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REVIEW OF RESEARCH

ASSESSMENT OF GROUNDWATER QUALITY FOR AGRICULTURAL USAGE IN YAMUNANAGAR DISTRICT, HARYANA, INDIA

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ABSTRACT

Groundwater is a precious resource for human existence as well as for different development activities. The present hydro geochemical study was confined to Yamunanagar district, Haryana which lies on the bank of Yamuna River. Groundwater resource has been intensively used as a primary source to meet the growing needs of various sectors (drinking, agriculture and industrial purposes) in study area. It is very important to know the geochemistry of groundwater to understand the suitability of this precious resource for irrigation. An attempt has been made to appreciate the comparative quality assessment of groundwater for irrigation purposes during the years 1992 and 2010. In order to achieve this objective total 11 groundwater samples from the study area were analyzed for the major cations (sodium, calcium, magnesium and potassium) anions (chlorine, sulphate, Bio carbonate) and physic-chemical parameters (Electrical conductivity). Piper trilinear diagram was constructed to identify groundwater facies. It was demonstrated that there was a dominance of alkalies (Na+K) and weak acid (Co_3+Hco_3). According to Gibbs diagram most samples falls in rock water dominance. Na, Cl, and Biocarbonate are dominant ions among the cations and anions. Based on physic chemical analysis, irrigation quality parameters such as sodium absorption ratio (SAR), sodium, Residual sodium carbonate (RSC), permeability index (PI) were also calculated. All these parameters reveals that groundwater of the study area is suitable for irrigation purpose in all parts of Yamunanagar district.

INTRODUCTION

Groundwater is a vital resource for meeting the requirements of different sectors of economy like agriculture, industry and domestic. It has played a vital role in India's economic development and ensuring its food security. The relevance of groundwater in development processes in India can be realized from the fact that about 85 per cent of Indian rural domestic requirements, 50 per cent of its urban water requirements and more than 50 per cent of irrigation requirements are being met by groundwater resource. However, rapid pace of industrialization, agricultural development and urbanization has resulted in over-exploitation and contamination of groundwater resources. Excessive pressure on groundwater resources has resulted in its overexploitation and deterioration of groundwater quality in many regions of India. In Haryana groundwater emerged as a dominant source of irrigation by early 1990s. With the intensification of cropping and expansion of rice-wheat crop combination not only did depletion of groundwater start, the excessive mining of water led to deterioration of groundwater quality. The excessive draft of groundwater in many parts of state has led to alteration in groundwater hydro-geochemistry and deterioration in its quality. This has made groundwater unsuitable for irrigation in many areas. In fact, the suitability of groundwater for irrigation depends on the chemical constituents of soil as well as water. Excessive concentration of ions in soil and water has negative effect on the yield of crops. Saline irrigation water also increases osmotic pressure in soils and high amount of ions negatively affects growth as well metabolism of plants. There is also negative impact of excessive salt on the soil properties in term of composition, structure, permeability and aeration. Nagarajan et al. (2010) pointed out that high concentration of potassium and sulphate in groundwater is attributed to surface contamination by the application of agricultural fertilizers. Nagaraju et al. (2014) recorded high salinity impaired groundwater for agricultural usages. There have been various studies which are carried out in India and different parts of world to evaluate the suitability of groundwater for irrigation and drinking purposes (Subba et al. 1999, Husain et al. 2005, Ravikumar et al. 2011, Sethi et al. 2012, Prasanth et al. 2012, Sappa et al. 2014, Salifu 2017).

The present study attempts to evaluate the groundwater quality in terms of its usage for irrigation in the Yamunanagar district of Haryana.

OBJECTIVES

The objective of present study are:-

- To analyse the spatio temporal changes in hydro-chemistry of groundwater in Yamunanagar.
- To analyse the groundwater quality for agricultural usage in the study area.

STUDY AREA

The present study pertains to Yamunanagar district of Haryana in India. Yamuna Nagar district (Fig. 1) is located in the Northeastern part of Haryana state and is extended between 77° 00′ to 77° 53′E longitude and 29° 55′ to 30° 31′N latitude. The geographical area of the district is approximately 1768 km2. Physiographically the district is divided into Shiwalik Hills, piedmont plain, dissected plain and Yamuna-Ghaggar alluvial plain. The district has a sub-tropical monsoon climate. The district receives rainfall from southwest monsoon season. The average annual rainfall of the district is approximately 1000 mm. The climate of the district is suitable for growing rice, wheat and sugarcane which are the major crops of the district. The overdependence on groundwater to meet the increasing demand in different sectors has resulted in excessive exploitation of groundwater and deterioration in its quality.

