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Assessment of Groundwater Quality for Irrigation Purpose in Amritsar District, Punjab, India

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Abstract : Amritsar district is one of major intensive agriculture districts of Punjab, producing food grains to the Indian nation. The district is covering about 5058 sq.km area drained by two perennial rivers Ravi and Beas. Irrigation water requirements are dependent on shallow/deeper tube wells in addition to the existing surface water irrigation facility from canals. Dwindling flows in canal supplies has lead to rapid decline of the groundwater levels about 50-60 cm/yr during last two decades. Incriminate use of agrochemicals tend to increase salinity and sodicity of the soils in this district. Main objective of the present study is to evaluate the groundwater suitability for irrigation and to classify it according to amount of salts present. Groundwater samples and has been collected at 51 observation wells and physiochemical (pH, EC, Ca^{+2}, Mg^{+2} Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{-2}, F^{-} and NO_3^{-}) parameters were analyzed during last two hydrologic cycles. Based on these analyses, Sodium absorption Ration (SAR), % Sodium, and Residual Sodium carbonate (RSC) were calculated for one hydrological cycle of the year 2007.

The groundwater quality analyses revealed that most of the samples were within the lower alkalinity limit (pH 7.14–8.10). The electrical conductivity of the samples ranged from 434 to 2499 μs/cm. Other parameters like sodium adsorption ratio, SAR (0.76–10.83), RSC (0-5-7.51), %Na (19.71-84.64) were found above the permissible limit in the most of the samples. Wilcox diagram of pre-monsoon indicated that 2 samples fall in high saline and high sodium hazard, 12 samples falling in Medium saline and high sodium hazard, 6 samples are found in medium saline and medium sodium hazard, 31 samples falls in High saline and low sodium hazard. The groundwater quality analyses further indicated that almost all samples exhibits increasing trend of salinity during post monsoon period.

Keywords: Groundwater, Salinity, Sodicity, Sodium absorption ratio, % Sodium.

INTRODUCTION

The required quality of irrigational waters varies substantially, depending principally upon the salinity, soil permeability, toxicity, soil permeability and some miscellaneous concern such as excessive nitrogen loading or unusual pH of water. Quality of irrigation water depends on the amount of suspended sediment and chemical constituents in the water. One of the important issues that impact sustainable water management practice in India is related to water quality (Rao and Mamatha. 2004). The effect of sediment is influenced by the nature of the soil condition of irrigated area. The concentration and composition of dissolved constituents in water determines its quality for irrigation use. The kind of water used for irrigation has effects in the quality, production and type of culture. Whatever the origin of the water, it should be evaluated and must fulfills some quality empiric indices required for irrigation water. Therefore, its quality should be verified before establishing the culture. The quality indices studied are second grade indices and they depend on the cations and anions concentration present in water and could be influenced by the type of soil or water (Hernández et al., 2003). The use of these indices is very important to evaluate the quality water, because they relate, at least, two variables such as electrical conductivity, sodium adsorption ratio, total dissolved solids, etc., given a more extended and wide point of view (Orihuela., 1992). The use of a unique variable is not appropriated. The usual criteria include salinity, sodicity, and element toxicity. The adequate amount of water is very essential for proper growth of plants but the quality of water used for irrigation purpose should also be well within the permissible limit otherwise it could adversely affect the plant growth. Questions have been raised as to the social and environmental sustainability of this intensive mode of crop production (Arrojo., 2001). Very often, tube well irrigation is used to supplement canal irrigation. Unlike surface waters, underground waters are not always suitable for irrigation, their salt content and composition depends upon the location and geo-climatic factors. The water quality in watershed is directly affected by vegetative cover and agricultural and other land management practices (Bhattaria et al., 2008). The quality of groundwater is the resultant of all the processes and reactions that act on the water that is condensed in the atmosphere until the time it is discharged by a well or spring. The degree of adverse effect on soil properties and crop productivity is mainly related to the chemical composition of irrigation water. Specific water quality problems in effluent-dominated streams are often related to one or more components of water quality standards (Brooks et al., 2006). The continuous use of poor quality water without drainage and soil management may lead to saline and sodic soil, particularly in clayey soils. The world bank and other development agencies also calls for encouraging efficient water use, preservation of water quality, transfer of water to non agricultural high value uses, and reduce ground water overdraft(Pitman., 2004). Irrigation water quality criteria developed by US salinity laboratory has received acceptance in many countries. Total salt concentration and probable sodium hazard of irrigation water are two major constituents of the criteria (Richards., 1954).

