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Ground Water Suitability for Domestic and Irrigation Purpose at Villages of Meham Block, Rohtak, Haryana, India

Amarjeet[1], Sandeep Kumar[1], Sunder Singh Arya[2], Sunil Kumar[1*]

[1]Department of Environment Science, M. D. University, Rohtak-124001, Haryana, India

[2]Department of Botany, M. D. University, Rohtak-124001, Haryana, India

E-mail address: sunilevs@yahoo.com

ABSTRACT

The present study was carried out to assess the suitability of Meham Block ground water for domestic and agriculture purpose. Total fifty seven samples of ground water (well, tube well and hand pump) from nineteen villages were collected and analysed according, APHA. Groundwater assessment for domestic purposed was determined by computing the standard indices such as ground water quality index (GWQI), synthetic pollution index (SPI) and by comparing the measured water parameter with desirable and highest permissible limits of WHO and BIS. GWQI and SPI ranged from 90.46-534.09 and 1.14-3.09, respectively. GWQI and SPI indicate that ground water of study area was unfit for drinking purpose. Agriculture parameters such as sodium absorption ratio (SAR) was ranging from 0.448 to 9.396 while, residual sodium carbonate (RSC) of ground water was ranging from -7.434 to 7.552epm, In the present study 60% ground water samples were exceed the desirable limit 50% value of magnesium. According to Permeability Index (PI), 88.8% samples of ground water in study area showed the class I, 9.2 % sample showed class II and 1% samples were of class III. US salinity diagram which showed that 11.1% of ground water samples were of C2S1 indicating the medium salinity to low alkali class, whereas 50% sample were of C3S1 class indicating high salinity to low alkali class and 29% of the samples come under C4S1 class indicating the very high salinity to low alkali class. Base exchange indices showed that 64.8 % ground water samples are classified as Na^{+}-SO_4^{2-} type (r1<1) and rest are Na^{+}-HCO_3^{-} type (r1>1).

Keywords: Water quality index, Synthetic pollution index, Sodium absorption ratio

INTRODUCTION

Groundwater contribution in rural areas for drinking purpose is about 88%, where water treatment and transport do not exist (kumar et al., 2010). By understanding the chemistry of groundwater, we can determine its usefulness for domestic and agricultural purposes. If the quality of ground water is good then it can yield better crops under good soil and water management practices. Factors like the quality of water, soil type, salt tolerance characteristics of plants, climate and drainage decides the suitability of irrigation water in agriculture sector (Michael, 1990). There are many salts present in ground water and quality of these salts depends upon the sources for recharge and the strata through which it flows. Ground water depends on the parent rock, intensity of weathering, residence time and external factors, such as precipitation and temperature, control the concentration of major and minor ions in groundwater (Rajmohan and Elango, 2004; Liu et al., 2008; Singh et al., 2008; Rajmohan et al., 2009; Tirumalesh et al., 2010; Singh et al., 2011; Zhu and Schwartz, 2011; Rajesh et al., 2012). Ground water also contaminated through leaks and spills at factories, improper hazardous waste disposal, leachate from landfills, salts and chemicals used to deice roads, fertilizers, animal wastes and by radioactive elements (Garg et al., 2009). Today irrigated agriculture is the largest abstractor and consumer of groundwater, with almost 40% of all cultivated land under irrigation being irrigated by ground water in South & East Asia. Intensive agricultural activities have increased the demand on groundwater resources in India.

The Rohtak district is occupied by Indo-Gangetic alluvial plain of Quaternary age, and falls in Yamuna sub –basin of Ganga basin. Ground water is potable at places along canals and surface water bodies like ponds and depressions, where salinity has decreased and is collected for drinking purposes. Ground water of Rohtak district at shallow depth of 20 m is fresh and fit for irrigation. The deep ground water is saline and salinity increases with depth and that water is not fit for irrigation (CGWB, 2007). Keeping in view of associated problems with ground water in Meham block of Rohtak district, present study was carried out to find out its suitability for domestic and agriculture purpose.

