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RESEARCH ARTICLE

Assessing Variation in Physicochemical Characteristics of Groundwater of Digod Tehsil of Kota District of Rajasthan, India, Using Statistical Correlation Study

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Abstract: Groundwater is an important and renewable natural resource on the earth. The physicochemical characteristic of groundwater plays a significant role on health of Human beings and other uses. The present paper deals with the study of physicochemical parameters like pH, TDS., specific conductivity, total alkalinity, hardness and levels of chloride, magnesium, nitrate, sulphate, phosphate, sodium, potassium and fluoride from 2011 to 2013. During the study period various parameters were determined with the help of standard research techniques. Correlation statistical analyses were used to evaluate the overall factors influencing the groundwater quality. The groundwater hydrochemistry investigations revealed that the seasonal effect changes the concentration of various parameters. Results of the investigations of few of the samples show that some of the parameters like nitrate and fluoride were above permissible limit affecting the quality of groundwater of Digod tehsil of Kota District of Rajasthan state in India.

Keywords: Groundwater quality, correlation statistical analysis, Digod Tehsil, Kota District

Introduction

Water is essential for all forms of life including human beings. Groundwater has been considered renewable natural resource of safe drinking water and other uses like domestic, industrial, agricultural and commercial in the world. Groundwater quality is a function of physical and chemical parameters that are affected by geological formations and anthropogenic activities[1]. The groundwater quality degraded by modern civilization, industrialization, urbanization and increase in population[2]. In several states of India, more than 90% of populations are dependent on groundwater for drinking and other purpose[3]. Their ground water is reported as contaminated by various ways such as by use of fertilizers in farming, seepage from effluent bearing water body, industrial discharge[4-5]. Groundwater studies have been considered the main part of pollution studies on the environment[6].

A continuous monitoring of groundwater becomes mandatory to minimize the groundwater contamination and to make control over the pollution causing agents. Usually groundwater quality modified by the hydrological cycle that depends on the natural and anthropogenic processes. Change in quality of natural waters may disturb the equilibrium in between different forms of life and ultimately would become unfit for intended purpose of the human being. The availability of groundwater sources is becoming critical day by day. The use of water resource to human's benfit has been a fundamental factor in development of civilization throughout the world. The increasing population of Kota District and surrounding areas putting pressure on the fresh water resources. The main aim of study is to report seasonal variation in quality of the groundwater of Digod tehsil in district Kota of Rajasthan (India) by assessing different physicochemical characteristics of different water samples collected from the area in four different seasons (pre-monsoon, post-monsoon, winter and spring) and analysing results obtained statistically.

Experimental

Digod tehsil (Rural area) of Kota district of Rajasthan state in India was selected as the study area. Kota District extends from $24^0$25' and $25^0$51' North latitudes and from $75^0$31' and $77^0$26' East in longitude. It is situated on the Eastern bank of perennial river Chambal in the Southern part of Rajasthan at an average height of 280 meters above sea level. It covers an area of 5217 sq km, of which 310.05 is urban area and 4906.95 sq. km is rural area. The district is bounded by Bundi district in North, Baran district in East, Jhalawar district in South, and Chittorgarh district in West. According to the 2011 census Kota District had population of 1,951,014 of which male and female were 1,021,161 and 929,853 respectively. There are five subdivisions namely Kota, Digod, Itawa, Sangod & Ramganjmandi and five tehsils namely Ladpura, Digod, Pipalda, Sangod and Ramganjmandi with 874 villages in Kota District. Kota district lies in hot, semi–arid (moist), agro–climate sub region with dry summers and mild winter. The annual temperature generally ranges from 8 - 47 ^{0}C having long summers up to six months. The Rainy season is of comparatively lower temperatures, but higher humidity and frequent downpours. The average annual rainfall is about 885.6 mm. Kota has an extensive industry of stone polishing of a particular kind of limestone called "Kota Stone". Kota's economy today is driven by the all India fame of its coaching classes. The main occupation of the people in Digod tehsil is agriculture, cattle rearing and Sari & Bidi making.

