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Hydrochemistry of Groundwater and its Suitability for Different Purposes in the Pathri Rao Watershed, Haridwar District, India

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ABSTRACT

he hydrochemistry of water samples have been used to identify the chemical characteristics of groundwater in the pathri rao watershed within Haridwar District, India. Water samples in the project area were chemically analyzed for major cations and anions at the laboratory by the standard analytical procedures. Chemical data were manipulated using Piper diagram for chemical facies. Interpretations of hydrochemical analysis reveal that 90% of the studied groundwater samples belonged to Ca^{2+} – HCO_3^{1-} type with significant portion of Mg^{2+}. At places which are getting additional recharge to the aquifers from different sources, the groundwater belongs to SO_4^{2-}- Cl^{1-} type. Parameters such as Total dissolve sold (TDS), Sodium Adsorption Ratio (SAR), Soluble Sodium Percent (SSP) and Residual Sodium Carbonate (RSC) were used to assess the suitability of water for irrigation purposes. It is observed from these parameters that all the collected groundwater samples are suitable for irrigations. Assessment of the suitability for drinking was also evaluated in this paper by comparing the hydrochemical parameters of groundwater in the study area with the prescribed specification of World Health Organization (2004) and Indian standard (1993). The result shows that the groundwater in the region is mostly suitable for drinking without pretreatment except one site in the southwest of the study area unsuitable for human consumption without proper pretreatment.

Introduction

Groundwater assessment for drinking and irrigation has become a necessary and important task for present and future groundwater quality management. In recent years, because of climate change and government regulation, the surface water available for drinking and irrigation is decreasing, and hence, groundwater is becoming more and more important for human and agriculture uses. Many studies have focused on groundwater quality monitoring and evaluation for domestic and agricultural activities around the world [1, 2, 3, 4, 5]. The Study area (Pathri Rao watershed) is a traditional agricultural area with heavy population and located in a semiarid area so groundwater has always been the major source for drinking and irrigation due to the lack of surface water. Therefore carry out groundwater suitability assessment for agricultural and drinking uses in this region practically significant. The main objectives of the present work is to understanding the spatial and temporal distribution of hydrochemical constituents of groundwater related to its suitability for irrigation and drinking use of Pathri Rao watershed in the Hardwar district, India. It is located between 29° 50' 00" to 30° 11' 21" North and Longitude 77° 59' 19" to 78° 06' 21" East covering an area of approximately 44 square km (Fig. 1).

Geologically the study area is comprised of Siwalik rocks consisting of interbedded mudstones, sandstones, conglomerates and subordinate marls [6]. The Formation occurring to the south of the Siwaliks is alluvial fan deposits of recent age which are made up of assorted sands and gravel associated with occasional clays [7, 8, 9]. The borehole lithology at Tanda Village (Lat. 30 01.641N and Long. 77 58.102E) indicates that

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the unconsolidated Quaternary sediments comprising sands clay with pebble constitute the upper layer underlain by sand with boulder which represents the main aquifer in the study area underling by fine sand and clay (Fig.2). Hydrogeomorphologically, the area is classified into four geomorphic units. Siwalik hill, Upper Piedmont, Lower Piedmon and Flood plain The Upper Piedmont zone bordering the Siwalik hill comprise of unconsolidated coarse material and provide an excellent hydrogeological setup for recharge and infiltration. It is separated from the lower piedmont zone by the spring line along their junction. This zone is composed of coarse-grained sand and clays with gravel. The Flood plains form the youngest geomorphic unit, including sandbars, channel bars and meander scars. These are characterized by very gentle slope and consist of sub rounded to rounded fragments of sand.

