Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 2, No. 2, p. 14-20, 2012
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Evaluation of underground waters quality for various purposes with special reference to drinking and irrigation parameters

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Received: 28 January 2012
Revised: 14 February 2012
Accepted: 15 February 2012

Key words: Groundwater, heavy metals, physico-chemical, salinity hazard.

Abstract

The present study comprised suitability evaluation of underground waters for drinking and irrigational uses. A total of sixteen underground waters samples were collected from the upper Ghaggar river basin starting from Badisher-Koti (Panchkula) to Ratanheri (Patiala) along the Ghaggar river course. The collected water samples were subjected to the physico-chemical and heavy metals characterizations. Physico-chemical and heavy metals characterization of the groundwater samples revealed that many of the water sources were not suitable for drinking purpose owing to the high concentration of one or other parameter above the safe prescribed limit. Suitability for irrigation, too, was low since most of the water sources had high concentration of cadmium and contained medium to high salinity hazard. The high concentration of the chemical parameters may be attributed to the lithologic composition and intensive agricultural activities of the area.

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Introduction

Pollution of groundwater is one of the major areas of concern to environmentalists. The degradation of the groundwater resources quality has increased rapidly in the past decades throughout the world and India is not exception to that. Most of the rural population in India depends on groundwater for drinking, domestic and agricultural uses. Groundwater appears to be safe and sound as compared to surface water, however, it need not essentially be safe (Banks *et al.,* 1998). The demand for quality drinking and irrigational water had changed considerably with the development. Injudicious and indiscriminate use of agrochemical and disposal of untreated or partially treated sewage, industrial and domestic effluents has rendered the groundwater unfit for drinking and agriculture or both (Bruce and McMahon, 1996). The quality of irrigation water can affect the soil fertility and productivity. Soil may develop saline and alkaline character if excessive soluble salts or exchangeable sodium are allowed to accumulate in the soil as the result of improper irrigation or inadequate drainage. There have been very few studies and reports on assessment of groundwater quality for drinking and irrigation in the region (Haritash *et al.,* 2008). The present study was conducted to characterize and assess the suitability of groundwater particularly along the Ghaggar River for drinking and irrigational purposes.

Materials and methods

Description of the research area

The selected research area situated between North latitudes 30˚00′00″ to 30°50′00″ and East longitudes 76˚11′24″ to 77˚07′20″ and covers a distance of 135 km. Groundwater samples were collected from different locations spreading over Panchkula, Ambala and Kaithal districts of Haryana and Patiala and SAS Nagar (Mohali) districts of Punjab.

Sampling and analysis

The Ghaggar river basin area located in the upper reaches was selected for groundwater sampling as area is used extensively for agriculture. Groundwater samples were collected in summer season (June, 2006) of the year. Sixteen sampling sites were identified along the Ghaggar River main course and samples were collected from tube wells, hand pumps, open wells and bore wells situated in the agricultural land. These sources of groundwater are being used for drinking and irrigational purpose. Samples were collected in clean polyethylene bottles of two-litre capacity. During sampling, bottles were thoroughly rinsed thrice with the water to be sampled. Parameters like pH, EC and TDS were measured in the field itself with help of water and soil analysis kit. All other parameters of the water were analyzed in the laboratory using standard recommended methods (APHA, 2005). The groundwater quality was analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), chloride (Cl^-), fluoride (F^-), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), total hardness (TH), cadmium (Cd), zinc (Zn), iron (Fe), copper (Cu), lead (Pb) and mercury (Hg). The suitability of groundwater for irrigational use was calculated using different equations. Percent sodium (% Na), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and permeability index (PI) were calculated as per Wilcox (1955), Richards (1954), Eaton (1950) and Ragunath (1987), respectively.

$\% Na = [(Na^+ + K^+)] \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$

$SAR = Na^+ / \sqrt{Ca^{2+} + Mg^{2+}/2}$

$RSC\ (meq/l) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$

$PI = (Na^+ + \sqrt{HCO_3^-}) \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$

Where, ionic concentrations of sodium, potassium, calcium, magnesium, carbonate and bicarbonate are expressed in epm.

