ESSENCE - International Journal for Environmental Rehabilitation and Conservation
Volume V: No. 1 2014 [36 – 46] [ISSN 0975 - 6272]
[www.essence-journal.com]

Assessment of ground water quality for drinking and irrigation suitability in Jaunpur District (U.P.) India

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Received: February 21, 2014 | **Accepted**: May 19, 2014 | **Online**: July 07, 2014

Abstract

The physico-chemical status of ground water samples from 21 blocks major part of locality in Jaunpur district was assessed. The sampling points were selected on the basis of irrigation and drinking purpose.The major hydro-chemical parameters for determine the quality of water as pH, Electrical conductivity, Turbidity, TDS, TS, Acidity, Alkalinity , Chloride , Bicarbonate, sulphate, Dissolved Oxygen, Total Hardness, Major cations (Ca^{++}, Mg^{++}, Na^{+}, k^{+},) and major anions (Cl^{-}, F^{-},NO_3^{-}, PO_4^{-} SO_4^{-} were analysed and compared with WHO Standards. The pH varies from 7.5 to 8.9, indicating alkaline nature. The electrical conductivity (EC) value varies between 484 and 3120 (µs/cm^{-1}) in the ground water. TDS varied from 443 to 2434 (mg/l) and higher concentration of dissolved ions was observed in the water samples. High values of salinity, sodium absorption ratio (SAR), Na%, residual sodium carbonate (RSC) and permeability index (PI) of ground water in some blocks of Jaunpur district were found unfit for drinking and irrigation purpose.

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Keywords: Physico-chemical parameters | Drinking quality | Irrigation suitability | Ground water

Introduction

The groundwater chemistry have contributed important information on the suitability of the groundwater for drinking and agricultural purposes, and presently its contamination has been recognized as one of the most serious water pollution problems in the world (Adams *et al*. 2001; Jalali 2007, 2009, Djabri *et al*. 2007). Groundwater is the only available water resource for human consumption, as well as for drinking and agriculture uses. It is estimated that approximately one-third of the world's population use groundwater for drinking (UNEP, 1999). Urbanization and unregulated growth of the population have altered local topography and drainage system directly affected both quality and quantity of the ground water.

Water is essential to the existence of human beings and other living organisms. Water is the precious gift of nature to the human being. The

quality of water is of vital concern for mankind since it is directly linked with human health, protection of the environment and sustainable development. Groundwater occurs almost everywhere beneath the earth surface not only in a single widespread aquifer, but also in thousands of local aquifer systems and compartments that have similar characters. Man's activities such as food production, nutrition are dependent on water availability in adequate quantities and good quality.

The rapid depletion of ground water quality through leaching of open dumping of solid wastes and thus the estimation of ground water quality of extremely importance for proper assessment of the associated health hazards (Mathur and Maheswari, 2005; Warhate *el al*, 2006). Groundwater resource in Jaunpur district is widely exploited for irrigation and other domestic purposes in addition to drinking purpose. The Jaunpur resident mainly depends on groundwater for their drinking and irrigation purpose. Sources of water pollution in the study area occurred mainly due to run off agriculture fertilizer, sewage, hospital waste etc. Concentration of pollutants more than permissible limits in drinking water leads to health problems, such as water borne diseases, like fluorosis, typhoid, jaundice, cholera, premature baby and other problems, especially in infants (Spalding and Exner, 1993).

Materials and Methods

Study area

Jaunpur district is one of the important districts of eastern part of Uttar Pradesh, India. It lies between 25^0 24' N and 26^0 12' N latitude and 81^0 19' E and 82^0 27' E longitude and located at of 261 to 290 meter from sea level with covering an area of about 4,038 km^2. According to the 2011 census, district had a population of 4,494204 with the rural and urban area both Population depend upon agriculture for their livelihood. The climate of district is extreme nature temperature deep 5 to 7 ^{0}C in winter season and 45 to 47 ^{0}C in summer season. Average rainfall in Jaunpur district is 987 mm.