Materials and Methods

Twenty one water samples have been collected from the shallow and deep aquifers at eleven selected sites during premonsoon season of 2002. The locations of these samples are shown in Fig.1. Of all these samples, 9 were collected from shallow aquifer and the other 12 were collected from deep aquifer. Before any sample collection, the water column in the well was discharged and fresh sample was collected to avoid stagnant case contaminated water. After the collection, the containers were labeled for identification and brought to the laboratory. Cations and anions in addition to other physical parameters such as pH and EC have been measured in all water samples. Cations (Ca^{+2}, Na^{+2}, and K^{+1}) have been analyzed by flame photometer, Mg^{+2} in EDTA titration method, HCO_3^{-1} and Cl^{-1} analyzed by H_2SO_4 and $AgNO_3$ titration method, respectively.

To prove above objectives the following techniques and data results have been used:

- Plotted percentage reacting values of major ions in Pipers trilinear diagram [10] (Fig. 3). Trilinear (Hill piper) which adds to the original two triangles, is a diamond shaped area in which two points (percentage epm values of major cations and anions) plotted with triangles are projected into diamond and plotted as a single point for the representation of overall characteristics of water.
- Comparing of the hydrochemical parameters of groundwater in the study area with the prescribed specification of World Health Organization (WHO) and Indian standard, (ISI) (table 1) has been use to assess of the suitability for drinking uses [11,12].
- Sodium Adsorption Ratio (SAR), Soluble Sodium Percent (SSP), Residual Sodium Carbonate (RSC) has been calculated from the following equations to evaluate the suitability of groundwater for irrigation uses.

$$SAR= Na^{+1}/ [(Ca^{+2} + Mg^{+2}) /2]^{0.5} \quad (1)$$

$$RSC=(CO_3^{-2}+HCO_3^{-1})-(Ca^{+2}+Mg^{+2}) \quad (2)$$

SSP = (Soluble Na^{+2} concentration/ Total ionic concentration) *100 (3)

Where, all the ions are expressed in meq/L

Result and discussion

Hydro-chemical Facies

Hydrochemical facies for the present investigation has been carried out by plotting percentage reacting values of major ions in Pipers trilinear diagrams[10]. The block wise data on the hydrochemical facies of groundwater in the study area has been presented in trilinear diagrams (Fig. 3). This diagram shows 90% of groundwater in the study area belongs to [Ca^{+2} –HCO_3^{-1}] type with significant portion of Mg^{2+}. At few places which are getting additional recharge, the groundwater belongs to [SO_4^{-2}- Cl^{-1}].

Quality Assessment for drinking purposes

Suitability of groundwater for drinking was evaluated by comparing the hydrochemical parameters of groundwater in the study area with the prescribed specification of World Health Organization, and Indian standard, [11, 12] (table 1). Accordingly the range of desirable pH values of water prescribed for drinking purposes is 6.5 – 9.5. The pH values of the collected groundwater samples vary between 8.2 and 9.4, indicating alkaline nature of groundwater and there are 8 water samples with pH values outside of the desirable ranges (Fig. 4).

TDS is an important parameter for assessing groundwater quality which is usually affected mainly by topography, lithology of aquifer, recharge, runoff

and discharge conditions of groundwater. According to standards for drinking water quality of (WHO & ISI), and [13] classification the permissible value of TDS is 500-1000 mg/L (table 2). Only one sample collected from shallow aquifer (S. No. 12) is outside of the desirable ranges and the other of the samples contain suitable amounts of the total dissolved solids (Fig.5).

The total hardness (TH) is varying from 5 to 41 mg/l (Fig.6). Groundwater of the entire study area lies within the minimum permissible limit prescribed by ISI & WHO (table 1). [14] classified groundwater, based on TH, as ground water with TH <75, 75–150, 150–300 and >300 mg/l, designated as soft, moderately hard, hard and very hard, respectively (table 3). According to the above categorization, 100 % of the groundwater samples are soft. The hardness of the water is due to the presence of alkaline earths such as calcium and magnesium.