Results and discussion

The collected groundwater samples were analyzed for their physico-chemical and trace elements to check their suitability for drinking and agricultural purposes.

Drinking

Tables 1 & 2 are showing physico-chemical and heavy metals characteristics of groundwater samples respectively. Most of the aquatic organisms are adapted to average pH and do not withstand abrupt changes (Shyamala *et al*., 2008). The pH in all the groundwater sampling sites was in the range of 7-8.5 with highest value at Bijdoli-Ki-Doli. pH values in all the sites remained well within the WHO (2004) set limit for drinking water. The area groundwater showed slightly alkaline nature but in general it was suitable for drinking purpose. Electrical conductivity (EC) varied in the range from 312-1147 (in μmho/cm). Generally, high value for conductivity indicates proportionately high values of calcium, magnesium, sodium and potassium. Conductivity in water samples remained well within the WHO guideline of drinking water.

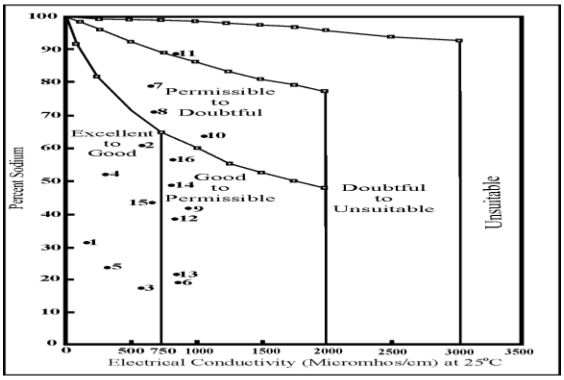

Fig. 1. Rating of groundwater on the basis of % Na and EC for irrigation (Wilcox, 1955).

To determine the suitability of groundwater of any purpose, the total dissolved solids (TDS) should be below 500 mgl^{-1} (Catroll, 1962; Freeze and Cherry, 1979). Water with high dissolved solids (> 1000 mgl^{-1}) may cause noticeable change in taste or make the water unsuitable for drinking. During the study, TDS values in groundwater samples varied from 202 at Badisher-Koti to 745 mg/l at Utsar. Dissolved solids in the groundwater samples were below the WHO set limit for drinking water. Carbonates concentration were found almost absent in most of the groundwater sources. Bicarbonates concentration ranged from 205-425 mgl^{-1}. Bicarbonates concentration had crossed the WHO standard range for drinking at Bijdoli-Jodian and Mohamdpur sites. Total hardness (TH) values ranged from 215 to 521 mgl^{-1} and water at Mubarkpur-Camp site crossed the WHO prescribed limit for drinking. Soft waters are those with a hardness of less than 75 mgl^{-1}; moderately hard waters are those with having range from 75-150 mgl^{-1}; hard waters are those with a hardness range from 150-300 mgl^{-1}; and very hard waters are those which have hardness over 300 mgl^{-1}. In the study, fifty percent of the samples were found in very hard category and rest in hard category.

High concentration of chloride in the water may possibly derived from pollution sources such as fertilizers, domestic effluents, septic tanks and from natural sources such as rainfall and chloride bearing minerals (Ritzi *et al.,* 1993; Jeong, 2001). Cl^- ranged from a minimum 35.5 mgl^{-1} to a maximum 180.4 mgl^{-1} at Surala site. In general, all the Cl^- values of all groundwater sites fall well within the standard of WHO (2004) for drinking. In case of sulphate concentration unusual high variation was noted and values ranged from 6-488 mgl^{-1}. During the study, sulphate concentration was not suitable for drinking at Manouli-Surat, Devigarh, Mohamdpur and Sarala sites. Phosphate concentration was varied from a minimum of 0 at Utsar to a maximum of 14.8 mg/l at Surala.