DATA BASE AND METHODOLOGY

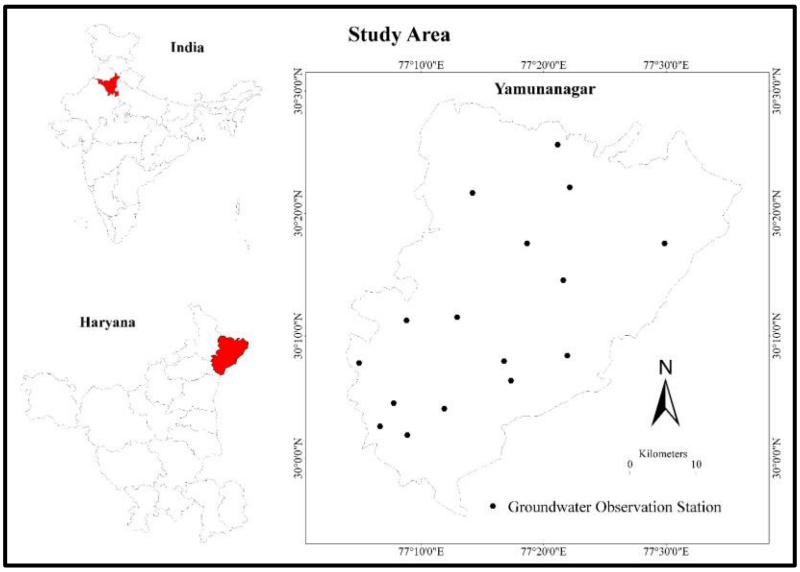
The present study is based on secondary sources of data pertaining to the years 1992, and 2010. The data about salts and chemicals dissolved in groundwater of observations wells have been collected from the Annual Reports of Central Groundwater Board, North-western Region, Chandigarh. Details are given below:

Source	Parameters	Data unit	Year
Groundwater Annual Year Book, Haryana, Central Groundwater Board, Northwestern Region, Chandigarh.	EC, Cation, Anions.	Groundwater Observation Wells (11 in 1992 and 12 in 2010)	1992 2010

Following indices have been utilized to assess the suitability of groundwater for irrigation purpose.

Electrical Conductivity (us/cm) (Salinity Hazards)

Fig.1



Sodium Absorption Ratio (Alkalinity Hazards) values were calculated for each observation wells across different regimes by the following equation suggested by Richard (1954):

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

Concentrations is expressed in meq/l.

Residual of Sodium Carbonate (Bicarbonate Hazards) has been calculated by following equation (Ragunath 1987)

$$[CO3^{2-}+ HCO^{3-}-(Ca^{2+} + Mg^{2+})]$$

The concentration is expressed in meq/l.

Permeability Index (PI), as defined by Donean (1964) and Ragunath (1987), has been calculated by using equation:

$$PI= \frac{(NA+\sqrt{HCO\,3}}{\sqrt{(CA+Mg}+Na} \times 100$$

All ions are expressed in meq/l

Piper Diagram has been constructed to plot the parameters of physic-chemical data of groundwater and for depicting different hydro-geochemical facies. It comprises of three parts, a ternary diagram in the lower left representing the cations, a ternary diagram in the lower right representing the anions and the diamond plot in the middle representing a combination of the two. Quality of water has been classified into different categories on the basis of classification scheme given by Back 1961, Hanshow 1965. Gibbs Diagram has been prepared to depict controlling mechanism of groundwater chemistry.

RESULTS AND DISCUSSIONS

Hydro-Geochemistry of Groundwater

The hydro-geochemistry of groundwater has been obtained through Piper trilinear diagram (Fig 2). Piper diagram is a tool for visualizing the chemistry of water (Piper 1994).

Cations Characteristics

It is evident from Table 1 that in 1992 there was dominance of calcium cations (72 percent observation wells) followed by no dominant type (27 percent) in groundwater of observation wells. In 2010 there was equal dominance of magnesium, sodium and potassium cations (33 percent) in groundwater of observation wells.

