Groundwater Quality Assessment and its Suitability for Drinking Purpose: A Case Study of Barnala Block, District Sangrur, Punjab, India

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Abstract : In the groundwater protection and its conservation, Groundwater quality plays an important role. Due to growing populations and increasing pollution of surface water bodies we are depending more and more on finite groundwater reserves. Although addressing water shortages in the short term, groundwater exploitation brings with it its own host of problems. Due to excessive pumping and weak recharge of the groundwater, depletion of water tables is taking place in the state of Punjab. In the present study Barnala block of Sangrur district is selected for the research work. 'Green Revolution' boosted up the agriculture production due to introduction of high yielding crops and large scale mining of groundwater. Injudicious irrigation, excessive pumping, poor recharge and excessive use of fertilizers have led to a situation of shrinking groundwater resource and salinization at an alarming rate. Barnala block falls in the over exploited (dark) category. Random sampling was done in the study area for the analysis. The result of the chemical analysis reveals that the groundwater of the study area is of brackish water type and values of major ions, in comparison with the permissible limits for drinking water (as by BIS) are not suitable for drinking purposes either due to salinity or fluoride. Various water quality problems like high sodicity and high salinity were also reveled. The concentration of Fluoride varies from 0.65 to 3.1 mg/l, which could be dangerous from health point of view. The situation needs a constant vigil in monitoring of groundwater quality in this area to avoid serious degradation.

Keywords: Groundwater, salinization, brackish, sodicity, water crisis.

INTRODUCTION

On the planet Earth, water resources are fundamentals for our existence. Despite the fact that Groundwater accounts for less than half a percent of the entire stock of fresh water on our blue planet; it is the main controlling factor for economic development. It provides more than half of humanity's freshwater for everyday uses; as well as 30 percent of irrigated agriculture and industrial development. The prevailing trend towards huge population, urbanization, water intensive life styles and hi-Tec agriculture are leading towards overexploitation and depletion of groundwater. Decreasing groundwater tables are posing serious challenges to the sustainability of agriculture in North India.Depletion of water tables; saltwater encroachment, groundwater pollution, water logging and salinity are major consequences of overexploitation and intensive irrigation.

Punjab, a modest-sized state tucked away on the north-western border of India, is often known as the bread basket of India. During Green Revolution, the spectacular increase in agricultural production in Punjab has been made possible due to large-scale adoption of high yielding crops and cultivars along with assured irrigation facilities and high fertilizer use. Irrigation facilities extended from 54 to 95 percent of cultivated area, and the fertilizer use leaped from about 30 to 190 kg/ha percent area in 2001-02 as compared to only 54 percent in 1960-61(Arora and Gajri,1998). Punjab has exhausted its upper layer of Groundwater and farmers are now exploiting deeper aquifers. Over exploitation and unplanned development of ground water can disturb the dynamic ecological balance and leads to depletion and salinization of aquifers (Galloway, 1998).

STUDY AREA

Barnala is situated in the southern part of Punjab.It is located at 30°23' N 75°32' E 30^{0}38'N 75^{0}53'E. It has an average elevation of 227 meters (744 feet). The climate of the block is characterized by the dryness of the air an intensely hot summer and cold winter. The area forms a part of Indo gangetic plain. The master slope of the area is towards the south west. Soils of the block are loamy sand and sandy loam kaller land is also spotted at a few places. The core economy of this city is agriculture based and it is still a developing city.

MATERIALS & METHODS

Water samples were drawn from bore-wells and hand pumps during Pre and Post-monsoon period of the year 2008. Seventy groundwater samples were collected from each district in March 2003 (pre-monsoon) and same locations were again sampled in September 2003 (post-monsoon) to evaluate seasonal variations 70 water samples were collected in plastic container as possible to avoid unpredictable changes in physico-chemical characteristics. The testing of samples was done according to the procedure prescribed by APHA (1995). Present study comprises of interpretation and analysis of water samples collected from 70