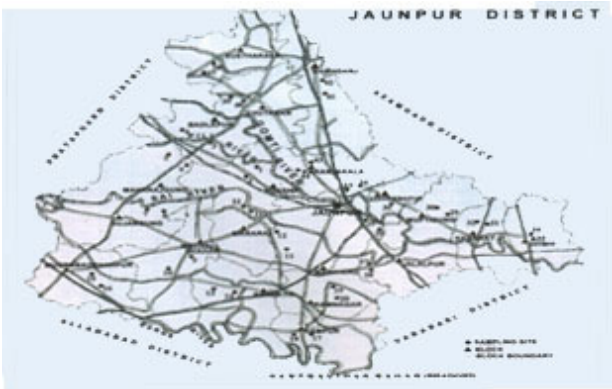

Fig.1: **Jaunpur district showing sampling sites**

Analytical methods

The ground water samples were collected using acid washed polypropylene bottles to avoid unpredictable changes in quality characteristic as per standard procedures. At the time of sampling, bottles were thoroughly rinsed two to three times before sampling. The measurements of physico-chemical parameters analyzed including Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Alkalinity, Acidity, Total Suspended Solids (TSS), total hardness were determined as per (APHA,1998) and major cations (Ca^{2+}, Mg^{2+},Na^+, K^+) and major anions (Cl^-, F^-, NO_3^- ,PO_4^-,SO_4^-) measured by UV

spectrophotometers and Some measurement of agricultural purpose for the suitability of irrigation like Sodium absorption ratio (SAR), Permeability index (PI), Residual sodium carbonate (RSC) calculated by following formula as.

Sodium absorption ratio (SAR)

Sodium absorption ratio is an important parameter to determine the suitability of irrigation water and was calculated by (Richards, 1954).

$$S.A.R = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Permeability index (PI)

Permeability index was calculated as per the method suggested by (Doneen, 1964)

PI= $[(Na^{++}HCO3^{-})/(Ca2^{++}Mg2^{++}Na^{+})]$ 100

PI was used to evaluate the sodium hazards of irrigation water.

Residual sodium carbonate (RSC),

The concept of residual sodium carbonate is employed for evaluating high carbonate waters and was calculated by (Aghazadeh and Mogaddam, 2010) the formula given below.

RSC= $(CO_3^{-}+HCO_3^{-})-(Ca^{2+}+Mg^{+2})$

Results and Discussion

pH

pH is a term used universally to express the intensity of the acid or alkaline condition of water. Most of the ground water samples were slightly alkaline due to presence of carbonates and bicarbonates. The pH values of water samples were measured maximum and minimum value between 7.8 to 8.9. The average pH value was found 8.32 of ground water from Jaunpur district. The range 5.5 to 8.5 pH of ground water is suitable for drinking and irrigation purpose according to (WHO, 2002).

Electrical Conductivity

Electrical conductivity of water is generally related to the amount of dissolved solid or minerals ions and represents the ability of water to conduct an electric current. The minimum (484 µS/cm) and maximum (3120 µS/cm) concentrations of EC were recorded from the samples of ground water. High range of EC in ground water area was indicated the enrichments of salts in the ground water.

Total Dissolved Solids

The TDS value of ground water ranged as minimum value (443 mg/l) and maximum value (2434 mg/l) and mean value was ranged 1140.8 mg/l. ground water contain less than 500 mg/l of total dissolved solids is desirable for drinking uses but water contain more than 1,000 to 3,000 mg/l of TDS value is not recommended for drinking as well as for other domestic purpose. Such water may be use for irrigation, according to classification of (Davia and DeWiest, 1966). TDS value of the ground water of some blocks i.e. Badalapur, Rampur, Jaunpur, Sircony and Darmapur were fall in the class three and the quality of ground water indicated that water may be used for only irrigation purpose not for drinking shown in Table. 1.

Class	TDS (mg/l)	Classification
1	500	Desirable for drinking
2	500–1,000	Permissible for drinking
3	1,000–3,000	Useful for irrigation
4	> 3,000	Unfit for drinking and irrigation

Table 1: Groundwater classification based on TDS (Davis and DeWiest, 1966)

Total Hardness

Water hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride, and sulphate in ground water. The total hardness (as CaCO3) values ranged between 212 - 1094 mg/l and average value 471 mg/l were found shown in Table 2. The ground water of Jaunpur district was indicated that 80 % of water samples were out of permissible limit for drinking purpose (WHO, 2002).

Major cations

The present results demonstrate that calcium concentration in ground water ranged between 14.5 to 212.5 mg/l as average values 68.74 mg/l were found shown in Table. 2. The high concentrations of calcium in water samples were not hazardous both on human health and agricultural purpose. High concentration of Calcium may be attributing to the passage through or deposits of limestone, dolomite and gypsum (APHA, 1992). The magnesium concentrations of ground water were found 23.6 to 178.4 mg/l and average 78.11 mg/l. The concentration of manganese in Jaunpur city and Dharmapur block were out of permissible limit according to (WHO, 2004). The sodium concentrations were found 10.7 to 557.9 mg/l and average concentration 157.61 mg/l and concentration of potassium 2.4 to 11.8 mg/l and average concentration 4.98 mg/l shown in the Table. 2.

