).. In the present study, the permeability index values range between 8.55 for borewell 3 to 18.03 for reject RO water which fall within Class II (Table 3) indicating that all water samples can be categorized as good irrigation water (Doneen, 1964).

Therefore it is inferred from the above results that although most of the standard are met for water to be suitable for irrigation purpose but the values of MAR and TDS limits the applicability of water except for raw water to RO for irrigation purpose.

Table 2: Different Indices of ground water

Parameters/Source	**Borewell 1**	**Borewell 2**	**Borewell 3.**	**Pond**	**Raw to R.O.**	**Reject R.O.**
SAR	3.78	3.57	2.98	4.75	1.99	2.73
SSP (%)	4.46	3.22	3.01	4.84	8.69	6.57
EC(Mhos/cm)	7.12	9.27	7.85	9.55	1.8	5.78
MAR (%)	68.27	72.68	68.5	58.54	65.96	63.42
KR(meq/L)	0.044	0.031	0.029	0.048	0.091	0.068
PI(%)	10.56961601	8.57668642	8.55775951	10.183298	37.1140531	18.033842
TDS (mg/L)	5010	6580	5550	6740	1420	3750

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Table 3: Limits of some ground water indices for rating ground water quality and its suitability for irrigation (Aiyer and Wesscot 1985, Eaton 1950)

Category	EC(μMhos/cm)	SAR	SSP (%)	Suitability for Irrigation
I	<117.509	<10	<20	Excellent
ii	<117.509	01--18	29-40	Good
III	508.61	16-26	40-80	Fair
iv	>503.61	>26	>80	Poor

Table 4: Range of Total Dissolved Solid for Irrigation Use (Robinove et al., 1958)

Classifications	Total Dissolved Solids (mg/L)	Remarks
Non saline	<1000	All sample fall in the study area
Slightly saline	1000-3000	NIL
Moderately saline	3000-10000	NIL
Very saline	>10000	NIL

3.3. Assessment of Suitability of water for Domestic Use

The water quality parameters such as pH, Hardness, Sulphate (SO4), Bicarbonate (HCO3), Chloride (Cl), Total Dissolved Solid (TDS), Electrical conductivity were used to assess the suitability of groundwater for domestic and drinking purpose by comparing these parameters of groundwater in the study area with the prescribed specification of World Health Organization (WHO, 2004). An additional source of water that is treated water from RO was also added in the sample to see its suitability for drinking purpose (Table 5).

Table 5: Water quality parameters analysis for the domestic use

Parameter / Source	Bore Well 1	Bore Well 2	Bore Well 3	Pond	Raw to R.O.	Drinking	R.O. Reject	WHO std, 2004
K (mg/l)	6.92	8.65	6.35	10.03	0.94	0.18	2.37	200
Na (mg/l)	159.75	199.6	149.1	231.6	21.72	4.194	54.72	200
Mg (mg/l)	2437.5	4543.7	3425	2781.2	157	20	501	150
Ca (mg/l)	1312.5	1706.2	1575	1968.7	81	5	300	200
SO4 (mg/l)	840	2680	2600	3320	114.2	21.8	284.52	250
Cl (mg/l)	2662.5	3328	2485	3860.5	362	69.9	912	250
HCO3 (mg/l)	642.6	1250	850	760	55.76	2.2	99.2	240
pH	7.27	6.9	7.1	8.03	8.2	7.8	7.9	6.5-9.5
TDS (mg/l)	5810	7480	6320	6740	1420	280	3750	1000
EC (Mhos/cm	8.1	10.59	8.9	9.55	1.8	0.38	5.78	1500
TH (mg/l)	3570	6250	5000	4750	238	20	801	500

The pH values of the groundwater vary between 6.9 to 8.3 for different sources of water indicating slightly alkaline to alkaline nature of water samples. According to the WHO, the range of desirable pH values of water prescribed for drinking purposes is 6.5 – 9.2 (WHO, 2004). There are no water samples with pH values outside of the desirable ranges.