MATERIAL AND METHOD

Study area

Map of study area is given in figure 1. Rohtak district of Haryana lies between 28º40’: 29º 05’ N latitudes and 76º13’: 76º 51’E longitudes and 220 meters above mean sea level. District geographical area is 1745 sq.km. There are five blocks in Rohtak, Meham is one of them. The study area extends over the Meham block which is situated on the north- west of the district Rohtak. This block has a rural area of 36977 hectares. Due to good network of canals, the region has shown great progress in the field of agriculture. The climate of Meham Block can be classified as subtropical monsoon, mild & dry winter, hot summer and sub-humid which is mainly dry with very hot summer and cold winter except during monsoon season when moist air of oceanic origin penetrates into the district. The climate is ideal for agricultural development, particularly for wheat, rice, sugarcane and cotton crops. Limited rainy season, good and healthy climate is suitable for industrial development also. Normal annual rainfall is 592 mm and normal monsoon rainfall is 499 mm. Temperature varies from 3◦C (January) to 45◦C (May and June).The sediments consist of sand, slit, clay, gravel and kankar. The soil texture varies from sandy to clay having heterogenous composition with frequent calcium carbonate layers at shallower depths. The soil is coarse to fine loam in texture in most of the area. 10% of the total soil is affected by salinity and alkalinity problem due to poor drainage, brackish waters and compact kankar layer below root zone (CGWB, 2007).

Water sampling and Analysis

Fifty seven samples of ground water were collected during the month of January 2014 from 19 villages of Meham block, district Rohtak, Haryana. From each village, three samples were collected by selecting one from each, tube well, well and hand pump, which were extensively used for drinking and irrigation purpose. Electric conductivity and pH were measured using Systonic soil and water testing kit at the sites. For the analysis of other parameters, samples were collected in clean Jerry canes and kept in ice boxes and transported immediately to the laboratory. The water samples were filtered using a Millipore filtering system and analyzed according with Standard Methods of Examination of Water and Waste as prescribed by American Public Health Association (APHA, 2005). Sodium absorption ratio and per cent sodium were calculated by following (Richards, 1954) and (Wilcox, 1995) expressions, respectively. Residual sodium carbonate and base-exchange indices were estimated by following (Sadashivaiah and Soltan, 1998) equations, respectively. Magnesium ratio and permeability index measured accordance with (Szabolcs and Darab, 1964) and (Doneen, 1964), where alkali and salinity hazard was calculated as per given by US salinity lab (1954).

The data was statistically analyzed using Microsoft Excel. Mean, minimum, maximum and standard deviation of different samples was calculated by MS Excel.

Calculation for Ground Water Quality Index (GWQI) and Synthetic Pollution Index (SPI)

Domestic suitability was determined by computing the standard indices such as ground water quality index (GWQI), synthetic pollution index (SPI) and by comparing the measured water parameters with desirable and highest permissible limits of WHO and BIS. The WQI was calculated accordance with Tiwari and Mishra (1985) and synthetic pollution index (SPI) by following Ma et al., (2009). These indices are very useful and efficient methods for assessing the quality of water and presently used by many scientists and water managers. To determine the suitability of the water for drinking purposes, GWQI can be estimated by using the following methodology:

$$GWQI = [(\sum_{i=1}^{n} Q_i \times W_i) / (\sum_{i=1}^{n} W_i)] \quad (1)$$

Where W_i is the weighting factor computed by using the Eq. 2

$$W_i = \frac{1}{S_i} \quad (2)$$

Where, S_i is the highest permissible limits WHO (1997) of the water quality parameter. The Qi is calculated by using following expression

$$Qi = [(V_{actual} - V_{ideal})/(V_{standard} - V_{ideal})] \times 100 \quad (3)$$

Where V_{actual} is the value of the water quality parameter obtained from laboratory analysis, V_{ideal} is the desirable value of parameter given by WHO (1997) and $V_{standard}$ is the highest permissible limit of parameter prescribed by WHO (1997).