Table 1 : Barnala Block at a glance

S.no.	Items	Statistics
1	**Geographical area (Sq.Kms)**	1414 km^2
	Blocks	(3)Sehna, Mahal Kalan, Barnala
	Villages	133
	Population(as 2001 Census)	526931
2	**Physiography**	
	3 main units	Sand bars i.e. tibbas, Alluvial plains and Palaeochannels
3	**Major Drainage**	No Major stream, major canals are Bathinda branch, Kotla branch and its distributaries
4	**Hydrogeology**	
	Major Water bearing formations	Sand
	Pre-monsoon depth to Water Level	8.77-23.89
	Post-monsoon depth to water level	9.95-24.52
5.	**Ground Water Scenario**	Table.2
Ground water Resources & Development Potential as on		**31.3.2004**
	Total Replenishable Groundwater (MCM	274.58
	Utilizable Groundwater Resources for Irrigation	550.86 MCM
	Existing groundwater for domestic industrial and other	3.97 MCM
	Gross draft as on 31.3.04	554.83
	Net groundwater availability for future irrigation development	-281.83 MCM
	Stage of groundwater development %	202
	Category	Over exploited

(Source – Groundwater information Booklet, Sangrur district, Punjab) (CGWB, 2007)

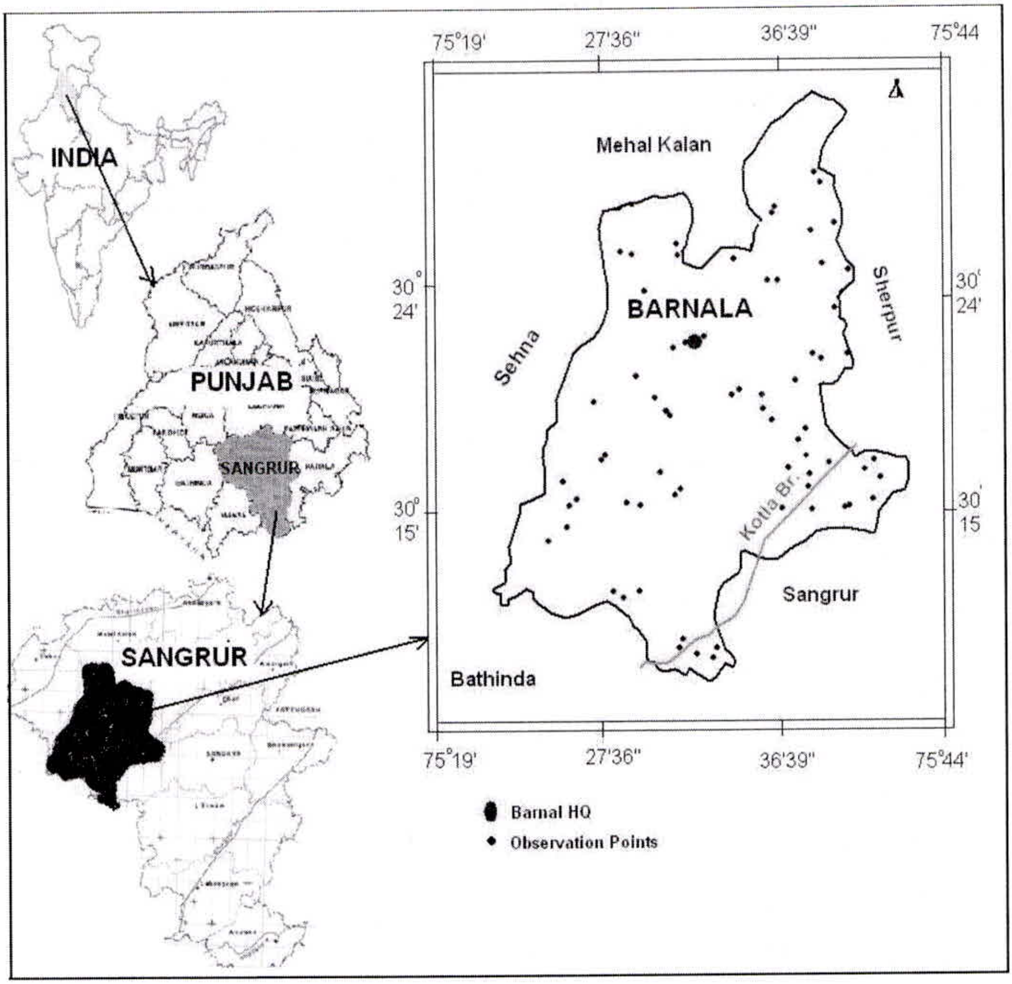

Fig.1 : Location map and observation points of Study area

different locations (Fig.1) selected randomly from the Barnala block. The samples were analyzed for different chemical and physical parameters. Immediate parameters like Ph, EC and TDS were analyzed with potable analysis kit. The results were carefully studied and analyzed.

RESULT AND DISCUSSION

Groundwater chemistry

Groundwater quality plays an important role in the groundwater protection and its conservation. It is the factor that determines suitability groundwater for drinking, domestic, agricultural and industrial purposes. From the Barnala 70 groundwater samples for pre & post monsoon seasons were collected. The analytical results, computed values and the statistical parameters like minimum, maximum, average values and standard deviation of water samples of Barnala block of Sangrur district given in Tables 2.