Table 5 show that most of the parameters exceed the maximum permissible limits of WHO (2004). The EC is more than the maximum permissible limits of 1500 μmhos cm in all the samples. The concentration of TDS is also more than the maximum permissible limits of 1000 mg/ l in most of the sample except for the treated sample of RO water. Total hardness is also beyond the limit for most of the sample except for the raw water to RO and treated RO water. Water hardness has no known adverse effects; however, hard water is unsuitable for domestic use. Depending on factors such as pH and alkalinity, a hardness of more than about 200 mg/ l will lead to scale deposits in the piping system. In our case, result indicate that raw water to RO can be used for domestic use but not for drinking. The recommended limit for sodium concentration in drinking water is 200 mg/ l. A higher sodium intake may cause hypertension, congenial heart diseases and kidney problems (A.K. Singh, 2008). Concentrations of sodium are within the prescribed limit of 200 mg/ l in all the sample of study area. Sulphate occurs in water as the inorganic sulphate salts as well as dissolved gas (H2S). Sulphate is not a noxious substance although high sulphate in water may have a laxative effect. The concentration of sulphate4) in the study area is also beyond limit except for the sample of Raw water to RO and treated RO water. Bicarbonate combines with calcium carbonate and sulphate to form heat retarding, pipe clogging scale in boilers and in other heat exchange equipment. In the study area, the concentration of bicarbonate (HCO3) is within the limit for three samples namely raw water to RO, Rejected water from RO and treated water from RO. High concentration of chloride in water is known to cause no health hazard. In the study area, the concentration of chloride is only acceptable for the drinking water which is treated water from RO. All other sample fall beyond the accepted limit of chloride.

Therefore it is inferred from the above result that only treated RO water meets the standard of water to be suitable for drinking and raw water to RO can be suitable for other domestic uses. None of other water is suitable either for domestic or drinking purpose.

Conclusions

Ground and surface water samples collected from different sources in the Hindustan College of Science and Technology Campus Mathura, India campus were analyzed to assess chemical groundwater compositions and its suitability for different uses (i.e. domestic, irrigation and drinking purposes). Sample collected from first 6 sources of water in the campus have been analyzed for assessing suitability for irrigation purpose. For assessing the suitability for domestic and drinking purpose one additional sample i.e. the treated water from RO apart from six previous samples has also been analyzed. Value of SAR obtained in the present study are generally less than 5 indicating low alkali hazards and suitable for irrigation. The SSP values water samples in the study area ranges between 3.01% for borewell 3 to 8.69 for raw to RO, indicating low alkali hazards and suitability for irrigation. Kellys Ratio (KR) values of the study area ranged between 0 and 0.029 for borewell 3 to 0.068 for reject to RO water. These indicate that all of the KR values for the water samples however fall within the permissible limit of 1.0 and are considered suitable for irrigation purposes. The permeability index values range between 8.55 for borewell 3 to 18.03 for reject RO water which fall within acceptable limit indicating that all water samples can be suited for irrigation. The values of The magnesium adsorption ratio (MAR) of water sample in the present study varies from 58.54 % for pond water and 72.68 % for Borewell 2, indicating that they are above the acceptable limit of 50% . The waters are therefore, unsuitable for irrigation. The TDS value of the water sample in the study area ranges from 1420 for raw water to RO to 6740 for pond water indicating that only raw water to RO can be used for irrigation purposes.. Therefore it is concluded from the above results that although most of the standard are met for water to be suitable for irrigation purpose but the values of MAR and TDS limits the applicability of water except for raw water to RO for irrigation purpose.

The pH values of the groundwater vary between 6.9 to 8.3 for different sources of water indicating slightly alkaline to alkaline nature of water samples which are within the prescribed limit of WHO guidelines. The EC is more than the maximum permissible limits of 1500 μmhos cm in all the samples. The concentration of TDS is also more than the maximum permissible limits of 1000 mg/ l in most of the sample except for the treated sample of RO water. Total hardness is also beyond the limit for most of the sample except for the raw water to RO and treated RO water. Results indicate that raw water to RO can be used for domestic use but not for drinking. Concentrations of sodium are within the prescribed limit of 200 mg/ l in all the sample of study area. The concentration of sulphate in the study area is also beyond limit except for the sample of Raw water to RO and treated RO water. The concentration of bicarbonate (HCO3) is within the limit for three samples namely raw water to RO, Rejected water from RO and treated water from RO. The concentration of chloride is only acceptable for the drinking water which is treated water from RO. All other sample fall beyond the accepted limit of chloride. Therefore it is inferred from the above result that only treated RO water meets the standard of water to be suitable for drinking and raw water to RO can be suitable for other domestic uses. None of other water is suitable either for domestic or drinking purpose.

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