Another index which can be used to integrate the impact of various pollutants on the water quality is synthetic pollution index (SPI) given by Ouyang et al. (2006) and earlier described by Ma et al. (2009). The index is calculated using the following Eq. 4

$$P_r = \sum_{i=0}^{n} P_i \times W_i$$

$$P_i = \frac{C_i}{C_{io}}$$

Where Pr is the synthetic pollution index, Pi is the pollution index of pollutant i, Ci is the measured concentration of pollutant i, Cio is the evaluation criteria of pollutant i. The criteria used in monitoring sections are from the corresponding highest permissible standards given by WHO (1997).

RESULT AND DISCUSSION

Geomorphology of an area largely influences the parameters of the groundwater. Soil of Meham block is loamy with coarse loam and alluvian. The present study involves the analysis of ground water of Meham block (Rohtak) with a view to evaluate the suitability of this groundwater for domestic and agriculture purpose.

Suitability of Groundwater for Domestic Purpose

Table 1 shows the range of different analysed ground water parameters with maximum desirable and highest permissible limits prescribed by WHO (1997) and BIS (1991). The pH values of water samples in study area were within highest permissible limit of WHO and BIS, however two samples exceeded the maximum desirable limit (8.5) of WHO and BIS. EC and TDS in 89.4% water samples were exceeded the maximum desirable limit (750 µmho/cm & 500 mg/l) of WHO and BIS, respectively, while TDS concentration in 35% samples were higher than highest permissible limit of (1500 mg/l) prescribed by WHO and 21% samples showed the greater concentration than highest permissible limit (2000 mg/l) given by BIS. 85.9% water samples shown the excess sodium concentration than the recommended (50 mg/l) desirable limit of WHO. The sodium content in 9% of the evaluated samples is found to be more than its highest permissible quantity i.e. 200 mg/l of WHO. Calcium concentration in 52.6% samples were exceeded the maximum desirable limit (75 mg/l) of WHO and BIS, however all the samples were within the highest permissible limit of WHO and BIS. 77.1 % water samples showed the excess magnesium concentration that the recommended maximum desirable limit (30 mg/l) of WHO and BIS, while 12.2% water samples showed the greater concentration than the (100 mg/l) highest permissible limit of BIS. Three samples showed the potassium level greater than (100 mg/l) maximum desirable limit of WHO. Sulphate concentration in six samples showed the exceeded level than recommended (200 mg/l) maximum desirable limit of WHO and BIS. One sample showed the excess concentration of chloride than the maximum desirable limit of WHO and BIS. 96 % water samples were exceeded the maximum desirable limit of bicarbonate (200 mg/l) prescribed by WHO and BIS, while bicarbonate in 29.8 % water samples were exceeded the highest permissible limit (600 mg/l) of WHO and BIS. Total alkalinity was exceeded in 47.3 % samples than maximum desirable limit (400 mg/l) of BIS and 31.1% samples were exceeded than maximum desirable limit (500 mg/l) of WHO. While two samples showed the greater concentration than (600 mg/l) highest permissible limit of WHO and BIS. All the water samples were greater values of total hardness than recommended (100 mg/l) maximum desirable limit of WHO, where 78.9 % water samples also showed the excess concentration of total hardness than (300 mg/l) the maximum desirable limit of BIS. Total hardness in 40.3% and 19.2% water samples were exceeded the highest permissible limit (500 mg/l) of WHO and (600 mg/l) BIS, respectively. The nitrate content in the 31.5 % samples in present study was found more than highest permissible limits (50 mg/l) given by WHO. 86% of the samples were exceeded than the highest permissible limit of fluoride concentration of WHO and BIS i.e. 1.5 mg l^{-1}.