Table 2 : Summary statistics of chemical constituents of groundwater in Barnala Block, District Sangrur for pre &Post monsoon season.

Parameter	Units	Minimum		Maximum		Average		Std. deviation	
		Pre mon	Post mon	Pre mon	Post mon	Pre mon	Post mon	Pre mon	Post mon
pH	–	7.37	7.06	8.92	8.71	8.31	7.96	0.36	0.39
TDS	mg/l	471.90	457.38	2296	1811.25	1063.26	918.62	418.32	350.59
EC	µS/cm	726	706	3532	2875	1635.79	1458.13	643.57	556.49
Na^+	mg/l	7.80	6.72	451	700	134.04	165.08	110.05	236.32
K^+	mg/l	4.20	3.50	29.30	26.40	8.81	8.68	4.31	4.36
Ca^{2+}	mg/l	4.81	3.21	53.71	26.45	22.12	12.54	11.27	5.08
Mg^{2+}	mg/l	17.66	20.09	69.17	65.58	37.58	42.81	11.34	11.96
HCO_3^-	mg/l	88	100	630	530	325.59	318.50	149.48	119.90
Cl^-	mg/l	14.20	14.20	327.80	248.50	96.79	64.58	71.88	46.98
SO_4^{2}	mg/l	0.14	0.12	122.42	82.22	47.44	37.36	27.79	20.80
PO_4^{3-}	mg/l	0.01	BDL	0.21	0.01	0.02	0.01	0.04	0.00
NO_3^-	mg/l	0.01	1.26	29.36	21.89	9.19	7.82	6.98	5.89
F^-	mg/l	0.30	0.65	3.10	2.56	1.57	1.43	0.61	0.48
T.H	mg/l	96	89	304	284	176.12	170.23	46.48	49.02
SAR	–	0.22	0.17	16.96	11.76	4.26	3.77	3.81	7.97
RSC	meq/l	-4.24	-3.13	8.33	7.32	2.01	1.96	3.02	2.53
%Na	%	11.93		88.15		52.87		17.68	
PI	%	37.85	30.91	100.97	91.84	74.05	71.43	15.90	11.71
Mg. ratio	–	43.60	39.89	95.16	94.75	73.40	71.82	11.62	9.89
Mg Hazard	-	0.44	0.40	0.95	089	0.74	0.70	0.11	0.09

(BDL –Below detection limit)

(Pre Mon –Premonsoon: Post Mon –Post monsoon period)

1. pH -pH value ranges from 7.37 to 8.92 in pre monsoon and in post monsoon it ranges to 7.06 to 8.71.36% of samples in premonsoon and 6 % samples in post monsoon were above the permissible limit.

2. EC -Electrical Conductivity -Electrical conductivity of water sample is the measure of its total dissolved contents and gives an idea about the extent of mineralization of ground water. .In the study area the EC was found varying from 726μS/cm to 3532μS/cm in Pre-monsoon and 706μS/cm to 2875 μS/cm in Post-monsoon. 88.6 % samples in pre monsoon and 46% in post monsoon were having value above than the permissible limit.