DESCRIPTION OF THE STUDY AREA

Amritsar district falls in between Ravi and Beas rivers. Ravi River flows in North West of the district and forms international boarder with Pakistan. Beas River flows in the eastern part of the district. There are three nalas which drains Amritsar district from north east to south west. Kiran Saiki nala flows in the northern part of the district. Hudiara nala and Kasur nala drains the central part of the district where as Patti nala drains south eastern part of the district. Upper Bari Doab canal is the main canal passing through central part of the district. Lahore branch and Kasur branch lower are the major distributaries of the Upper Bari Doab canal (Fig.1). Soils in the western part of the district are coarse loamy, calcareous soils, where as in the central part of the district soils are fine loamy, calcareous and are well drained. The soils are Ustochrepts to Haplustaff type has shown in Fig. 2 (GSI District Resource map, 1984). Net area under irrigation through canals is 650 sq. km and area under irrigation through tubewells is 1570 sq. km (Saigal, S.K., 2007).

Hydrogeology

The district forms part of Uppar Bari Doab and is underlain by formations of Quaternary age comprising of alluvium deposits belonging to vast Indus alluvial plains. Sub surface geological formations comprise of fine to coarse grained sand, silt, clay and kankar. Gravel associated with sand beds occurs along left bank of Ravi. The beds of thin clay exists alternating with thick sand beds and pinches out at short distances against sand beds.

Groundwater Condition

Depth to water level in the district ranges from 7.5 to 24.6m below ground level (bgl) during pre monsoon period and between 7.29 to 20.7 m bgl during post monsoon period in the year 2007. In the central part of the district around Amritsar,