Ground Water Quality Index (GWQI) and Synthetic Pollution Index (SPI)

Water quality index values (GWQI) and synthetic pollution index (SPI) of ground water of different villages has been given in Table 2 and ratings with category has been described in Table 3&4, respectively. Parametric mean of three samples from each village is used for calculation of GWQI and SPI, respectively. All the calculated values of GWQI in study area are explicitly higher than value of 100, except at village Gurawar, where the groundwater comes under the highly polluted category with value of 90.46. WQI value of greater than 100 (Table 3) indicates that ground water is unfit for drinking purpose. High value of fluoride in groundwater drastically increase the ground water quality index (GWQI), most of villages showed very high values (>100). Calculated SPI values of most of villages for ground water of studied area falls under the polluted category (0.5 – 3.0), where Bedwa and Madina Korsan shows the value more than 3.0, which indicates the ground water of these two villages come under moderately polluted category. Result indicates that the maximum (534) and minimum (90) value of ground water quality index is reported at Madina Korsan and at Gurawar village, respectively. The maximum (3.07) and minimum (1.149) value of synthetic pollution index is reported at Madina

Korsan and at Gurawar village, respectively. The study revealed that groundwater of Meham block was highly polluted and unfit for human consumption.

Suitability of Groundwater for Agriculture Purpose

Mean, maximum, minimum and standard deviation of different agriculture parameters have been described in Table 5. Suitability of ground water for irrigation purpose is mainly depends upon the estimation of parameters like sodium adsorption ratio (SAR), present sodium (%Na), residual sodium carbonate (RSC), total Na concentration and EC (Wilcox, 1995). Na is important cations which in excess deteorites soil structure and reduce crop yield. SAR was calculated using Richards1954 expression i.e

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}}$$

SAR score from 0-10 indicate the suitability of water for all types crops and soils, 10-18 suitable for coarse textured soil, 18-26 harmful for almost all types of soil and >26 unsuitable for irrigation. In the present study it was found that ground water samples fall in excellent categories. SAR was ranging from 0.448 to 9.396 with mean and standard deviation of 2.596 ± 1.993. Data on the SAR from ground water indicates that SAR was between the 0-10. It means that water is suitable for all types of crops and all types of soils except for those crops which are highly sensitive to sodium on the bases of SAR.

Present Sodium

The sodium in irrigation waters is usually denoted as percent sodium and can be determined using the following formula (Wilcox, 1995)

$$\% Na = (Na^{+}) X100 / (Ca^{2+} + Mg^{2+} + Na^{+1} + K^{+1})$$

The percentage of Na <20 is excellent, 20-40 good, 40-60 permissible, 60-80 doubtful and >80 unsuitable (Sadashivaiah et al., 2008). In the present study 25% sample come under the permissible category, 39.2% sample come under the good quality and 25% samples come under the excellent quality of ground water.

Residual sodium carbonate

In waters having high concentration of bicarbonate, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium.

Residual sodium carbonate was estimated by using Sadashivaiah (2008) equation i.e

$$RSC = (HCO3^{-} + CO3^{2-}) – (Ca^{2+} + Mg^{2+})$$

RSC in epm having range <1.25 come under good water quality, 1.25-2.5 come under doubtful and >2.5 unsuitable. According to the US Department of Agriculture, water having more than 2.5 epm of RSC is not suitable for irrigation purposes. In the present study 76% samples were having very good quality because most of the samples values are in minus EPM. 15% samples in study area were found unstable. High magnesium content in relation to total divalent cations in soil can adversely affect its physical properties. Its value more than 50% can be hazardous to soil. In the present study 60% ground water samples were exceed the 50% value of magnesium. Magnesium ratio proposed by Szabolcsand Darab (1964) i.e

$$\text{Magnesium ratio} = \frac{\text{Mg}}{\text{Mg+Ca}} \times 100$$

Permeability index

Permeability is the ease with which water can flow into the medium. This parameter is very important for retaining the water at a station. According to this index water can be classified into three classes. Class I and class II of water with 75% or more of maximum permeability is suitable for irrigation purpose, while class III water type having 25% of maximum permeability is not suitable (Fig. 2). Permeability index was estimated by using Doneen (1964) equation i.e

$$PI = \frac{\text{Na} + \sqrt{\text{HCO}_3}}{(\text{Ca+Mg+Na})} \times 100$$

88.8% samples of ground water in study area showed the class I, 9.2 % sample showed class II and 1% samples were of class III.