3. TDS -Total Dissolved Solids -TDS concentrations ranged between 471.90 and 2296 mg/l in pre monsoon and 457.38 and 1811.25 mg/l in post monsoon.

4. Total Hardness -TH concentrations ranged between 96 and 304 mg/l in pre monsoon and 89 and 284 mg/l in post monsoon.

5. Sulphate, Phosphate, Nitrate and Ammonical Nitrate – The values of these four parameters in all the ground water samples were well within the limit prescribed by BIS in both the seasons Post and Pre-monsoon.

6. Chloride -Chloride is one of the major anions in water and is generally associated with sodium. High concentrations of chloride ions may result in an objectionable salty. Chloride concentrations ranged between 14.20 to 327.80 mg/l in pre monsoon and 14.20 to 248.50 mg/l in post monsoon.7 % of samples were above than desirable limit in premonsoon.

7. Fluoride - F^{-} concentrations ranged between 0.30 and 3.10 mg/l in pre monsoon and 0.65 to 2.56 mg/l in post monsoon. In pre monsoon 54 % of the samples were having value of fluoride above than 1.5 mg/lt and 27% samples in post monsoon.

8. Calcium & Magnesium - Ca^{2+} concentrations ranged between 4.81 to 53.71mg/l in pre monsoon and 3.21 mg/lt to 26.45 mg/l in post monsoon. Mg^{2+} concentrations ranged between 20.09 and 65.58 mg/l in post monsoon and 21.27and 68.73 mg/l in pre monsoon.77% in premonsoon and 47% samples in post monsoon exceed desirable limit of Mg^{2+}.

9. Potassium-In Barnala block, K^+ concentrations ranged between 3.5 and 26.40 mg/l in post monsoon and 4.20 and 29.30 mg/l in pre monsoon .Value of Potassium in 33% samples was above than the permissible limit i.e. 10 mg/lt.

10. Sodium- In Barnala block, Sodium concentrations ranged between 6.72 and 700 mg/l in post monsoon and 7.80and 451 mg/l in pre monsoon. In Pre monsoon, 18 % of samples in premonsoon and 11% samples in post monsoon were having value above than permissible limit.

As per analysis the groundwater is alkaline in nature in both pre and post monsoon, however, it was more alkaline in pre-monsoon than post monsoon because of water recharging due to rains. The higher average value of EC in the pre-monsoon suggests the enrichment of salt due to evaporation effect in the pre-monsoon followed by subsequent dilution through rainwater. Bicarbonate is higher in the pre-monsoon period. Bedrock containing fluoride minerals is generally responsible for high concentration of fluoride in groundwater (Handa 1975; Wenzel and Blum 1992).Sodium was also found in higher concentration in the both the seasons. High sodium water will alter the soil chemistry and absorption properties, eventually sealing the soil surface. There was a clear seasonal variation both in minimum and maximum concentrations.

Graphical representation of Hydrochemical data

The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations and anions in the Piper (*1944*) tri-linear diagram. The piper plot of Barnala for Premonsoon period (Fig. 2) showed that almost all the groundwater samples fell in the category of Na–HCO_{3-}Cl type of water. Some water samples also represent mixed type (Ca, Mg, Na, K, CO_3, HCO_3 and Cl). It is clearly evident from the plot that the alkalis (Na^+ and K^+) exceed the alkaline earth metals (Ca^{2+} and Mg^{2+}) significantly and weak acids (HCO_3^- and CO_3^{2-}) dominated strong acids (Cl^- and SO_4^{2-}). The groundwater had secondary salinity, as indicated by the carbonate hardness.