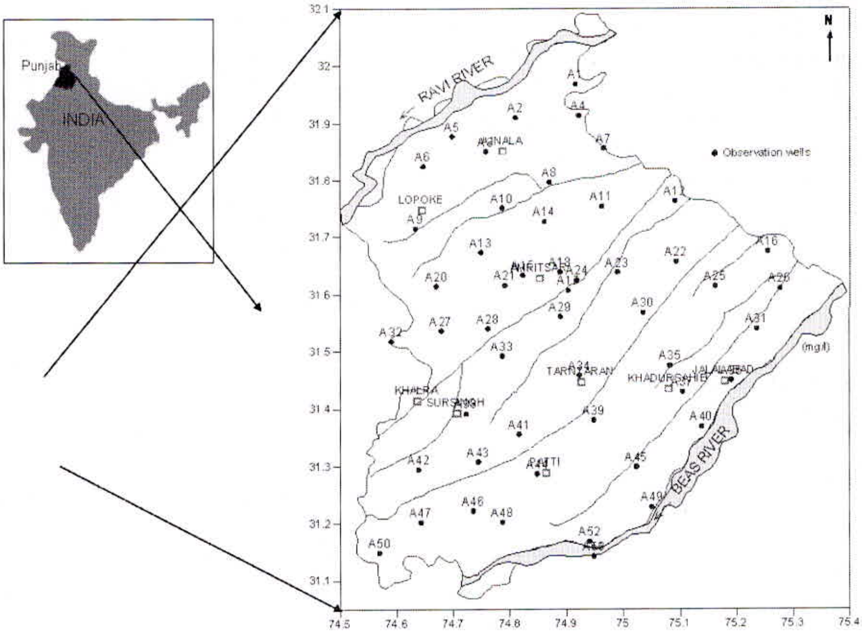

Fig.1 : Location map of Observation wells in Amritsar district, Punjab - India

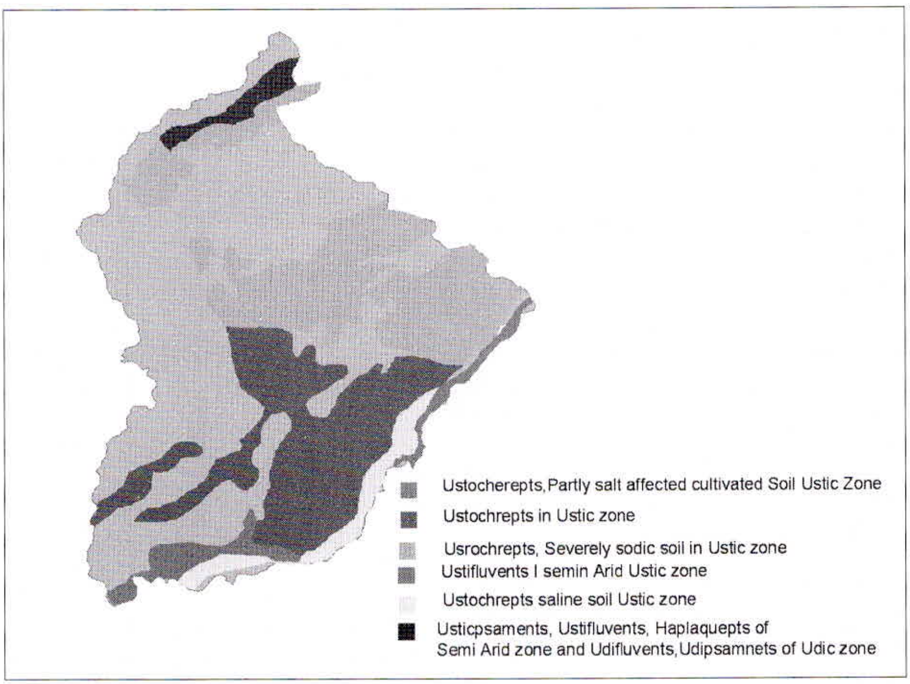

Fig.2 : Soil type Map of Amritsar district

water levels are more than 20mbgl. Depth to water level in rest of the district ranges between 10 to 20 m bgl. Groundwater decline in this district of 0.40 m to 0.65 m in whole of the district had been observed during the year 2007 to 2009. The decline in water levels is more in the central and eastern part of the district. Water level elevation in the district ranges from 205m to 240 .23m average mean sea level (amsl). The ground water flow direction is from north east to south west. The gradient of water table elevation is steeper in the north east part and gentle in the south west part of the district. In the area around Amritsar the ground water flow from all directions is towards city and a ground water trough has been formed in the central part of the city.

METHODOLOGY

Groundwater samples were collected from 51 bore wells of the Amritsar during pre and post monsoon periods of the year 2007. The location of sampling points is shown in (Fig.1). To evaluate water quality and its suitability for irrigation, in situ measures such as pH, electrical conductivity and nitrite, and laboratory analyses such as total hardness, calcium, magnesium, bicarbonate, flouride, nitrate, sulphate, chloride, pH, electrical conductivity, sodium and potassium were carried out. Determinations were performed using procedures recommended in the Standard Methods for Examination of Water and Wastewater (APHA, 1992).

RESULTS AND DISCUSSIONS

The analytical results of Major ions have been utilized for estimating the Sodium absorption Ratio (SAR), % Sodium, Residual Sodium carbonate (RSC) presented in the Table.1. In general groundwater was found in alkaline nature 7.14 to 8.15 with a mean value of 7.61, in the post monsoon it is slightly increasing. Increase of pH in the post-monsoon suggests that dissolution has been enhanced due to high interaction between soil and rainwater as well as due to dilution from

Table1 : Statistical analysis of chemical parameters in the groundwater of Amritsar district, Punjab

	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Pre Monsoon 2007			Post Monsoon 2007		
pH	7.14	8.1	7.61	7.28	8.56	7.9068
EC	434	2150	996	455	2491	1143
Cl	20	190	69	20	270	98.3
SO4	18	244	82.8	23	384	92.9
NO_3	0.9	360	26.13	0.7	225	27.57
F	0.11	1.17	0.69	0.97	2.21	0.755
HCO_3	135	460	282	138	556	296.5
Na	22	353	116	16	491	132.14
K	6	120	13.96	6	90	13.7
Mg	10	73	34.2	19	83	44.68
Ca	8	88	34.67	8	96	35.36
TH	98	500	227	138	540	272
SAR	0.76	10.83	3.6	0.4	15.94	3.74
%Na	19.71	84.64	52.08	13.1	86.31	49.45
RSC	0.01	7.51	1.57	0.03	7.45	1.97

the influx of rainwater of lower alkalinity. EC found higher in the post-monsoon in terms of range and mean values. This pattern of data clearly shows that this area is affected with salt due to additional leaching is taking place. On the other hand the higher average value of EC in the pre and post monsoon suggests the enrichment of salts due to enhanced evaporation followed by subsequent dilution through rainwater.