The concentration of calcium in the studied samples ranges between 29 and137 for shallow water sample and 25 and 96 ppm for deep aquifer (Fig.7). Accordingly, all of these samples except samples 6, 10, 12 for shallow and sample 7 for deep aquifer are suitable for drinking uses. All of the studied samples contain suitable concentration of magnesium for drinking water uses (Fig.7). According to the (WHO) and U.S.A. standards [13] the water used for drinking purposes should not contain sodium in amount exceeding 200 ppm. Accordingly, 100% of the studied samples are suitable. The entire studied samples for the deep aquifer contain suitable concentration of potassium, while for shallow aquifer 0.44% of the studied sample contain unsuitable amount for drinking purposes (table 1). The concentration of Chlorides and bicarbonate in studied sample is suitable for drinking. All of the studied samples (except sample no.12) contain suitable concentration of the Sulphates (Fig. 8). It can be seen from the above analysis that the groundwater in the region is mostly suitable for drinking without pretreatment except one site located in the southwest of the study area the concentration of TDS is higher than 1000 mg/L which is unsuitable for human consumption without proper pretreatment

Quality Assessment for Irrigation purposes

The suitability of groundwater for irrigation is dependent on the effects on the mineral constituents of the water on both the plant and the soil [15]. Salts can not only limit growth of plants physically, by restricting the taking up of water through modification of osmotic processes, but also may damage plant growth chemically by the effects of toxic substances upon metabolic processes. In the present study, TDS, SAR, SSP and RSC were used to carry out the assessment of the suitability of water for irrigation purposes.

The permissible concentration of TDS in groundwater for irrigation is < 3000 mg/L [4]. When the concentration is >3000 mg/L, the risk to cause salinity may be higher. The TDS in the studied sample varies from 227 to 1320 for both aquifers. Fortunately, none of the water samples fall into salinity contamination class

Sodium adsorption ratio (SAR) gives the clear idea about the adsorption of sodium by soil. It is widely used in the USA and some western countries for the assessment of sodium hazards [5]. SAR is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop [16]. It can be calculated from the ratio of sodium to calcium and magnesium equation (1) [17]. Based on the grading criteria of water for irrigation, SAR is classified into excellent (<10), good (10-18), permissible (18-26), unsuitable (>26) [15]. The calculated SAR ranges from 0.14 to 1.7 in groundwater in the study area and all the samples fall into excellent category .

The Residual Sodium Carbonate (RSC) were calculated by equation (2) and also used for irrigation water quality assessment. Based on RSC, irrigation water is classified as suitable (<1.25), marginal (1.25–2.5), and not suitable (>2.5) [18]. With respect to RSC, all samples fall into suitable category and can be used for agricultural irrigation purpose.

Soluble Sodium Percent (SSP) is also used to evaluate sodium hazard. SSP is defined as the ration of sodium to the total cation which can be calculated using by equation (3). Water with a SSP greater than 60% may result in sodium accumulations that will cause a breakdown in the soil's physical properties [15].The

values for the soluble sodium percent (SSP) in the study area range from 4.63 to 27.32%. It is observed that all samples have low sodium percent (less than 60%) and are suitable for irrigation purposes.

The assessment results with these methods are listed in table 4. which is show that the groundwater quality in the study area is fit for consumption and will not cause serious health problem

Conclusions

The groundwater sample of pathri rao watershed was assessed for their quality in terms of their potential for drinking and irrigation. Interpretation of hydrochemical analysis reveals that the groundwater in area is soft and mostly alkaline in nature. The dominant hydrochemical facies of groundwater in the study area is [Ca^{2+} –HCO_3^{1-}] type with significant portion of Mg^{2+}. Based on the pH, TH and TDS of almost all samples, the groundwater from the study area is found to be safe and suitable for drinking purposes. TDS, SAR, RSC and SSP values suggests suitability of groundwater from the study area for irrigation. This paper may give out as a preliminary study to provide baseline information that may direct future water quality assessment studies in the study area