Major anions

The chloride concentration of ground water ranged between 11.1 to 685 mg/l and average concentration 196.11 mg/l were found shown in Table 2. The concentration of chloride in ground water of some blocks i.e. Badalapur, Rampur, Sircony and Jaunpur city were out of permissible limit (WHO, 2002). The chloride concentration in ground water was caused injurious effects to people suffering from diseases of heart and kidney. The fluoride concentration in ground water ranged between 0.15 to 1.95 mg/l and average concentration was found 1.02 mg/l. Fluoride affects mainly dental caries at low concentrations and higher concentration of fluoride causes serious problems such as dental and skeletal fluorosis (Schafer *et al*. 2010). Fluoride is one of the main trace elements in groundwater, which generally occurs as a natural constituent. In fact, fluoride related to groundwater has been studied intensively during the past decades (Roberston 1986; Zhaoli *et al*. 1989; Travi and Faye 1992; Hitchon 1995; Subba Rao 2003; Coetsiers *et al.* 2008). These studies showed that concentration of fluoride was increased with the process of leaching from minerals in various aquifers with different lithological process. Bedrocks containing fluoride minerals are generally responsible for high concentration of fluoride in groundwater (Handa 1975; Wenzel and Blum 1992; Bardsen *et al.* 1996. Subba Rao, 2003). Nitrate

Blocks	Physico-Chemical Parameters				Major Anions						Major Cations		
	pH	EC	TDS	TH	Cl^-	F^-	NO_3^-	HCO_3^-	SO_4^-	Ca^+	Mg^+	Na^+	K^+
Buksha	8.3	647	557	365	29.7	0.89	3.3	403	3.7	33.8	68.2	10.7	4.3
Badalapur	8.3	3000	2434	651	475.9	1.72	3.2	749	454.8	71.5	114.8	557.9	5.6
Maharajgang	8.5	1588	1368	559	208.4	1.95	11.8	741	59	75.5	90.1	178	2.4
Sujangang I	8.1	484	443	213	17.8	0.9	4.3	310	17.2	46.3	23.6	20.1	3.1
Mariyahoo	8.4	1153	1008	212	75.8	0.15	39.8	512	119.5	40	51.8	165	4.9
Barsathi	8.5	853	780	313	31.5	1.19	13.8	481	55.1	28.5	37.6	127.5	3.7
M.Badsahpur	8.7	1017	979	793	22	1.7	13.3	589	115.4	61	58.3	114	3.9
Rampur	8.9	2700	2084	226	685.9	1.54	2.3	473	325.8	14.5	72.1	500.5	8.4
Ramnagar	8.3	826	758	333	17.7	1.63	26.2	525	18.3	62.5	58.4	44.5	3.3
Sikrara	8.1	1345	1220	396	269.5	0.73	12.8	496	140.6	68.5	116	113.5	2.6
Jaunpur	8.4	3120	2263	500	532	1.06	48.9	523	466.1	140	175.9	364	11.6
Sircony	8.0	2800	1992	648	391	0.38	1.5	329	748	212.5	112.5	191.5	5.5
Jalalpur	7.8	945	846	994	149	1.0	20.7	449	7.0	81	87.6	45.5	4.5
Muftigang	8.1	518	492	329	21.2	0.86	1.9	336	7.8	59.8	48.3	11.9	4.0
Kerakat	8.3	581	550	563	11.1	0.89	28.6	368	4.5	46.2	52.5	34.4	3.9
Dobhi	8.3	555	519	376	43.7	0.32	2.5	317	27.1	39.8	48.8	37	2.9
Darmapur	8.6	3100	2188	300	611	0.67	119.6	655	103	144.5	178.4	364.5	11.8
Suithakala	8.4	751	645	1094	87.3	0.99	41.5	356	11.8	26.5	48.7	68.5	4.0
Kutahan	8.1	579	551	266	45.6	0.87	1.5	355	3.5	53.7	40.5	45.7	4.4
Shahgang	8.4	763	680	301	49	1.87	1.4	438	17.1	33.5	48.3	89.5	1.8
Minimum	**7.8**	**484**	**443**	**212**	**11.1**	**0.15**	**1.5**	**310**	**3.5**	**14.5**	**23.6**	**10.7**	**2.4**
Maximum	**8.9**	**3120**	**2434**	**1094**	**685.9**	**1.95**	**119.6**	**749**	**748**	**212.5**	**178.4**	**557.9**	**11.8**
Average	**8.32**	**1398**	**1140.8**	**471.6**	**196.11**	**1.02**	**20.92**	**471.94**	**141.48**	**68.74**	**78.11**	**157.61**	**4.98**