Sampling and analytical procedure

For this work water samples were drawn from tube wells and hand pumps in spring, winter, pre-monsoon, and post monsoon, periods during years 2011, 2012 and 2013. Water samples were collected from 36 different sampling points of 6 village sites (Table 1). The samples were collected as composite samples, at every village site samples were collected from six different points and then mixed together. Samples were collected in clean polythene bottles prewashed with dilute Nitric acid and rinsed three to four times with the water to be sampled, ensuring that sampling device causes minimal physical or chemical alteration to the sample i.e. does not cause degassing, aeration, volatilization. The samples were stored at a temperature below 4 ^{o}C prior to analysis in the laboratory. Major ions such as bicarbonate (HCO_3^-) and chloride (Cl^-) were analyzed by titration. The pH, TDS, EC, NO_3^-, SO_4^{2-}, PO_4^{3-} and F^- were determined by using standard methods[7]. Sodium and potassium estimated by Flame Photometric methods. Analytical reagents were used for the analyses 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.

Table 1. Selected sampling site in Digod Tehsil

Sample No.	Sampling Time	Sampling Sites
D1	Morning	Lakh-Sanija
D2	Evening	
D3	Morning	Takarwara
D4	Evening	
D5	Morning	Notara
D6	Evening	
D7	Morning	Sarola
D8	Evening	
D9	Morning	Moondla
D10	Evening	
D11	Morning	Bhandahera
D12	Evening	

Results and Discussion

To explore the groundwater quality of Digod tehsil 15 different physicochemical parameters *viz*. pH, TDS., specific conductivity, total alkalinity, Calcium hardness, Magnesium hardness, total hardness and levels of chloride, magnesium, nitrate, sulphate, phosphate, sodium, potassium and fluoride were determined of the groundwater samples collected from six selected sites viz. Lakh-Sanija, Takarwara, Notara, Sarola, Moondla and Bhandahera in four different seasons viz. pre-monsoon, post-monsoon, spring and winter of the year 2011, 2012 and 2013. Table 2 represents the average results of the physicochemical parameters of the samples (D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11 and D12) of six sampling locations of Digod tehsil. No different trends was observed in obtained values of different physicochemical parameters for different groundwater samples either collected from six different sites or collected at different times *i.e*. morning and evening hours.

pH

The data Table 2 shows that in the study period (2011 to 2013) the maximum pH was recorded 8.5 in the pre-monsoon season of the year 2013 and 8.0 in post-monsoon season of the year 2011. The pH is a measure of acid–base equilibrium. pH is controlled by the carbondioxide–bicarbonate-carbonate equilibrium. pH values lower on increasing concentration of carbon dioxide whereas pH values rise on decreasing concentration of carbon dioxide. The pH of most raw water lies within the range 6.5–8.5[8]. Eye, skin and mucous membrane irritation have been associated with higher pH values (greater than 11) and lower pH values. Below pH 4, redness and irritation of the eyes have been reported and at below pH 2.5 irreversible and extensive damage to the epithelium. pH can affect the degree of corrosion of metals as well as disinfection efficiency, it may have an indirect effect on health[9].

Conductivity

Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. Table 2 shows that in the study period 2011-13 the maximum recorded conductivity 1173.2 µS was in the pre-monsoon season of the year 2012 and the minimum recorded conductivity was 718.2 µS in the post-monsoon season of the year 2011. Conductivity offers convenient way for determining the total amount of ionic substances in groundwater. Concentration, ionic strength and nature of various substances affect the conductance.