Bedrock containing fluoride minerals is generally found responsible for elevated value of fluoride in groundwater (Handa, 1975; Wenzel and Blum, 1992). Fluoride concentration varied from a minimum of 0.07 at Panchkula S-3 to a maximum of 0.88 mg/l at Manouli-Surat. The research area groundwater was found safe for drinking purpose as it remained within the maximum permissible limit. Sodium was found in the range of 25.9-740 mgl^{-1}. In thirty one sampling sites, Na^+ concentration exceeded the WHO prescribed limit for drinking. Potassium concentration ranged from 0.4-11.7 mgl^{-1}. The lowest value was noted at Devinagar, whereas, the maximum value occurred at Utsar. K^+ concentration remained well within the WHO (2004) drinking water standards. At some stations high concentration of K^+ is attributed principally to the agricultural activities taking place in the region.

Calcium values in water samples ranged from a minimum of 56 at Bijdoli-Jodian to a maximum of 160.8 mg/l at Maru. At Mubarkpur-Camp, Maru and Mohamdpur sites high concentration of Ca^{2+} above the WHO (2004) guideline was noted. Magnesium in the water samples ranged from 6.5-47.3 mgl^{-1}. Mg^{2+} concentration was found well within the WHO guideline for drinking.

Trace metals are generally responsible for various health hazards when present in excessive amounts. The deficiencies of heavy metals in human beings and animals have been identified (Frieden, 1972). The same metals, however, at increased level may have severe toxicological effects on human beings (Chapman, 1992). Cadmium concentration in the groundwater samples ranged from 0-0.152 ppm. In sixty three percent of water samples cadmium concentration was found above the prescribed limit for drinking. In thirty-one samples, cadmium contents were absent. In the groundwater samples, zinc concentration was varied from 0-0.845 ppm. Zinc concentration in the groundwater samples was reported well within the prescribed range of the WHO for drinking. The concentration of iron in groundwater samples ranged from 0-3.385 ppm. At about sixty nine percent sampling sites groundwater had crossed the WHO (2004) limit and hence water was not suitable for drinking.

Copper in the water samples ranged 0-0.755 ppm. In nearly seventy five percent samples copper contents were found absent. During the study, at three sites such as Bhankarpur, Devinagar, Utsar and Maru sites trace amount of lead was reported and it remained well within the WHO (2004) range of drinking. The concentration of lead in groundwater depends upon the chemistry and texture of the soil profile because of high affinity of the metal for adsorption. Soil chemistry plays an important role in the distribution of lead in groundwater. Lead had crossed the prescribed limit for drinking at Thapali-Narda, Burjkotian and Mubarkpur-Camp sites. At 88% sampling sites, mercury concentration was found absent in the water.

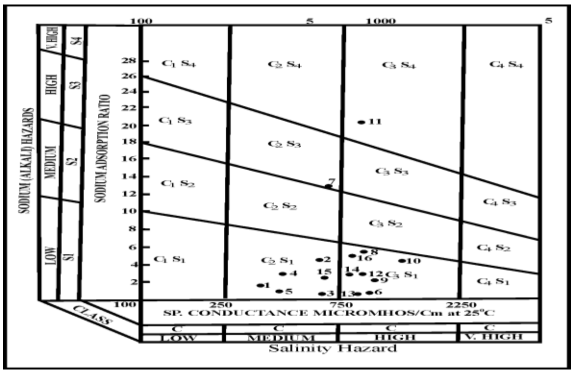

Fig. 3. Plots of calculated values of SAR and EC (After USSL, 1954).

Irrigation

The concentration and composition of dissolved constituents in water determine its suitability for irrigation use. The various constituents such as EC, Na^+, K^+, Ca^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^- and trace elements have been utilized by various agencies and workers to ascertain the suitability of the water for agricultural purposes. The different formulae were used to determine irrigation related parameters. The cropping pattern in the research area was as per Rabi (wheat in winter) and Kharif (paddy in summer) system of India. Important parameters with respect to the use in irrigation are represented in Table 3.

