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RESEARCH ARTICLE

ASSESSMENT OF SEASONAL TRENDS IN GROUNDWATER QUALITY ACROSS THE ITAWA TEHSIL OF KOTA DISTRICT OF RAJASTHAN, INDIA

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ABSTRACT

To assess the impact of seasonal trends on groundwater quality, samples were collected during pre-monsoon, post-monsoon, spring and winter seasons from selected locations of Itawa tehsil of Kota District of Rajasthan state (India) from 2011 to 2013 and determined physicochemical parameters like pH, TDS, specific conductivity, total alkalinity, magnesium, nitrate, sulphate, phosphate, potassium, sodium, hardness, chloride, and fluoride. Standard research techniques were used to evaluate the quality of groundwater and its suitability for irrigation and drinking purpose. Results of investigation showed that conductivity, alkalinity and hardness parameters have higher values during the post-monsoon season than in the spring season. The average values for groundwater in pre-monsoon, post-monsoon, spring and winter seasons of the pH was 7.3 - 8.1, EC (Electrical Conductivity) 910 - 1313 µs/cm, TDS (Total Dissolved Solid) 659 - 911 mg/L, TA (Total Alkalinity) 205 - 407 mg/L, TH (Total Hardness) 120 - 312 mg /L, Ca (Calcium) 79 - 185 mg/L, Mg (Magnesium) 43 -125 mg/L, Na (Sodium) 109 - 183 mg/L, K (Potassium) 5 - 11 mg/L, Cl (Chloride) 54 - 107 mg/L, SO_4^{2-} (Sulphate) 64 - 125 mg/L, NO_3^- (Nitrate) 19 - 41 mg/L, PO_4^{3-} (Phosphate) 0.28 - 0.55 mg/L. The results were compared with the World Health Organization (WHO, 2006) guideline limits for drinking water[1]. The study suggested that the majority of the groundwater samples were unsuitable for irrigation in post-monsoon compared to that in pre-monsoon.

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INTRODUCTION

Groundwater is the precious source for irrigation and drinking purpose in rural and urban area communities. Along with natural process human activities generate an undesirable change in groundwater quality. In recent years degradation of groundwater quality is a major environmental issue of concern. Water is an essential substance for all living beings to survive on this planet. In India millions of people of rural and urban communities are dependent on groundwater for drinking and other purposes. Assessment of groundwater quality is very important to check the suitability of water for various purposes (Shrinivasa *et al.,* 2000). Groundwater is a most abundant ecological resource which situates below the land surfaces and withdrawn by people of urban and rural areas for different activities (Singh *et al.,* 2008). If human use upsets the balance between recharge, capture, and natural outflows, aquifer equilibrium lost until a new balance is reached.

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The major anthropogenic activities responsible for degradation of groundwater quality are urbanization, industrialization, and agricultural practices (Hakim *et al.,* 2009). Physicochemical properties of Groundwater vary due to intense agriculture activities (use of fertilizers, insecticides, pesticides and lime), industrial waste (chemical waste, toxic waste and solid waste), improper handling of domestic waste, seasonal variation, high population density etc. (Sharma *et al.,* 2004). Most of the rural and urban populations have to depend on unsafe groundwater sources for their routine purpose (Reza *et al.,* 2009).

Chemical contamination of groundwater may pose serious health hazards. In order to understand the contamination level and effect of seasonal trends on physicochemical properties of groundwater, an intensive investigation was undertaken (Rajankar *et al.,* 2011). A huge number of studies have been carried out to estimate the suitability of groundwater for irrigation and drinking purpose in various parts of India and across the world. Earlier researches indicate that groundwater quality status varies due to climate change and seasonal variations (Sharma *et al.,* 1995; Subba 2002; Jha *et al.,* 2000; Sreedevi 2004; Jain *et al.,* 2010; Singh *et al.,* 1994;

Mittal *et al.,* 1994). People of Itawa tehsil of Kota District of Rajasthan state, India largely depend upon groundwater for drinking and irrigation purpose. Therefore, it is considered worthwhile to carry out systematic studies and report variations in quality of the groundwater of the selected area in different seasons by analysing different physicochemical characteristics of different water samples collected from the study area in four different seasons (pre-monsoon, post-monsoon, winter and spring).

MATERIAL AND METHODS

The Study Area

The tehsil of Itawa is in Kota District, which is in the Eastern part of Rajasthan state, India. In geographical terms, the location of the Kota District is 24º 25' and 25º 51' North latitude and 75º 31' and 77º 26' East longitude. The Kota District is situated on the banks of Chambal, one of the premier rivers in the nation.