In Amritsar district, dominant cations are in the order of (Na>Ca>Mg>K). Although, clear seasonal variations were observed both in minimum and maximum concentrations of these cations, in the post monsoon cationic concentrations was increased except potassium. This is due to the dynamic change among the different hydro-geochemical processes operating in the area. At few places is due to urban pollution and fertilizer leaching high value of K was found. Alkalinity of water is the measure of its capacity for neutralization. Bicarbonate represents the major sources of alkalinity. Bicarbonate is slightly higher in post-monsoon period in terms of range indicating the contribution from carbonate weathering process at some places. The significant increased of Cl in the post-monsoon substantiate the high leaching of salt with percolating rain water. In general, the most of the natural waters contain SO_4 in smaller concentrations than the Cl. In Amritsar, it ranged from 18–224 mg/l in pre-monsoon and 22–384 mg/l in post-monsoon. This indicates addition of sulfate by organic substances of weathered soils, sulfate leaching, from fertilizers and other human influences. The average value of nitrate found higher in the post-monsoon, due to leaching of NO_3 from fertilizers and biocides during irrigation of agriculture land. Total hardness of the groundwater samples found high in the post monsoon.

Wilcox and Piper diagram has been drawn using the Aquachem software for the Major ions. Wilcox diagram depicting that pre monsoon, 2 samples fall in high saline and high sodium hazard,12 samples falls in Medium saline and high sodium hazard, 6 samples falls in medium saline and medium sodium hazard, 31 samples falls in High saline and low sodium hazard. In post monsoon almost all samples exhibits increasing trend of salinity. It is attributed to continuous addition of salts by agrochemicals, poor infiltration rates and improper drainage system from the agriculture fields (Fig.3, 4). Piper diagram indicating that dominance of the cations compare to the anions which is causing the salinity problems in terms of the sodium concentrations. Basically the soils are magnesium rich soils so that, magnesium also one of the dominate cation other than agriculture pollution (Fig.5, 6).In the post monsoon piper diagram indicating that increase of cationic concentrations.

Sodium Percent (%Na)

Doneen method is used to calculate the sodium percentage.

$\%Na = [(Na^{+} + K^{+)} / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})]\ 100$ (Concentrations are in meq/l).Sodium percent is another important factor to study sodium hazard. It is calculated as the percentage of sodium and potassium against all cationic concentration. It is also used for adjudging the quality of water for the use of agricultural purpose. The use of high percentage sodium water for irrigation purpose stunts the plant growth. Sodium reacts with soil to reduce its permeability. Sodium percent in water is a parameter computed to evaluate the suitability for irrigation. Usually little or only minor problems occur when %Na are less than 15%. When > 15%, reduced permeability will occur. The finer the soil texture and the greater the organic matter content, the greater the impact of sodium on water infiltration and aeration. The sodium percent values of Amritsat district varies from 19.71 to 84.64 in pre-monsoon and in post-monsoon 13.10 to 86.31. All samples exhibiting high sodium percent is attributed continuous addition of salts and not suitable for agriculture. Gypsum can be added to the soil to reduce the effect of high percentage of sodium in irrigation water.