The water type is Na + Ca+Mg-HCO_3 mixed anion. Piper plot for Post monsoon (Fig.3) shows three distinct types of Hydrochemical facies. These are:

(1) $NaHCO_3$

(2) NaCl

(3) Mixed type (Ca, Mg, Na, K, CO_3, HCO_3 and Cl).The order of abundance of major cations in the ground water of the area is Na >Mg^{2+}>K^+> Ca^{2+} while that of anion is HCO_{3-}> Cl^->SO_{42-}>NO_{3-}>$PO_{4.}$

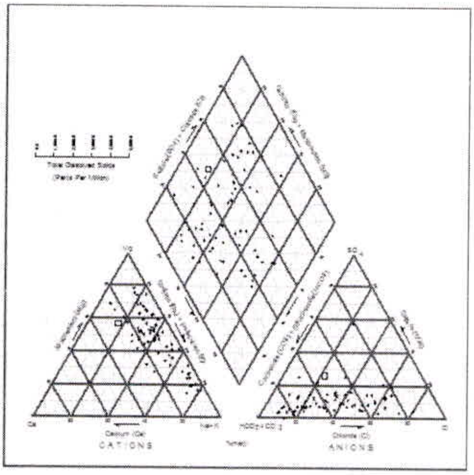

Fig. 2 : Piper plot for Barnala for pre monsoon

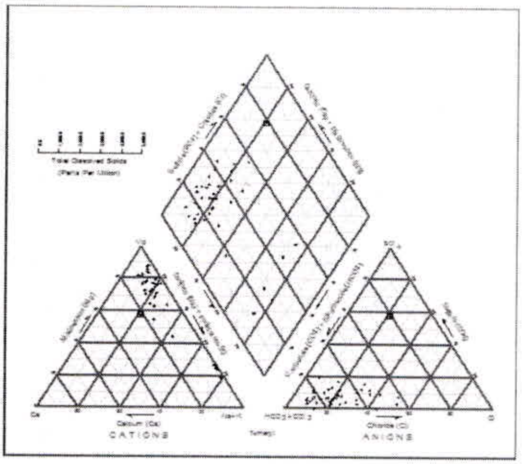

Fig. 3 : Piper plot for Barnala for post-monsoon

Drinking water quality

Suitable Quality of water is one whose characteristics make it acceptable to the needs of particular purpose. As we know that water is the most important constituent of our body. Thus, its quality should be good & perfect because it directly affects our health. The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption.

Suitability of groundwater for drinking based few classifications

· 25% of samples in pre monsoon and 22 % samples in post monsoon fall in the category of poor and 31% samples in pre monsoon and 26% in post monsoon period fall in category Unacceptable. WHO (*1996a, b*) suggests a permissible limit of 1,000 mg/l. In both the seasons .Apporx. 56 % in premonsoon and 48% samples in post monsoon were in below than the fair water class.

· As per Taste water of Barnala block taste Brackish.55 % samples in pre monsoon and 42% samples in post monsoon fall in category of brackish type. Brackish water is unpleasant in taste.

· Based on total hardness as $CaCO_3$(mg/l) after Sawyer and Mc Cartly (*1967:-83%* samples in premonsoon and 77% samples of post monsoon fall in class of hard water whereas 4% of premonsoon and 2% samples of post monsoon fall in class of very hard water .

· All the samples (70) both of pre & post monsoon period were above the desirable limit of EC.(Table.4).88% & 47% samples in pre & post monsoon resp. were above than permissible limit .High exposure to higher EC value water can cause Gastro-intestinal irritation

The analytical results of physical and chemical parameters of groundwater were compared with the standard guideline values

Table 3 : Suitability of groundwater for drinking based on two classification .

TDS (mg/l)	Water class	% of sample	
		Pre-monsoon	Post-monsoon
<300	Excellent	0	0
300–600	Good	7	11
600–900	Fair	37	41
900–1,200	Poor	25	22
>1,200	Unacceptable	31	26
Nature of groundwater based on TDS (mg/l) values			
0–1,000	Fresh	45	58
1,001–10,000	Brackish	55	42
10,001–100,000	Salty	0	0
>100,000	Brine	0	0
Based on total hardness as $CaCO_3$(mg/l) after Sawyer and Mc Cartly (*1967*)			
<75	Soft	0	0
75–150	Moderately hard	13	21
150–300	Hard	83	77
>300	Very hard	4	2

Table 4 : Different guideline values for the drinking water with the percentage of sample beyond permissible limit (PL) and the resulting health implications.