The geography of Kota district is such that it is surrounded by Bundi and Tonk district in North, Sawai Madhopur in North West, Baran district in East, Jhalawar and Mandsor district of M.P. in South, and Chittorgarh district in West. The Kota district features a hot, semi–arid climate, with high temperature and mild winter. Kota district has several major power plants and industries. The range of annual temperature is 8^0C – 47^0C including yearly high and low temperatures in degrees Celsius. The average annual rainfall in the Kota district is about 660.6 mm. Kota is famous all over India for its coaching industry. In Itawa tehsil agriculture is the principal occupation of the people. The climatic conditions of Itawa tehsil are favorable for agricultural activities.

Collection of water samples

A systematic sampling was done for the physicochemical assessment of ground water quality of Itawa tehsil. Water samples were collected from 36 different sampling points of 6 village sites (Binayaka, Ayana, Ganeshganj, Rajopa,Talab and Dheepri Chambal) from both tube wells and hand pumps in spring, winter, pre-monsoon, and post monsoon, periods during years 2011 to 2013. The samples were collected as composite samples in clean and sterilised polythene bottles. Before sampling plastic bottles were rinsed with groundwater to be sampled. The samples were stored at a temperature below 4°C prior to analysis. A physicochemical analysis was carried out for 15 parameters viz. pH, conductivity, TDS (total dissolved solid), TH (total hardness), TA (total alkalinity), Bicarbonate Alkalinity and major ions K^+, Na^+, Ca^{+2}, Mg^{+2}, nitrate,

Table 1. Selected sampling sites in Itawa Tehsil

Sampling sites →	Binayaka		Ayana		Ganeshganj		Rajopa		Talab		Dheepri Chambal	
Sampling Time →	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening
Sample No. →	I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8	I-9	I-10	I-11	I-12

Table 2. Physicochemical Parameters obtained for Itawa Tehsil (average of values of different locations)

S. No.	Year	2011				2012				2013			
	Parameters/Season	pre	post	winter	spring	pre	post	winter	spring	pre	post	winter	spring
1	pH	7.8	7.3	7.6	7.7	8.0	7.5	7.7	7.9	8.1	7.6	7.8	8.0
2	Conductivity	1299	926	1105	1233	1303	935	1133	1309	1313	910	1141	1266
3	TDS (mg/L)	886	677	745	795	911	703	771	828	866	659	729	787
4	Total Alkalinity	400	213	303	367	402	217	317	380	407	205	321	383
5	Bicarbonate Alkalinity	400	213	303	367	402	217	317	380	407	205	321	383
6	Total Hardness	300	129	218	267	303	126	212	280	312	120	219	289
7	Calcium Hardness	178	80	131	159	181	80	125	168	185	79	134	172
8	Magnesium Hardness	120	53	86	107	121	51	86	111	125	43	84	115
9	Sodium	178	109	139	163	179	110	147	170	183	116	152	174
10	Potassium	9	5	7	8	11	6	9	10	11	6	8	10
11	Chloride	100	55	73	89	103	54	75	96	107	61	78	101
12	Sulphate	123	69	97	109	120	64	93	113	125	70	99	117
13	Nitrate	34	19	27	28	40	22	28	36	41	22	30	37
14	Fluoride	1.3	0.8	1.1	1.2	1.4	0.9	1.2	1.4	1.5	1.0	1.3	1.5
15	Phosphate	0.5	0.3	0.4	0.5	0.5	0.3	0.3	0.5	0.5	0.3	0.5	0.6

phosphate, sulphate, fluoride, chloride. Analytical grade reagents were used for the assessment of samples and double distilled water was used for preparation of solutions. This was to ensure that the samples collected truly representing the groundwater of the selected area.

RESULTS AND DISCUSSION

Physicochemical properties

To illustrate the groundwater quality of Itawa tehsil 15 different physicochemical parameters viz. pH, T.D.S (total

dissolved solid)., conductivity, TA (total alkalinity), bicarbonate alkalinity, TH (total hardness), levels of Cl^- (chloride), Mg^{2+} (magnesium), Ca^{+2} (calcium), NO_3^- (nitrate), SO_4^{2-} (sulphate), PO_4^{3-} (phosphate), Na^+ (sodium), K^+ (potassium) and F^- (fluoride) were determined of the groundwater samples collected from six selected sites viz. Binayaka, Ayana, Ganeshganj, Rajopa, Talab and Dheepri Chambal in four different seasons viz. pre-monsoon, post-monsoon, spring and winter of the years 2011, 2012 and 2013. The Physico-chemical parameters obtain for water samples collected in Itawa tehsil of Kota District are shown in Table 2.