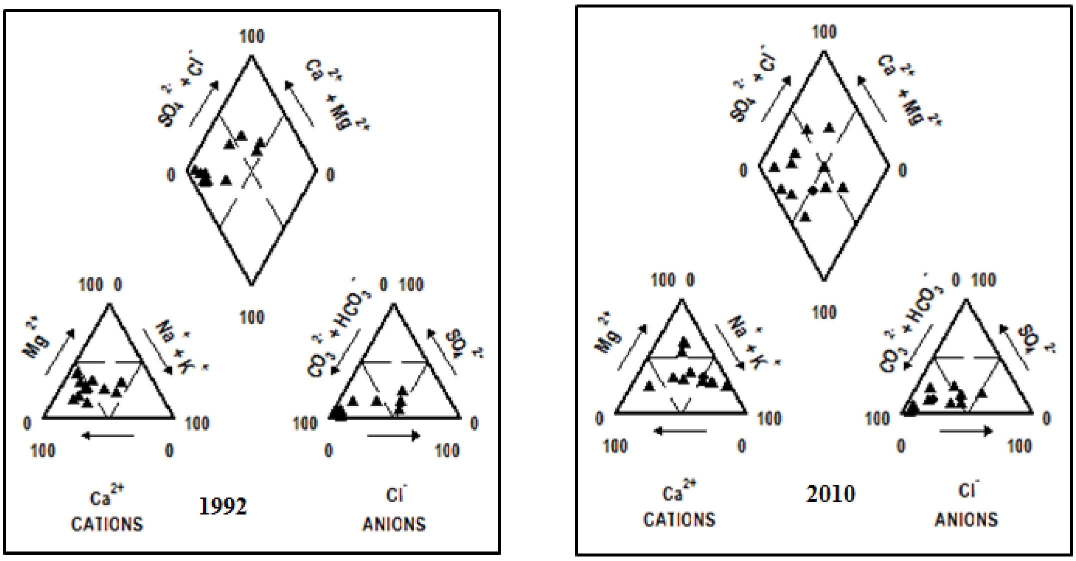
It is evident that over the period 1992 to 2010 on an average there was 67 percent increase in observation wells which have shown magnesium, sodium and potassium cations dominance. But calcium ions have declined very sharply.

Anions Characteristics

Table 2 shows that in 1992 there was dominance of bicarbonate ion in about 72 percent observation wells. In 2010 too there was dominance of bicarbonate in 75 percent observation wells followed by chloride (8 percent). It is evident from the analysis that over two decades on an average there has been increase in bicarbonate and chloride ions in groundwater.

Table: 1

Subdivison of the Cation Triangle	**Characterstics of corresponding subdivision of Triangle shaped fields**	**Total No. of Sample Total Number of Wells**	
		1992	**2010**
A	Calcium Type	8(72.72)	1(8.33)
B	No Dominant Type	3(27.27)	3(25)
C	Magnesium Type	0(0.00)	4(33.33)
D	Sodium and Potassium Type	0(0.00)	4(33.33)



Source: Fig. 2

Fig. 2 Piper Diagram

Table: 2

Subdivison of the Anion triangle	Characterstics of corresponding subdivision of triangle shaped fields	Total No. of Sample	
		1992	**2010**
E	Biocarbonate Type	8(72.72)	9(75.00)
F	Sulphate Type	0(0.00)	0(0.00)
G	Chloride Type	0(0.00)	1(8.33)
B	No Dominant Type	3(27.27)	2(16.66)

Source: Fig. 2

Alkalinity Characteristics of Groundwater

It is evident from Table 3 that overall in the district in 1992 there was dominance of alkaline earth (Ca^{2+} +Mg^{2+}) as it is observed in 100 percent observation wells. In 2010 there was too dominance of alkaline earth (Ca^{2+} +Mg^{2+}) in 58 percent wells followed by alkalies (Na^{+}+K^{2+}) 42 percent wells in the district (Table 3). Over the time alkaline earth (Ca^{2+} +Mg^{2+}) has increased in in the study area.

Table: 3

Subdivison of the Diamond	Characteristics of corresponding subdivision of diamond shaped fields	Total No. of Sample	
		1992	**2010**
1	Alkaline earth (ca+mg) exceeds alkalies (Na+K)	11(100)	7 (58.33)
2	Alkalies exceeds alkaline earth	0	5(41.66)
3	Weak acid (co_3+hco_3) exceeds strong acids (so_4+cl)	8(72.72)	9 (75)
4	Strong acids exceeds weak acid	3(27.28)	3(25)
5	Magnesium biocarbonate type	8 (72.72)	5 (41.66)
6	Calcium-chloride type	0 (00)	00 (00)
7	Sodium-chloride type	0 (00)	1 (8.33)
8	Sodium biocarbonate Type	0 (00)	1 1 (8.33)
9	Mixed type(No cation, anion)	3(27.28)	5 (41.66)

Source: Fig. 2

Acidic Characteristics of Groundwater

Table 3 shows that in 1992 there was dominance of weak acid (72 percent wells). In 2010 too weak acid dominated over strong acid in 75 percent observation wells. Over the last two decades it has been observed that there was 3 percent increase in weak acid in the observation wells in the district. It indicates increasing dominance of weak acid in the groundwater.