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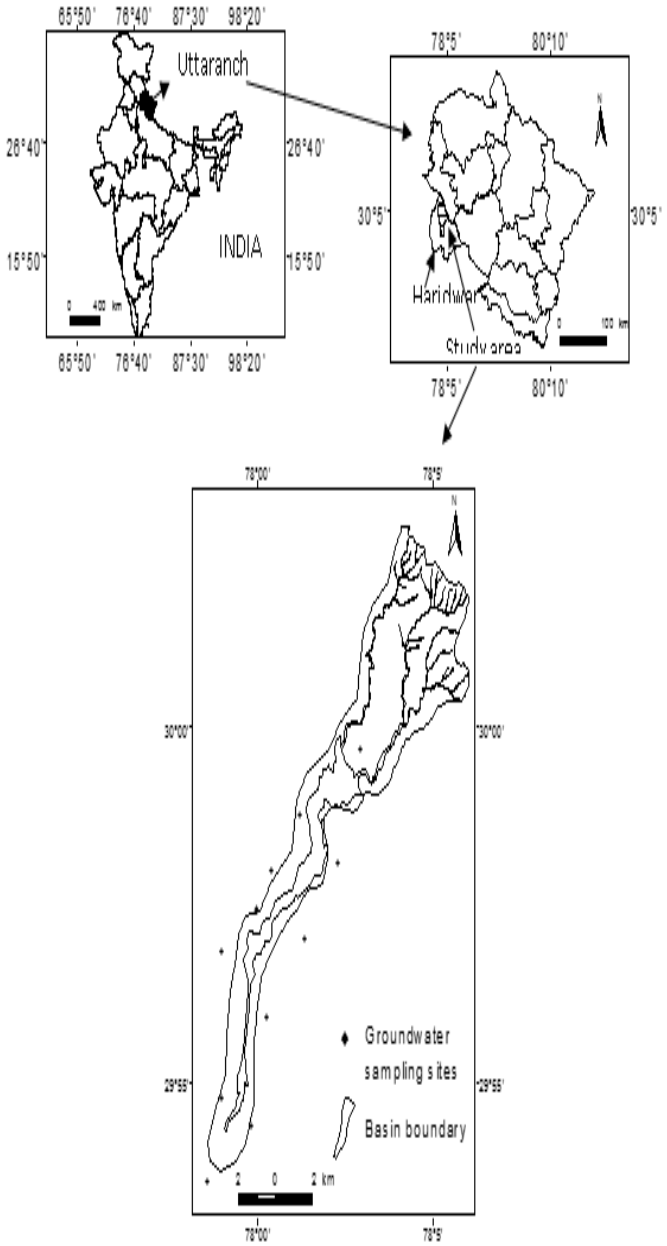