Table 3. Results of different indices calculated with average values of physicochemical parameters obtained for different sampling locations

Year	2011				2012				2013			
Calculated Indices	pre	post	winter	spring	pre	post	winter	spring	pre	post	winter	spring
%Na	56.5	63.5	58.9	57.6	56.3	64.0	60.5	57.1	56.1	67.1	60.5	57.0
SAR	4.6	4.2	4.4	4.5	4.6	4.4	4.6	4.6	4.7	4.7	4.7	4.6
ESP	5.2	4.7	4.9	5.1	5.2	4.9	5.3	5.2	5.3	5.4	5.3	5.3
RSC	2.0	1.6	1.7	2.0	2.0	1.7	2.1	2.0	1.9	1.7	2.1	1.9

Table 4. Showing correlation analysis between various physicochemical parameters

	pH	TDS	TA	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
pH	1	0.8035	0.8976	0.8933	0.9024	0.8758	0.9323	0.9555	0.9363	0.8957	0.9723	0.9859
TDS		1	0.9249	0.9241	0.9225	0.9325	0.9119	0.8861	0.9113	0.9089	0.8821	0.7850
TA			1	0.9973	0.9960	0.9949	0.9932	0.9352	0.9779	0.9907	0.9292	0.9110
TH				1	0.9992	0.9976	0.9907	0.9310	0.9829	0.9951	0.9341	0.9042
Ca^{2+}					1	0.9950	0.9923	0.9312	0.9869	0.9956	0.9389	0.9092
Mg^{2+}						1	0.9826	0.9290	0.9758	0.9883	0.9259	0.8875
Na^+							1	0.9467	0.9898	0.9909	0.9480	0.9399
K^+								1	0.9465	0.9195	0.9835	0.9546
Cl^-									1	0.9826	0.9603	0.9318
SO_4^{2-}										1	0.9305	0.9063
NO_3^-											1	0.9558
F^-												1

All parameters were compared with drinking water standards prescribed by BIS and WHO. Table 2 represents the average of the results of the physicochemical parameters of the samples (I-1, I-2, I-3, I-4, I-5, I-6, I-7, I-8, I-9, I-10, I-11, and I-12) of six sampling sites of Itawa tehsil. Classification of irrigation water on the basis of Na%, SAR, ESP and RSC is shown in Tables 3 and correlation matrix among 12 water quality parameters of groundwater of Itawa tehsil is shown in Table 4.

pH

pH values ranged between 7.3 and 8.1 during the study period (years 2011-2103). pH is a measurement of alkalinity of water in terms of hydrogen ion concentration. The results show that in the study period the maximum pH was recorded 8.1 in the pre-monsoon season of the year 2013 and the minimum pH was recorded 7.3 in post-monsoon season of the year 2011. The pH values were within the permissible limits as prescribed by WHO and BIS for all samples.

Electrical Conductivity (EC)

Electrical Conductivity values varied between 910 µS and 1313 µS. Electrical conductivity is the measurement of the ability of water to carry an electrical current. The maximum recorded EC 1313 was in the pre-monsoon season of the year 2013 and the minimum recorded EC was 910 in the post-monsoon season of the year 2013. Results show that conductance varies according to the season.

Total Dissolved Solids (TDS)

The value of total dissolved solids of groundwater ranged from 659 to 911 in the study period. Total dissolved solids denote weight of all solids that are dissolved in a given volume of water. The maximum value of total dissolved solids was examined in pre monsoon season of the year 2012 and minimum in post monsoon season of year 2013.

Total dissolved solids of all the examined samples were within permissible limit of BIS (10500).

Total Alkalinity (TA)

Total alkalinity of groundwater samples ranged from 205 to 407 mg/L. Total alkalinity is the total concentration of bases in water. The maximum value of total alkalinity observed 407 mg/L in the pre-monsoon period of the year 2013 and the minimum value of total alkalinity observed 205 mg/L in the post-monsoon period of the year 2013. All samples have values within the permissible limit of drinking water standard BIS (10500).

Total Hardness (TH)

Total hardness values varied between 120 and 312 mg/L. The maximum value of total hardness was recorded 312 mg/L in the pre-monsoon period of the year 2013 and the minimum TH value was 120 mg/L recorded in post-monsoon season of the year 2013.

Calcium Hardness

The calcium hardness values ranged from 79 to 185 mg/L and these values were within permissible limits by WHO and BIS.

The maximum calcium value 185 mg/L was observed in pre-monsoon season of the year 2013 and the minimum value 79 mg/L was observed in post-monsoon season of the year 2013.

Magnesium Hardness

Inspection of the data Table 2 reveals that the magnesium values varied from 43 to 125 mg/L for all groundwater samples and these values were within the limits prescribed by BIS and WHO. The maximum magnesium value observed 125 mg/L in pre-monsoon season of the year 2013 and the minimum magnesium value was recorded 43 mg/L in post-monsoon season of the year 2013.