Alkali and salinity hazard: The total concentration of soluble salts in irrigation water can be categorized as low (EC < 250 µS/cm), medium (250–750 µS/cm), high (7502, 250 µS/cm), and very high (2,250–5,000 µS/cm). High salt concentration in water leads to formation of saline soil and high sodium concentration leads to development of an alkaline soil. The plot of data on the US salinity diagram (USSL 1954), is given in Fig.3 in which the EC is taken as salinity hazard and SAR as alkalinity hazard showed that 11.1% of ground water samples were of C2S1 indicating the medium salinity to low alkali class, whereas 50% sample were of C3S1 class indicating high salinity to low alkali class and 3.7% sample were come under the C1S1 and C4S2 class indicating low salinity to low alkali. 29% of the samples come under C4S1 class.

Base-exchange indices

If r1<1, the surface water sources are of Na^+-SO_4^{2-} type, while r1>1 indicates the sources are of Na^+-HCO_3^- type. The base-exchange indices were estimated using Eq. given by (Soltan, 1998, 1999) i.e

$$r_1 = \frac{Na + Cl}{SO_4}$$

Based on the base-exchange indices (r1), about 64.8 % Meham Block ground water samples are classified as Na^+-SO_4^{2-} type (r1<1) and rest are Na^+-HCO_3^- type (r1>1). Base-exchange indices of ground water were ranging from -1.989 to 5.179.

CONCLUSION

Total fifty seven ground water samples were collected from villages of Meham block to find out its suitability for domestic and agriculture purpose. TDS in 35% and 21% samples showed the greater concentration than highest permissible limit WHO and BIS, respectively. 86% of the samples were exceeded than the highest permissible limit of fluoride concentration of WHO. GWQI and SPI indicate that ground water of Meham block was highly polluted and unfit for human consumption. The ground water of Meham block is good for the agriculture purpose based on SAR. The study shows that the SAR value was between 0-10, which indicates water is suitable for all types of crops and all types of soils. The present revealed that in study area medium salinity to high salinity with low alkali present in ground water. About 64.8 % Meham Block ground water samples are classified as Na^+-SO_4^{2-}type (r1<1) and rest are Na^+-HCO_3^-type (r1>1).

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Table 1. Range in Values of Chemical Parameters and WHO (1997) and Indian Standards (IS: 10500).

S.No.	Parameters	Range of ground water parameters	WHO (1997) Max. Desirable (V_{ideal})	WHO (1997) Highest Permissible ($V_{standard}$)	BIS (1991) IS:10500 Max. desirable	BIS (1991) IS:10500 Highest permissible
1.	pH	7.1-8.6	7.0-8.5	6.5-9.2	6.5-8.5	6.5-9.2
2.	EC	210-5530	750	1500	-	-
3.	TDS	134-3539	500	1500	500	2000
4.	HCO_3^-	171-957	200	600	200	600
5.	SO_4^{2-}	30-377	200	600	200	400
6.	Cl^-	14-247	250	600	250	1000
7.	NO_3^-	1-98	-	50	45	100
8.	Ca^{2+}	12-199	75	200	75	200
9.	Mg^{2+}	12-122	30	150	30	100
10.	Na^+	15-314	50	200	-	-
11.	K^+	0-137	100	200	-	-
12.	TH	140-788	100	500	300	600
13.	F^-	0.57-6.21	1.0	1.5	1.0	1.5
14.	TA	140-784	500	600	400	600

All the parameters are in mg l^{-1},except pH and EC (µmho cm^{-1}).

Table 2 GWQI and SPI of Meham block , Rohtak , Haryana (India)

Sr. No.	Villages	WQI	SPI
1	Ajaib	399.2188	2.517448
2	Bahelbhah	351.6661	2.323745
3	Bedwa	520.1939	3.000258
4	Bhaini Bharan	406.0236	2.532021
5	Bhaini chanderpal	354.2385	2.323257
6	Bharon	202.4466	1.665001
7	Farma.khas	482.3899	2.757037
8	Farma.Badshapur	280.5547	1.894875
9	Gurawar	90.46275	1.14909
10	Khar khara	289.4316	2.060061
11	Kheri meham	337.0267	2.260728
12	Madina korsan	534.0936	3.070017
13	Madina Gindhran	352.7497	2.275956
14	Mokhra khas	453.4543	2.728279
15	Mokhra kheri	212.5547	1.675845
16	Seman	439.7733	2.663301
17	Sisar khas	454.5325	2.625622
18	Meham rural	227.7969	1.795978
19	Nindana	241.8719	1.856673