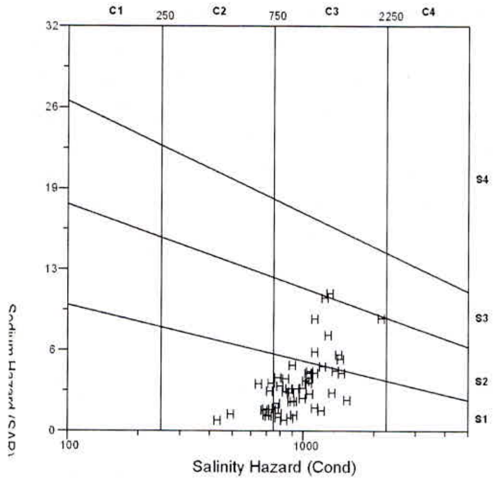

Fig. 3 : Wilcox diagram for groundwater samples in Amritsar district - July 2007

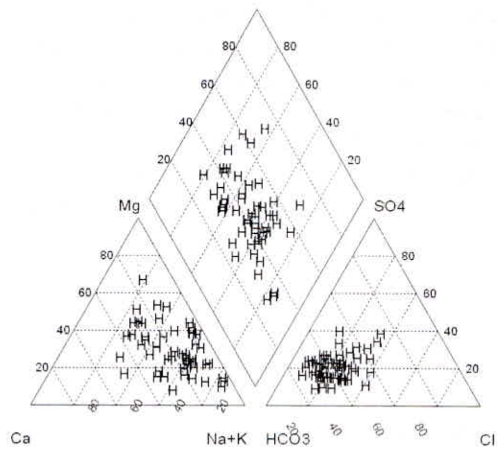

Fig. 5 : Piper diagram for groundwater samples in Amritsar district - July 2007

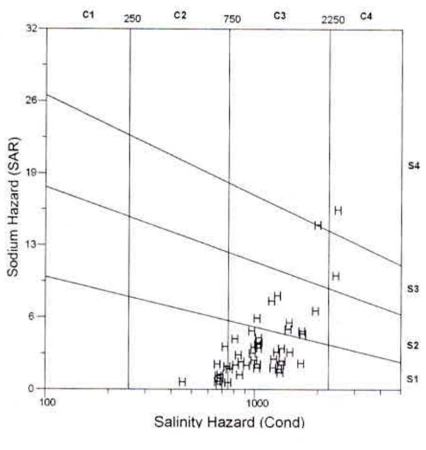

Fig. 4 : Wilcox diagram for groundwater samples in Amritsar district - November 2007

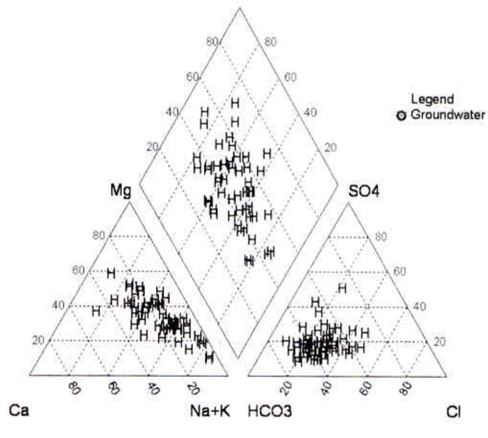

Fig. 6 : Piper diagram for groundwater samples in Amritsar district - November 2007

Sodium Adsorption Ratio (SAR):

Sodium absorption ratio is an important parameter to determine the suitability of irrigation water and is calculated by the following formula.

SAR= Na^{+} /”[(Ca^{2+} + Mg^{2+}) /2] (Concentrations are in meq/l)

Excess sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability. Hence the assessment of sodium concentration is necessary while considering the suitability for irrigation. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio[18]. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious. SAR is an important parameter for the determination of suitability of irrigation water because it is responsible for the sodium hazard. The waters were classified in relation to irrigation based in the ranges of SAR values. Water with SAR ranging from 0 to 3 is considered good and with greater than 9 is considered unsuitable for irrigation purpose. In the present study SAR was found to be 0.76 to 8.83 in pre monsoon and 0.4 to 15.94. In the pre monsoon two samples AM28, AM43 were exhibiting more than 10% and in Post monsoon AM46 and 48,49 were more than10 % which is not suitable for agriculture , remaining samples were below 9% in both pre and post monsoon . River water in both seasons less than 0.5%, excellent category for irrigation.

Residual Sodium Content (R.S.C.):

The concept of residual sodium carbonate (RSC) is employed for evaluating high carbonate waters and is calculated by the formula given below.

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

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^{2+} and Mg^{2+} precipitate as carbonate. Considering this hypothesis, Eaton proposed the concept of residual sodium carbonate (RSC) for the assessment of high carbonate waters. The water with high RSC has high pH and land irrigated with such water becomes infertile owing to deposition of sodium carbonate; as known from black colour of the soil. According to U.S. Salinity Laboratory, an R.S.C. value less than 1.25 meq/lit is safe for irrigation. A value between 1.25 and 2.5 meq/lit is of marginal quality and value more than 2.5meq/lit is unsuitable for irrigation. In present study RSC in 7 samples were found to be greater than 2.5 (AM15, 18, 26, 28, 32, 43, 52) in pre monsoon and at 16 samples were found to be greater than 2.5 in post monsoon (AM5,AM9, AM11, AM17, AM18, AM21, AM27, AM28, AM30, AM32, AM36, AM37, AM46, AM48, AM49, AM52) which is not suitable for irrigation. 9 samples in pre monsoon and 9 samples were found in marginal quality.

CONCLUSIONS

Ground water in Amritsar district exhibited medium to high salinity in pre and post monsoon seasons. And also all groundwater samples showing that increasing salinity in post monsoon which affect the soil structure and Permeability. It is suggested that gypsum can be added to minimize the effect of the salinity of the soils. And also advised to change the cropping pattern and less water consuming crops to minimize the evapotranspiration and to minimize to stress on groundwater resources. Greater emphasis needs to be given on efficient conveyance and distribution system for optimal utilization of available surface water. Ground water irrigation should be supplemented by canal irrigation to minimize the stress on ground water and power consumption.

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