Table 2: Water quality characteristics of ground water of Jaunpur district

EC (dS/m at 25°C)	Water class	Interpretation
<0.25	Low salinity (C1)	Safe with no likelihood of any salinity problem Developing
0.25 – 0.75	Medium salinity (C2)	Need moderate leaching
0.75 – 2.25	High salinity (C3)	Cannot be used on soils with inadequate drainage, since saline conditions are likely to develop
2.25 – 5.0	Very high salinity (C4)	Cannot be used on soils with inadequate drainage, since saline conditions are likely to develop

Source: Santhi. 2003

Table 3: Interpretation of irrigation water quality based on EC measurement

concentrations of the ground water samples ranged from 1.5 to 119.6 mg/l and average value was found 20.92 mg/l. The nine ground water samples of the study area were found above the permissible limit (WHO, 2004). The excessive nitrate content in drinking water can

cause 'blue baby syndrome' in infants (Fewtrell 2004). The minimum values of sulphate were found 3.5 mg/l and maximum value 141.48 mg/l and average concentration was found 141.48 mg/l in the ground water samples. The sources of sulphate contamination in ground water by leaching of agricultural fertilizers hence increased through runoff in ground water of Jaunpur district.

Sodium absorption ratio (SAR)

Sodium absorption ratio is the most commonly used for evaluating groundwater suitability for irrigation purposes (Ayers and Westcot, 1985). The classification of SAR content of alkali hazard, which is normally expressed in Sodium adsorption ratio (Rao, 2005, Hem, 1991). Sodium hazard of irrigation water can be well understood by calculation or the value of SAR index. This index quantifies of the proportion of sodium (Na^{+}) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water samples. In ground water samples, SAR values varied 0.24 to 11.93 and the classification of groundwater samples from the study area with respect to SAR was represented in Fig.3.

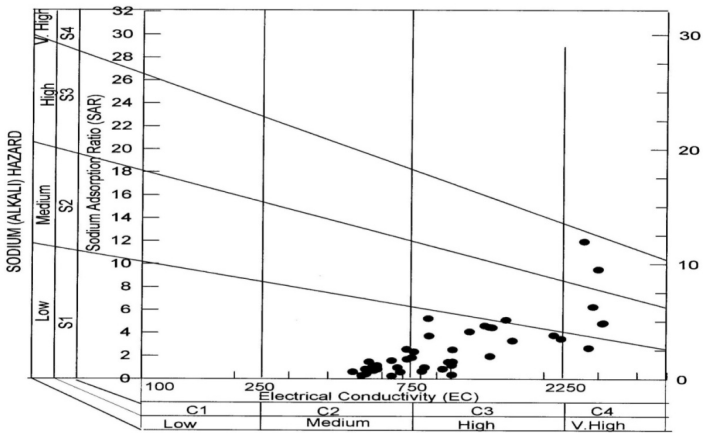

Fig. 3: Plots of calculation values of SAR and EC of ground water sample (Rechards, 1954)

USSL diagram

The SAR and EC values for groundwater samples of the study area were plotted in the USSL graphical diagram of irrigation water. Based on USSL diagram, the water quality showed that the majority of the samples falls in the C2-S1 and C3-S1 medium to high salinity with low sodium alkalinity hazard and two samples falls in the field of C4-S2 as very high salinity with low sodium alkalinity and C4-S3 was showed very high salinity and high alkalinity shown in Fig 3. The C4-S3 class water was not suitable for without proper treatment.

Residual Sodium Carbonate (RSC)

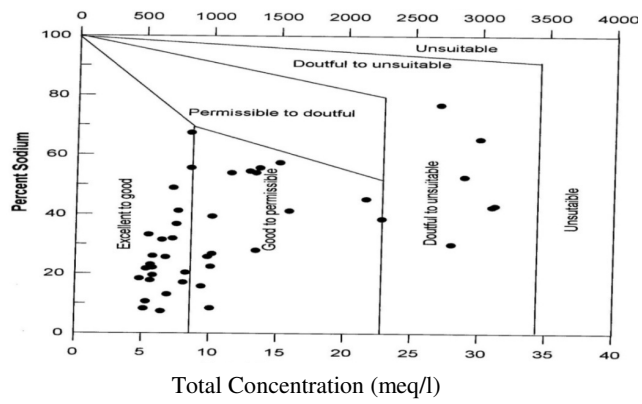

Fig. 4: Plot of sodium percent versus electrical conductivity

The concentration of bicarbonate and carbonate also influences the suitability of water for irrigation purpose. One of the empirical approaches is based on the assumption that all Ca and Mg precipitate as carbonate. Considering this hypothesis proposed the concept of residual sodium carbonate (RSC) showed for the quality assessment of high carbonate in water. A high value of RSC in water leads to an increase in the adsorption of Na in soil. Irrigation water having RSC values greater than 5 meq/1 are

considered harmful to the growth of plants. The most of the analysed water samples, RSC value was measured above 5 meq/1 making it unsuitable for irrigation uses. Only five ground water sample fall in doubtful to unsuitable for irrigation shown in Fig 4.