Salinity and Alkalinity of Groundwater

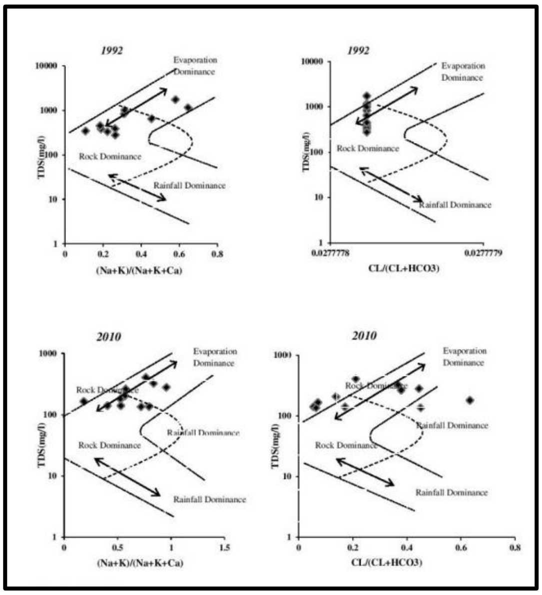
It is evident from Table 3 that in 1992 on an average there was dominance of magnesium biocarbonate type groundwater (73 percent observations wells) followed by mix type water (27 percent). In 2010 on an average there was dominance of magnesium biocarbonate and mix type water (84 percent observation wells) followed by sodium chloride and sodium biocarbonate (16 percent). It is evident from analysis that overall there has been increase in the concentration sodium chloride and sodium bicarbonate in the groundwater in the district.

Controlling Mechanism of Groundwater Chemistry

The chemistry of groundwater is influenced by various parameters like chemical properties of rocks and water, and rate of evaporation. In 1970 Gibbs suggested a diagram in which cation and anions were plotted against total dissolved solid (TDS). Gibbs diagram represents the ratio of $Na^{+}+K^{2+}$ / $Na^{+}+$, $K^{2+}+Ca^{2+}$ and Cl^{-} / ($Cl^{-}+HCO_3^{-}$) as a function of total dissolved solid (TDS) which is widely used to assess the functional sources of dissolved chemical constituents i.e., precipitation, rock and evaporation (Gibbs, 1970). Fig. 3 depict controlling mechanisms of water chemistry in district.

Fig. 3 shows Gibbs diagram of Yamunanagar district for the years 1992 and 2010. It reveals that it is the rock dominance that has influenced the chemical properties of groundwater during last two decades. Overall it is evident from the preceding analysis that groundwater quality is largely controlled by lithology in the district. It is advised to adopt conjunctive use of surface and groundwater to maintain the quality of groundwater for irrigation.

Fig.3 Gibbs Diagram



Suitability of Groundwater for Irrigation

The suitability of groundwater for irrigation usages is determined by interaction of different ions of water. The parameters which are used to assess groundwater suitability for irrigation in the present study are: (i) Electrical Conductivity us/cm (Salinity Hazards), (ii) Residual of Sodium Carbonate (Bicarbonate Hazards) (iii) Sodium Absorption Ratio (iv) Permeability Index.

Electrical Conductivity (EC)

Electrical conductivity is a measure of capacity of water to pass electric current. Higher values of EC indicate the enrichment of groundwater with salt concentration. It is a valuable measure to assess salinity hazards posed by saline groundwater to crops as it reflects the total dissolved solids in water. Higher EC in groundwater does negatively affect the yield of crops. Higher salt concentration of groundwater used for irrigation makes plants incapable to fetch water from soils (Tank and Chandel 2009). Table 4 revealed that in 1992 most of observation wells lie in good and permissible category for irrigation. In 2010 too mostly wells placed in good and permissible category for irrigation. There has been significant improvement in groundwater suitability for irrigation in Yamunanagar district during last two decades.