Table 2. Average values of different physicochemical Parameters of Digod Tehsil

S. No.	Year → / Parameters ↓ / Season →	2011				2012				2013			
		Pre	Post	Winter	Spring	Pre	Post	Winter	Spring	Pre	Post	Winter	Spring
1	pH	8.3	8.0	8.1	8.3	8.4	8.1	8.3	8.4	8.5	8.1	8.3	8.5
2	Conductivity	1140.2	718.2	882.2	1036.6	1173.2	760.3	966.7	1121.7	1160.3	749.0	967.2	1114.2
3	TDS (mg/L)	1070.4	860.6	931.1	981.9	1124.1	885.1	954.4	1011.6	1048.8	839.5	909.0	967.8
4	Total Alkalinity	570.1	359.1	441.1	518.3	578.3	380.2	483.3	560.8	580.2	374.5	483.6	557.1
5	Bicarbonate Alkalinity	570.1	359.1	441.1	518.3	578.3	380.2	483.3	560.8	580.2	374.5	483.6	557.1
6	Total Hardness	483.8	298.0	374.9	434.3	482.8	316.4	398.5	467.8	493.5	322.2	413.8	471.7
7	Calcium Hardness	290.4	191.5	234.2	264.3	198.9	200.0	241.7	279.8	296.9	205.1	253.2	285.3
8	Magnesium Hardness	193.5	106.4	140.6	170.0	283.9	116.4	156.8	188.0	196.7	117.1	160.6	186.4
9	Sodium	162.9	97.4	131.3	149.4	166.9	109.2	143.6	164.1	166.2	100.6	142.3	159.1
10	Potassium	8.5	3.9	5.9	7.3	9.1	4.7	6.9	8.5	8.8	3.9	6.2	8.0
11	Chloride	90.6	51.3	74.1	81.7	81.8	60.2	76.7	89.3	93.1	57.2	81.1	89.5
12	Sulphate	101.2	57.7	81.1	90.2	108.7	62.0	85.2	97.4	103.5	61.8	91.1	97.3
13	Nitrate	55.8	29.0	46.5	49.9	61.8	36.9	47.8	57.1	56.8	32.5	46.8	52.5
14	Fluoride	1.6	0.8	1.2	1.5	1.6	1.1	1.4	1.7	1.6	1.1	1.4	1.6
15	Phosphate	0.28	0.18	0.23	0.25	0.30	0.20	0.25	0.29	0.27	0.20	0.23	0.25

Corrosion of metallic surfaces by waters high in dissolved ions causes problems with industrial equipments and boilers as well as domestic appliances plumbing, hot water heaters and washing machines. Indirect effects of excess dissolved ions are primarily the elimination of desirable food plants and habitat-forming plant species. Agricultural uses of water due to excessive dissolved solids and high dissolved solids causing problem in water used for livestock and irrigation[10]. Conductivity can be reduces by reverse osmosis, desalination or electro dialysis.

Total dissolved solids (TDS)

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and, nitrate. Total dissolved solids in groundwater originate from natural sources, agricultural particularly groundwater runoff and industrial wastewater. During investigation period the TDS data given in Table 2 ranged from 839.5 mg/L to 1124.1 mg/L. The maximum TDS value observed 1124.1mg/L in pre-monsoon season of the year 2012.

Total alkalinity

The main source of alkalinity in groundwater is water soluble anions (carbonates, bicarbonates and hydroxides). During investigation period the observed value ranged from 359.1 mg/L to 580.2 mg/L. The maximum value of total alkalinity observed 580.2 mg/L in the pre-monsoon period of the year 2013 and the minimum value of total alkalinity observed 359.1 mg/L in the post-monsoon period of the year 2011. The values of bicarbonates were higher in summer months during the study period and minimum bicarbonates in rainy season. The values of bicarbonates decrease due to dilution effect of rains[11].

Total hardness

The total hardness of groundwater primarily depends on the presence of dissolved calcium and magnesium salts and to a lesser extent, iron in the water. Hardness is considered as a major character of drinking water. The data given in Table 2 show that in the study period the recorded maximum total hardness value was 493.5 mg/L in pre-monsoon season of the year 2013 and the recorded minimum total hardness value was 298.0 mg/L in post-monsoon season of the year 2011. The high value of hardness may occur due to chemical and industrial effluent as well as excessive application of lime to the soil in agricultural areas[12].

Calcium

Calcium is the most abundant natural element, present in all natural waters. The most common source of calcium in groundwater is through the erosion of rocks, such as limestone and minerals, such as calcite. Calcium associates in groundwater with carbohydrates and various organic acids. The results reveals that during the study period, calcium value ranged from 191.5 mg/L to 296.9 mg/L in the study period, the maximum calcium value 296.9 mg/L was observed in pre-monsoon season of the year 2013 and the minimum calcium value 191.5 mg/L was observed in post-monsoon season of the year 2011. Outcome of the study reveals that the maximum calcium values recorded in pre-monsoon and minimum calcium values were recorded in post-monsoon[13]. Very high concentrations of calcium may affect the absorption of other essential minerals in the body.