Permeability Index (PI):

Doneen (1964) classified waters quality characteristics based on the Permeability Index (PI) for irrigation and evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. The classification mainly based on sodium, calcium, magnesium and bicarbonate concentration in ground water. The ground waters can be classified as class I, Class II and Class III orders by Doneen's chart (Domnico & Schwartz 1990), implying that the ground water of Jaunpur district, was good quality for irrigation purposes about 75% of ground water fall in class I and class II indicate that maximum permeability. Only two groundwater samples belong to class-III, i.e. water unsuitable category for the irrigation shown in Fig 5.

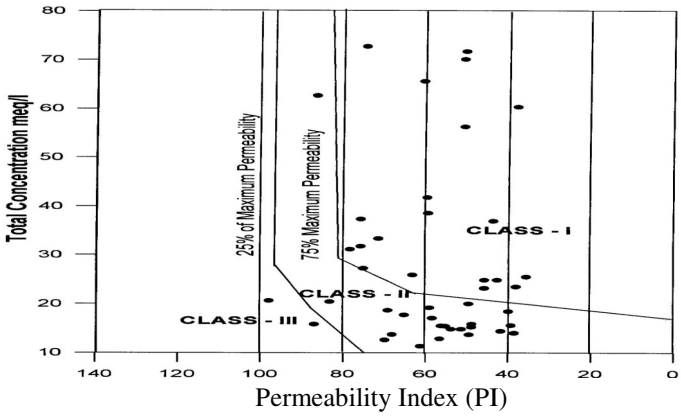

Fig. 5: Permeability Index verses Total Concentration of ion.

Suitability for drinking and general domestic uses

The most of ground water samples of study area were under the suitable index for drinking and domestic uses but few exceptions, as most of the parameters are within the permissible limits. The values of TDS & EC exceed the permissible limit of thirteen ground water samples, indicating the higher ionic concentration. Concentration of sulphate and nitrate in ground water on some sites was exceeding the permissible limits. High concentration of nitrate levels can cause methemoglobinemia in infants and high sulphate may contribute to the corrosions effect on human health system. The ground water was restricted for direct uses for drinking purpose in some particular block of Jaunpur..

Suitability for irrigation

The parameters like total hardness (TH), residual sodium carbonate (RSC), total dissolved solids (TDS), sodium absorption ratio (SAR) and permeability index (PI) which affects the quality of water for irrigation purpose were also computed and results were furnished of the important hydro-chemical properties of ground water to determine its suitability for irrigation. The calculated value of SAR ranged from 0.24 to 11.9 in ground water. The plot of data on the USSL salinity diagram, in which the EC is taken as salinity hazard and SAR as a alkalinity hazard showed that most of the water samples fall in the category C3S1and C2S1, indicating medium to high salinity and low alkaline water. High saline water cannot be used for irrigation with

restricted drainage and requires special management for salinity control. About 11% analysed water samples fall in the very high saline category shown in Fig. 3. The very high saline water is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. SAR indicates that the effect of relative concentration in the water, thus sodium adsorption ratio is a more reliable method for determination of the irrigation water as per the) classification (Richards, 1954).

Conclusion

The present study revealed that the ground water samples of Jaunpur district were under good quality. Although some of the quality parameters exceeded from World Health Organization guideline values, most of the analyzed physico-chemical parameters were satisfactory for drinking and irrigation purposes. The cations and anions concentration exceeded only 15% of ground water sample out of permissible limit according to (WHO, 2002, 2004), and 2- 3% of water samples were found unsuitable for irrigation. The classification of sodium absorption ratio (SAR) indicated that 78% of water samples were under good category for irrigation suitability and the permeability index indicated that 75% of ground water samples were accepted for irrigation. According to analyzed water samples indicated that the ground water samples of Dharmapur, Sircony, Rampur block and Jaunpur city were found unsuitable category for irrigation under normal condition and requires proper water purification management.

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