Fig.1: Location map of the study area

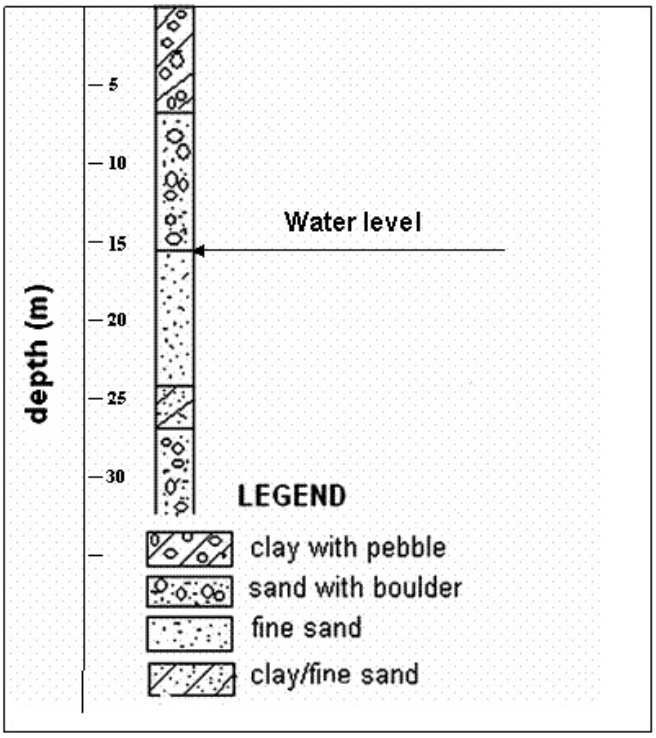

Fig. 2: Lithological data at selected site (Tanda village) in the study area

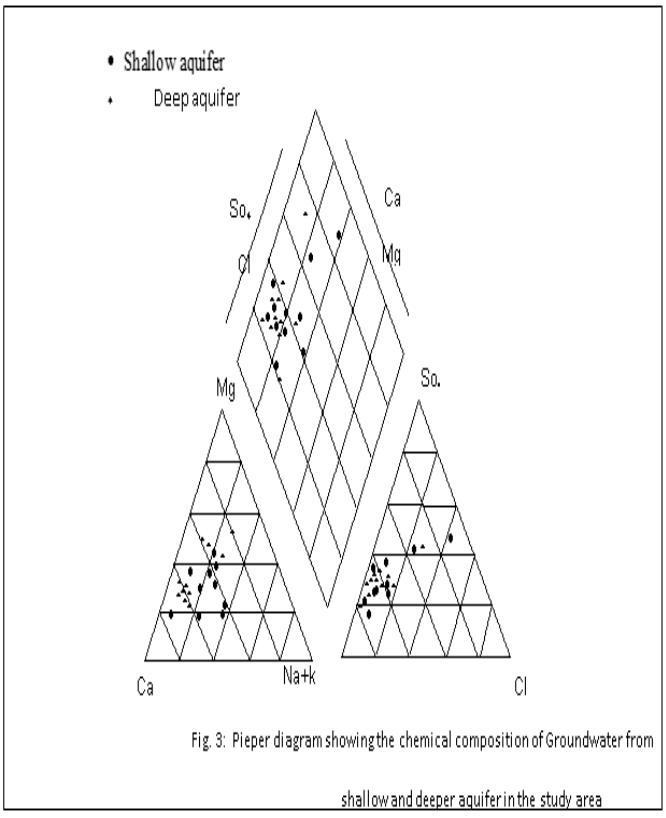

Fig. 3: Pieper diagram showing the chemical composition of Groundwater from shallow and deeper aquifer in the study area

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Table 1: Groundwater samples of the study area exceeding the permissible limits prescribed by WHO (2004) and ISI (1993) for drinking purpose

S. No	Water quality parameters	WHO International Standards 2004		Indian Standard (ISI 10500, 1993)		No. of sample exceeding Permissible limit		(%) of sample exceeding permissible limit	
		Most desirable limit	Max. allowable limit	Highest desirable	Max. permissible	Deep	Shallow	Deep	Shallow
1	pH	6.5	8.5	6.5	9.5	4\12	4\9	0.33%	0.44%
2	TDS	500	1500	500	2000	Nil	1\9	Nil	0.1%
	TH	100	500	300	600	Nil	Nil	Nil	Nil
3	Ca	75	200	75	200	1\12	3\9	0.08	0.33%
4	Mg	50	150	30	100	Nil	Nil	Nil	Nil
5	Na	--	200	--	200	Nil	Nil	Nil	Nil
6	K	--	12	--	--	Nil	4\9	19.05%	0.44%
7	Cl	200	600	--	--	Nil	Nil	Nil	Nil
8	So4	200	400	200	400	Nil	1/9	4.76%	0.1%
9	HCO	--	350	250	1000	Nil	Nil	Nil	Nil