Table 3 Rating and category chart of GWQI

Sr. No.	GWQI	Water Quality
1	0-25	Suitable

2	26-50	Polluted
3	51-75	Moderately polluted
4	76-100	Highly polluted
5	>100	Unfit

Table 4 Rating and category chart of SPI

Sr. No.	Synthetic pollution index (SPI)	Category pollution
1	<0.5	Suitable
2	0.5-3	Polluted
3	3-5	Moderately polluted
4	5-10	Highly polluted
5	>10	Unfit

Table 5 Agriculture suitability parameters for ground water of Meham block, Rohtak

	SAR	RSC	%Na	%Mg	PI	BEI
Mean	2.596	-0.700	33.41	53.43	55.660	1.051
S.D.	1.993	0.001	17.11	53.15	76.654	1.247
Min.	0.448	-7.552	10.02	0.34	30.646	-1.989
Max.	9.396	7.552	78.88	78.61	102.683	5.179

Fig. 1 Map of Meham Block with sampling villages

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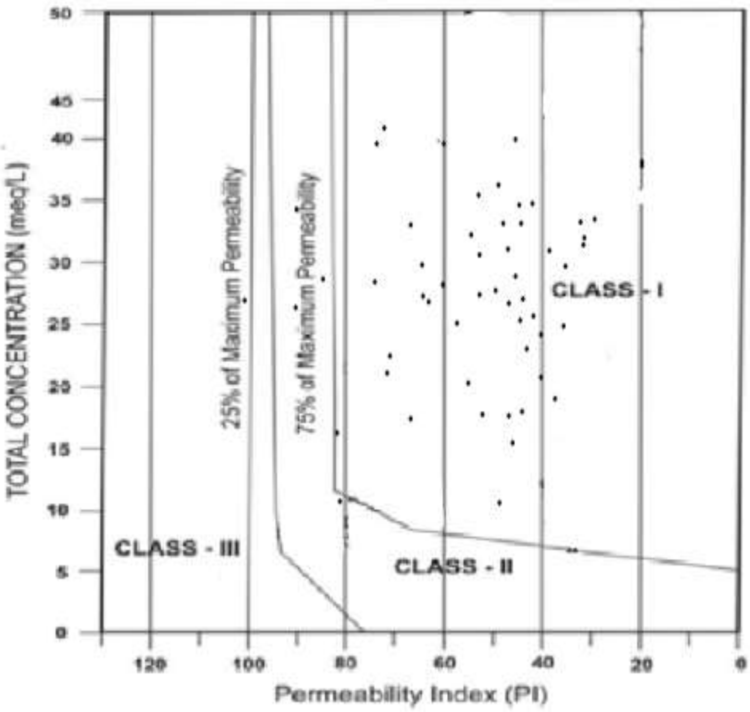

Figure 2 Classification of irrigation water based on Permeability Index

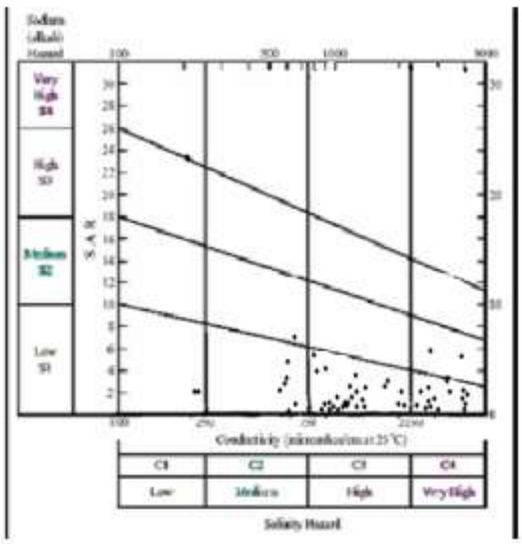

Figure 3 Classification of Meham block ground water