Sodium (Na^+)

The results recorded in Table 2 during study years show that amount of sodium ranged from 109 mg/L to 183 mg/L. In the year, 2013 the maximum value of sodium was recorded 183 mg/L in pre-monsoon and in the year 2011 minimum value of sodium was recorded 109 mg/L in post-monsoon.

Potassium (K^+)

The amount of potassium ranged from 5 mg/L to 11 mg/L. During Study Period the maximum value of potassium was recorded 11 mg/L in pre-monsoon season of the year 2013 and the minimum value of potassium was recorded 5 mg/L in post-monsoon season of the year 2011.

Chloride (Cl^-)

Chloride is found naturally in groundwater. Table 2 indicates that the chloride values extend from 54 mg/L to 107 mg/L. The maximum chloride values were recorded 107 mg/L in pre-monsoon season of the year 2013 and the minimum chloride values were recorded 54 mg/L in post-monsoon season of the year 2012.

Sulphate (SO_4^{2-})

The sulphate values displayed in Table 2 range from 64 mg/L to 125 mg/L. The observations recorded during study period 2011-2013, the maximum sulphate value was recorded 125 mg/L in pre-monsoon season of the year 2013 and the minimum sulphate value recorded 64 mg/L in post-monsoon season of the year 2012.

Nitrate (NO_3^-)

The data registered in the Table 2 for groundwater examined during the study years indicate that the nitrate values extend from 19 mg/L to 41 mg/ L. The observations showed that the maximum value of nitrate was recorded 41 mg/L in pre-monsoon season of the year 2013 and the minimum value of nitrate was recorded 19 mg/L in post-monsoon season of the year 2011.

Phosphate (PO_4^{3-})

During the years of investigations the quantity of phosphate has been found in range from 0.28 mg/L to 0.55 mg/L. During study period, the maximum phosphate value was recorded 0.55 mg/L in spring season of the year 2013 and the minimum phosphate value was recorded 0.28 mg/L in post-monsoon season of the year 2011.

Irrigation Water Quality

Evaluation of groundwater quality for irrigation was carried out calculating different indices like Na %, SAR, RSC, PI, AI and LSI. Statistics of water quality parameters of groundwater samples is presented in Table 3.

Sodium Percent (Na %)

Sodium percentage is used for adjudging the quality of water for agricultural purposes. The values of % Na varied from 39.9 to 43.5 (Table-3). According to Table-3 all the groundwater samples were within excellent to permissible limit for irrigation. Na% determined by using the following formula

$$Na\% = \frac{(Na^+ + K^+) \div (Ca^{2+} + Mg^{2+} + Na^+ + K^+)}{100}$$ (Concentrations are in meq/L).

Sodium Adsorption Ratio (SAR)

SAR is a measure of possible sodium hazard to crops. It is a most important parameter for the determination of suitability of water for irrigation. SAR values ranged from 2.4 to 3.3 (Table-3). The results show that all the samples were safe for irrigation point of view. SAR estimated by applying the following formula:

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}}$$ (Concentrations are in meq/L).

Residual sodium carbonate (RSC)

RSC is a significant parameter to determine the hazardous effect of carbonate and bicarbonate on quality of groundwater. RSC values ranged from 1 to 1.9 (Table 3). RSC was determined by the following equation:

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

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 1.58 to 2.07. The maximum value calculated of ESP was in winter season of year 2013 and the minimum value was in post monsoon season of year 2011. It was calculated with the help of the following relationship:

$$ESP = \frac{100\ (-0.02126\ +\ 0.014575\ SAR)}{1 + (-0.0126\ +\ 0.01475\ SAR\ )}$$

Correlation coefficient analysis

Correlation is the relationship between two variables. To find out the relationship between two parameters x and y, the Karl Pearson's correlation coefficient, r is used and it is determined as follows –

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[\,n\sum x^2 - (\sum x)^2\,]\,[\,n\sum y^2 - (\sum y)^2\,]}}$$

Here, n = number of data points x = values of x–variable,y = values of y–variable.

In the present study highly positive correlations obtained between Total Hardness and Magnesium, (r = 0.997) and between Total alkalinity and Calcium Hardness (R=0.996). Strong correlation also revolved between Calcium and Total Hardness (0.999), magnesium and Total Hardness (0.997), sodium and sulphate (0.990), TDS and sulphate (0.908) TDS and sodium (0.911). A linear regression analysis is a very useful technique to estimate the predictable relationship between variables.

Conclusion

The groundwater quality analysis of the Itawa tehsil of Kota District was observed fit for drinking and irrigation purpose during most of seasons in other words the study period. In groundwater quality of Itawa tehsil is not harmful to people. Most of the physicochemical parameters were within permissible standard limits for drinking and other purposes.

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