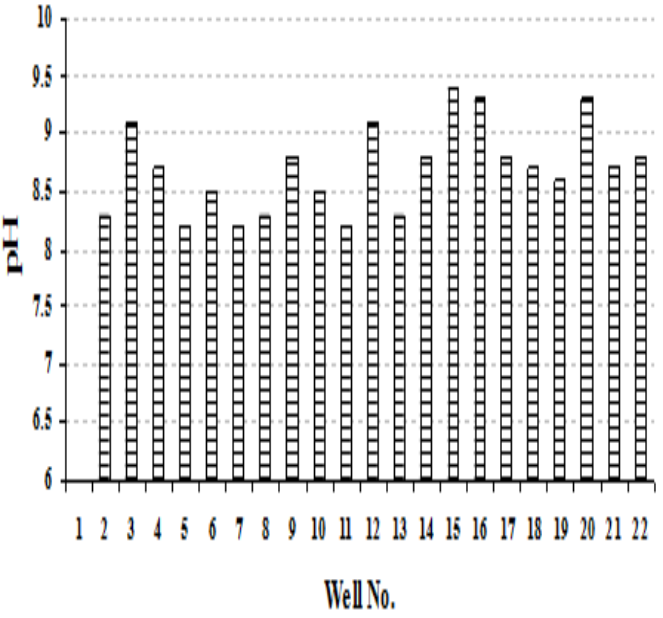

Fig.4: Values of pH for all studied sample

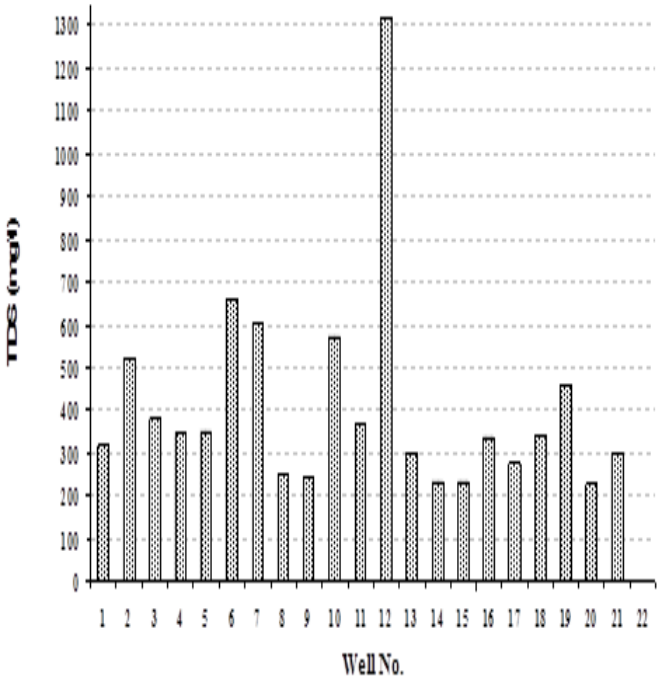

Fig.5: Values of TDS for all studied sample

Table 2: Classification of groundwater based on TDS (Davis and De Wiest 1966)

TDS (mg\l)	Water type	% of samples
>500	Desirable for drinking	76%
500- 1,000	Permissible for drinking	19%
1,000- 3,000	Useful for	5%

	irrigation	
>3,000	Unfit for drinking and irrigation	Nil

Table 3: Sawyer and McCarty's classification of groundwater based on hardness

Total hardness as CaCO3 (mg/l)	Water type	Range (no. of samples)	% of samples
>75	Soft	70	
75-150	Moderately Hard	88-142 (4 sample)	19%
150- 300	hard	154- 266 (11 sample)	52%
>300	Very hard	332-544 (6 samples)	29%