The total concentration of soluble salts in irrigation water can be expressed in terms of electrical conductivity for purposes of diagnosis and classification. Water having electrical conductivity <750 µmhos/cm is satisfactory for irrigation purpose. Water in the range of 750-2,250 µmhos/cm is generally used, and satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are not proper. In our study, conductivity varied from 312-1,147 µmhos/cm. Hence, conductivity was found well within the prescribed limit and this kind of water can be used for irrigation with proper drainage. The percent sodium varied from 17.08-87.39. Wilcox (1955) diagram (Fig. 2) revealed that out of sixteen samples, 6 fall into excellent to good category, 6 into good to permissible category, 3 into permissible to doubtful category and one in doubtful to unsuitable category. Most of the research area groundwater falls in excellent to good and good to permissible categories and indicating its usefulness for irrigation. Generally, agricultural yields are observed low in the lands irrigated with waters belonging to permissible to doubtful category. This is probably due to the presence of sodium salts, which cause osmotic effects in soil plant system.

Sodium adsorption ratio (SAR) in the groundwater samples ranged from 0.5-21.04. Figure 3 showed that as per the USSL (1954) classification, out of sixteen sampling sites, 6 falls into the C2-S1 category, indicating medium salinity hazard and low alkali hazard water class and 8 falls into the C3-S1 category, indicating high alkali hazard to low salinity hazard. One groundwater sample fall into C2-S3 category, showing medium salinity hazard and high sodium hazard class. Only one sample was found in C3-S4 category, indicating high salinity hazard but very high sodium (alkali) hazard.

Residual sodium carbonate (RSC) values of groundwater samples varied from -4.96 to 2.59 meq/l. It has been observed that out of sixteen samples, fifteen were found safe and one was unsuitable for irrigation. Permeability Index (PI) in groundwater varied from 34.1 to 92.8%. According to the PI values, 69% samples of groundwater fall in class II (25-75%).

The categorization of analyzed trace elements was done on the basis of prescribed tolerance limits of FWPCF (1968) and Ayers and Branson (1975) for irrigation. Cadmium is normally less toxic to plants; however, its toxic levels reduce plant growth. Based on the FWPCF (1968) and Ayers (1975) criteria, groundwater was not fit for irrigation at Thapali-Narda, Mubarkpur-Camp and Ratanheri sites even for short term as far as cadmium concentration was concerned. Whereas, the groundwater at Badisher-Koti, Bhankarpur, Devinagar, Utsar, Surala and Maru sites was suitable for irrigation for short term not for long term. Based on FWPCF (1968) criteria, only at Bijdoli-Ki-Doli, Burjkotian, Panchkula S-3, Manouli-Surat, Devigarh, Sarala and Devigarh sites groundwater was suitable for irrigation, if used continuously. At the same time, based on Ayers and Branson (1975) tolerance limit groundwater of Bijdoli-Ki-Doli, Burjkotian, Panchkula S-3, Manouli-Surat, Devigarh, Mohamdpur and Sarala was suitable for continuous use.

Zinc is an essential nutrient for plants but its high concentration is damaging in acidic soils. The concentration of zinc was well within the safe limits and hence water was suitable for irrigation even for continuous term. As far as iron concentration is concerned study area groundwater remained well within the tolerance limits. Groundwater was suitable for irrigation even for long term in almost all the sites as far as copper is concerned. Copper concentration at Maru site has crossed the short term tolerance limits and, hence, not suitable for irrigation. In the groundwater samples lead concentration was found well within the tolerance limits.

Conclusion

Based on the observed results, it was clear that most of the groundwater samples had the concentration of one or other parameter above the safe prescribed limit for drinking. The water of many sampling sites was unsuitable for drinking since it had high concentration of some of the sensitive parameters like hardness, sulphate, sodium, calcium, cadmium, iron and lead. For irrigation purpose, most of the samples had high concentration of cadmium and water from these sites was not suitable for irrigation. Most of the water sources were in excellent to good or good to permissible category based on % Na and EC but most of the samples had medium to high salinity hazard. It is suggested that the groundwater of the study area should either be treated before its use or be used intermittently for drinking and agricultural uses.

Acknowledgements
Author is thankful to University Grant Commission (UGC) for financial help through fellowship.

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