Parameter	WHO standard (1994, 2004)		***ISO:10500: 1991 standard		% of sample exceeding PL (DL)***		Health implications
	DL	PL	DL	PL	Pre-monsoon	Post-monsoon	(Values are given in comparison to ISO standard)***
PH	7–8.5	9.2	6.5–8.5	No relax	36	5.7	Taste
EC (µS/cm)	500	1,400	500	1,000	88.6 (100)	45.7(100)	Gastro-intestinal irritation
TH (mg/l)	100	500	300	600	0 (1.4)	-	Scale formation
Na^+ (mg/l)	–	200	–	–	17.14	11.42	Scale formation
Ca^{2+} (mg/l)	75	200	75	200	-	-	Scale formation
Mg^{2+} (mg/l)	50	150	30	100	0 (77.1)	0 (48.6)	Encrustations in water supply structure.
Cl^- (mg/l)	200	600	250	1,000	0 (7.1)	0 (1.4)	Salty taste
SO_4^{2-} mg/l)	200	400	200	400	-	-	Laxative effect
F^- (mg/l)	–	1.5	1.0	1.5	54.3	27.14	Fluorosis (Dental & Skeletal)

recommended by the World Health Organization (WHO *1996a, b, 2004*) for drinking and public health purposes (Table 4).

Hardness:-TH (as $CaCO_3$) mg/lt = (Ca^{2+} +Mg^{2+}) meq/l X 50

Water more 150 mg/l as CaCO3 is considered as extremely hard water which might lead to Urolitthiasis. Urolithiasis is the condition where urinary calculi are formed in the urinary tract. Cardiovascular diseases may start on prolong use. 84% samples in premonsoon and 71% samples in post monsoon were having value higher than 150 mg/l.

Fluoride: - Apart from the natural geological sources such as calcium fluoride and flour apatite, considerable amount of fluoride can be contributed by anthropogenic activities like using of phosphatic fertilizers to soils In water it is almost completely absorbed and is distributed rapidly throughout the body.

Retained mainly in the skeleton and small parts in teeth. Small amount reduces dental carries in adults and children. Higher doses may result in dental FLUOROSIS and Skeleton Fluorosis with denser bones, joint pain, and a limited joint movement. In pre monsoon 54 % of the samples were having value of fluoride above than 1.5 mg/lt and 27% samples in post monsoon.

TDS: - The TDS concentration is a secondary drinking water standard and is more of an aesthetic rather than a health hazard. The concentration of the dissolved ions may cause the water to be corrosive, salty or brackish taste, result in scale formation.

Sodium: - Too much sodium can damage our kidneys and increases the chances of high blood pressure.

Potassium: Potassium concentrations in water are generally very small. Although excessive intakes may have a laxative effect, public health authorities have not established a maximum limit.

CONCLUSIONS

The research work is an attempt to assess the groundwater quality. The hydro-chemical analyses reveal that the present status of groundwater is unsuitable for drinking purposes. Values of TDS, pH, EC and Potassium were found to be higher than the permissible limits. Fluoride in the ground water of the Barnala Block has been found beyond permissible limit at several places like Tanola Dihati, Toor kot, Sekha, Kothe Chunga, Poore .etc. It is suggested that areas with high concentrations of fluoride, defluoridation of ground water should be taken up. Quality problems have been found in the ground water southwestern parts of Barnala block. The quality of groundwater came out to be better than post monsoon period because of dilution and flushing by the monsoon. The quality of groundwater may deteriorate in future, as is evident from the very high percentage of water samples falling beyond the desirable limits according to WHO standards and almost approach the maximum permissible limit. For such areas, adequate drainage and the introduction of alternative salt tolerant crops are required. Efficient irrigation techniques should be introduced.. The situation needs a constant vigil in monitoring of groundwater situation in all the sensitive areas if its use is to be sustained for future generations and to avoid inevitable catastrophic syndrome

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