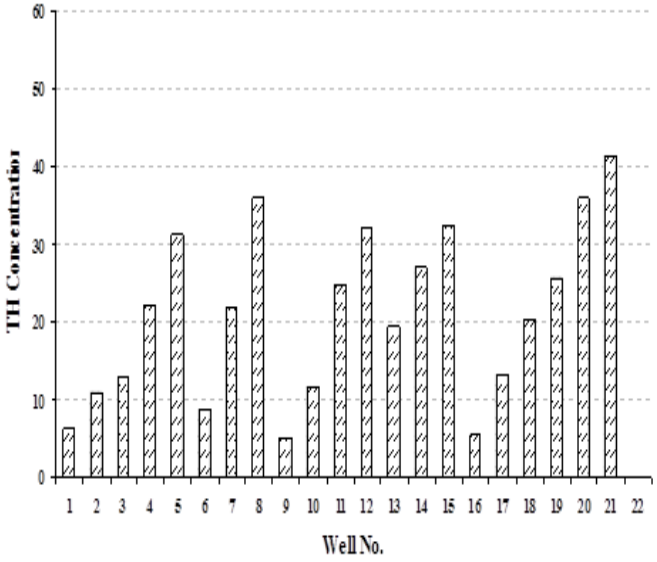

Fig.6: Values of TH for all studied sample

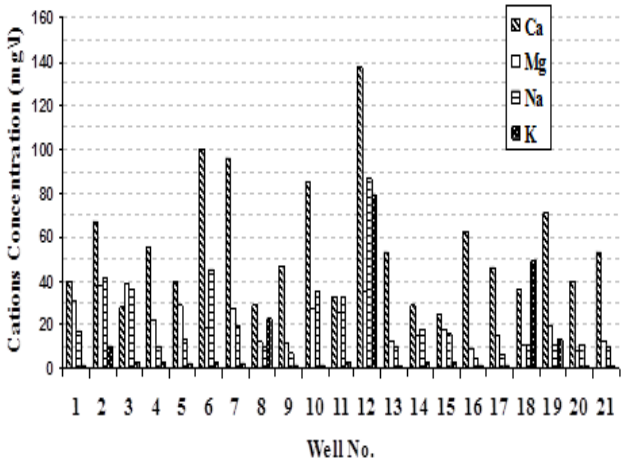

Fig.7: Cations concentration for all studied samples

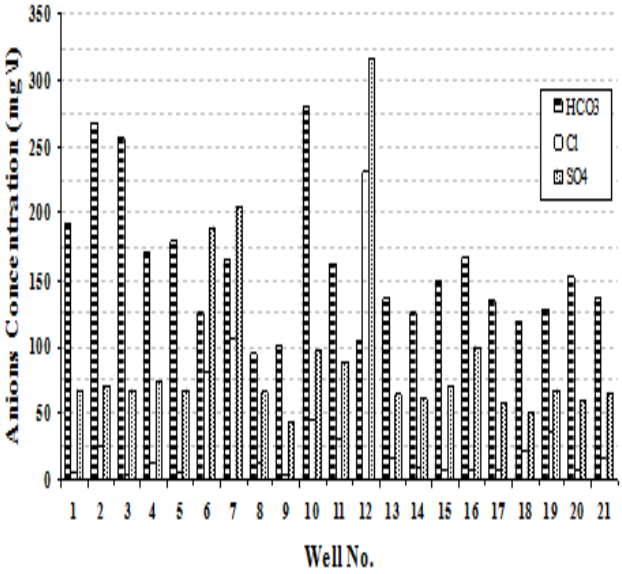

Fig.8: Anion concentration for all studied samples

Table 4: Assessment results of groundwater for irrigation

Sample No	Water	Assessment results and grading for irrigation purpose							
		TDS	Grading	SAR	Grading	SSP	Grading	RSC	Grading
1	Deep	320	Suitable	0.49	Excellent	13.83	Suitable	-1.44	Suitable
2	Shallow	520	Suitable	1.01	Excellent	21.32	Suitable	-2.04	Suitable
3	Deep	380	Suitable	1.02	Excellent	24.88	Suitable	-0.39	Suitable
4	Shallow	346	Suitable	0.30	Excellent	8.98	Suitable	-1.75	Suitable
5	Deep	350	Suitable	0.40	Excellent	11.78	Suitable	-1.39	Suitable
6	Shallow	658	Suitable	1.08	Excellent	22.81	Suitable	-4.50	Suitable