Table: 4 Based on EC (µS/cm) after Wilcox (1955)

Range	Classification	Number of samples	
		1992(11)	2010(12)
<250	Excellent	0(0.00)	0(0.00)
250-750	Good	6 (54.54)	9 (75.0)
750-2250	Permissible	4 (36.36)	3 (25.0)
2250-5000	Doubtful	1 (9.09)	0(0.00)
>5000	Unsuitable	0(0.00)	0(0.00)

Residual Sodium Carbonate (RSC) Concentration

The concentration of carbonate in natural water is a function of dissolved CO_2, temperature, pH, cation and other dissolved salts. The excess amounts of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also affect the suitability of groundwater for irrigation. Because due to high concentration of bicarbonate and carbonate there is tendency for calcium and magnesium to precipitate as water in soil becomes more concentrated. Higher concentration of these ions may be harmful for physical properties of soil. It also causes dissolution of agriculture matter in soil, which in turn leaves a black stain on soil surface on drying (Ravikumar et.al. 2011).

Table: 5 Based on RSC after Richard (1954)

□1.25	Good	11 (100)	8 (66.66)
1.25-2.5	Doubtful	0(0.00)	2 (16.66)
□2.5	Unsuitable	0(0.00)	2 (16.66)

Table 5 shows that in 1992 all observation wells had good quality groundwater. The analysis reveals that RSC based unsuitability of groundwater for irrigation has increased sharply over last two decades. About 17 percent observation wells fell in unsuitable category in 2010. It is evident from analysis that concentration of RSC has increased in the district due dominance of tubewell irrigation. Conjunctive use of canal and groundwater may have prevented deterioration of groundwater.

Sodium Absorption Ratio (SAR)

SAR is also an important indicator for analyzing the suitability of groundwater for irrigation as it depicts sodium hazards to crops. Na^+ is an ion which affects soil properties as well as permeability of soils. High concentration of sodium ion may be harmful for plants and soils (Kelly 1951 and Todd and Mays 2005). The concentration of this ion also determines cation exchange reaction in soils. Its property of replacing calcium and magnesium makes it a hazards for soil structure as well as permeability (Raju 2007).

Alkalinity of groundwater is measured in terms of SAR value (Richard 1954) which is presented in Table 6. It is observed that all observation wells in 1992 and 2010 recorded excellent water for irrigation purposes.

Table: 6 Based on alkalinity hazard (SAR) after Richard (1954)

□10	Low (excellent)	11 (100)	12(100)
10-18	Medium(good)	0(0.00)	0(0.00)
18-26	High (doubtful/fair poor)	0(0.00)	0(0.00)
□26	Very High	0(0.00)	0(0.00)

Permeability Index

Permeability is the property of soil to transmit water and air through different horizons. It is determined by various factors including composition of soil, water properties and agricultural activities.

Excessive irrigation affects soil permeability due to accumulation as well as exchange of various ions concentration in water as well as soil. Doneen (1964) and Ragunath (1987) have evolved a measure for analysing the suitability of water on the basis of permeability index. According to the index water is classified into three categories where Class 1 and Class 2 are categories with good water for irrigation with more than 25 percent permeability and Class (III) water is unsuitable as it has less than 25 permeability index value. Table 7 shows distribution of observation wells according to these categories. It is evident that no observation well in the district had unsafe water in terms of permeability. It suggests that groundwater in the study area is by and large suitable for irrigation in this regard.

Table: 7 Based on permeability index Ragunath (1987)

☐75	Safe	11(100)	12(100)
25-75	Moderate	0(0.00)	0(0.00)
☐25	Unsafe	0(0.00)	0(0.00)

CONCLUSIONS

The study of Haryana has experienced intensive groundwater irrigation and excessive mining of groundwater from aquifers during last two decades. It has led to changes in groundwater chemistry and deterioration of its quality. Over this period 1992 to 2010 there has been 33 percent increase in number of observation wells having dominance of sodium and potassium cations. There has been also increase in magnesium concentration in water. But calcium ions have declined very sharply in the district. There has been slight increase in bicarbonate and chloride ions in groundwater. The percentage of observations wells under alkaline earth (Ca^{2+} +Mg^{2+}) has declined over two decades. But overall there has been increase in weak acid presence in groundwater in the study area.

The groundwater quality is largely controlled by lithology. It has been found that Residual sodium carbonate (RSC) based unsuitability of groundwater has risen sharply in the state during last two decades. In this regard about 17 percent observation wells in district fell in unsuitable groundwater category in 2010. Sodium concentration has also increased in the study area where tubewells are only source of irrigation. This also underlines that conjunctive use of water resources for irrigation is an effective deterrent to groundwater quality deterioration. On an average all the parameters for groundwater quality usages reveals that groundwater of the study area is suitable for irrigation purposes.

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