7	Deep	602	Suitable	0.46	Excellent	10.82	Suitable	-4.35	Suitable
8	Shallow	248	Suitable	0.39	Excellent	12.27	Suitable	-0.95	Suitable
9	Deep	245	Suitable	0.23	Excellent	8.26	Suitable	-1.65	Suitable
10	Shallow	573	Suitable	0.85	Excellent	19.06	Suitable	-1.89	Suitable
11	Deep	365	Suitable	1.05	Excellent	27.32	Suitable	-1.09	Suitable
12	Shallow	1320	Suitable	1.71	Excellent	24.33	Suitable	-8.05	Suitable
13	Deep	298	Suitable	0.33	Excellent	10.63	Suitable	-1.45	Suitable
14	Shallow	233	Suitable	0.66	Excellent	21.73	Suitable	-0.65	Suitable
15	Deep	232	Suitable	0.57	Excellent	19.37	Suitable	-0.24	Suitable
16	Shallow	335	Suitable	0.14	Excellent	4.63	Suitable	-1.15	Suitable
17	Deep	276	Suitable	0.20	Excellent	6.99	Suitable	-1.30	Suitable
18	Shallow	339	Suitable	0.40	Excellent	10.55	Suitable	-0.76	Suitable
19	Deep	458	Suitable	0.29	Excellent	7.83	Suitable	-3.05	Suitable
20	Deep	227	Suitable	0.41	Excellent	14.91	Suitable	-0.20	Suitable
21	Deep	299	Suitable	0.33	Excellent	10.69	Suitable	-1.46	Suitable

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هيدرو كيميائية المياه الجوفيه وتحديد ملائمتها لاغراض مختلفه في الحد الفاصل لباثري راو في مقاطعة هريدوارفي الهند

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الخلاصة:

استخدمت هيدروكيميائية عينات المياه لتحديد الخصائص الكيميائية للمياه الجوفيه في الحد الفاصل لباثري راو في منطقة هريدوار في الهند. عينات المياه في منطقة الدراسه حللت كيميائيا في المختبر باستخدام الإجراءات المعيارية التحليلي لتحديد الايونات السالبه والموجبه. التفسير الهيدروكيميائي للتحاليل الكيميائية يشير الى ان 90% من المياه كانت من نوع [Ca2+ –HCO31–] مع كمية قليلة من المغنيسيوم الا انه هناك نوع اخر من المياه هو [So42– – Cl–]في مواقع قليلة لمنطقة الدراسة والتي تحصل على تغذية اضافية. تم استخدام مؤشرات متعدده مثل كمية الاملاح الكلية الذائبة (TDS) ونسبة امتزاز الصوديوم (SAR) ونسبة الصوديوم المذاب (SSP) وكاربونات الصوديوم المتبقية (RCS) لغرض تقييم مدى صلاحية المياه الجوفية في منطقة الدراسة لاغراض الري وتبين من خلال هذه المؤشرات ان كل عينات المياه المدروسة صالحة لاغراض الري. تم تقييم ملائمة المياه لاغراض الشرب ايضا في هذا البحث بمقارنة المواصفات الكيميائية للمياه الجوفيه في منطقة الدراسة مع المواصفات العالمية الموضوعة من قبل منظمة الصحة العالمية لسنة 2004 والمواصفات الهنديه لسنة 1993 وبينت النتائج ان المياه الجوفية لمنطقة الدراسة صالحة لاغراض الشرب عدا منطقة واحدة تقع الى الجنوب من المنطقة المدروسة غير صالحة .