Magnesium

The more common source of magnesium in groundwater are minerals such as dolomite, magnesite through the erosion of rocks. The data in Table 2 shows that during the study period magnesium value ranged from 106.4 mg/L to 283.9 mg/L. The maximum magnesium value perceived 283.9 mg/L in pre-monsoon season of the year 2012 and the minimum magnesium value perceived 106.4 mg/L in post-monsoon season of the year 2011. The general trend of the concentration of magnesium is that it is lower than the calcium. Magnesium may contribute undesirable tastes and laxative effect to drinking water. The human body tends to adapt to this laxative effect with time.

Sodium

Sodium is a highly soluble chemical element which naturally found in groundwater. The results recorded in Table 2 during study years show that amount of sodium ranged from 97.4 mg/L to 166.9 mg/L. In the year, 2012 the maximum value of sodium was recorded 166.9 mg/L in pre-monsoon and in the year, 2014 minimum value of sodium was recorded 97.4 mg/L in post-monsoon. Sodium has no smell in water, but it can be tasted by most people at higher concentrations. Higher concentration of Sodium in drinking water may affect people with hypertension, heart disease or kidney problems.

Potassium

Potassium is an essential nutrient for humans. In water, potassium is a soluble cation it has no smell but may give water a salty taste. Potassium is present in groundwater from surface sources, such as the leaching of fertilizers. The amount of potassium ranged from 3.9 mg/L to 9.1 mg/L. During Study Period the maximum value of potassium was recorded 9.1 mg/L in pre-monsoon season of the year 2012 and the minimum value of potassium was recorded 3.9 mg/L in post-monsoon season of the year 2011. The potassium content in all the samples of groundwater reveals that maximum potassium values were recorded in pre-monsoon and minimum potassium values were recorded in post monsoon. The study show that amount of potassium always lower than the sodium. Potassium may cause some health effects such as, kidney dysfunction, heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, hyperkalaemia, if present in higher amounts.

Chloride

Chloride is found in groundwater through both natural and anthropogenic sources, such as, weathering of various rocks, and leaching of inorganic fertilizers, septic tank effluents, dumps or landfills, animal feeds, industrial effluents and irrigation drainage. In the study period chloride contents reported in Table 2 indicate that the chloride values extend from 51.3 mg/L to 93.1 mg/L. The maximum chloride values were recorded 93.1 mg/L in pre-monsoon season of the year 2013 and the minimum chloride values are recorded 51.3 mg/L in post-monsoon season of the year 2011. Chloride affects the rate of corrosion of steel and aluminum. Chloride may cause corrosion of some metals in pipes, pumps, fixtures, and hot water heaters.

Sulphate

Sulphate (SO_4^{2-}) is found naturally in many soil and rock formations. Sulphate is present in groundwater from dissolution of minerals such as gypsum, saltwater intrusion, acid rock drainage, industrial discharge and deposition from burning of fossil fuels. In Digod tehsil, the sulphate value displayed in Table 2 ranged from 57.7 mg/L to 108.7 mg/L. The observations recorded during study period 2011-2013, the maximum sulphate value was recorded 108.7 mg/L in pre-monsoon season of the year 2012 and the minimum sulphate value recorded 57.7 mg/L in post-monsoon season of the year 2011. In groundwater sulphate produce a noticeable taste at higher concentrations and sulphate minerals in water may cause corrosion of plumbing, well materials and metal pipes.

Nitrate

In groundwater, nitrate has no taste or scent and can only be detected through a chemical test. Nitrate is found into groundwater through diffuse sources such as, leaching of chemical fertilizers, leaching from animal manure and water from septic and sewage discharges. In Digod tehsil, the groundwater examined during the study years and data registered in the Table 2 indicated that the nitrate values extend from 29.0 mg/L to 61.8 mg/ L. The observations showed that the maximum value of nitrate was recorded 61.8 mg/L in pre-monsoon season of the year 2012 and the minimum value of nitrate was recorded 29.0 mg/L in post-monsoon season of the year 2011. Nitrates remains in groundwater in various forms e.g. as dissolved molecular nitrogen, inorganic nitrogen as ammonia nitrite, nitrate and organic nitrogen as amino acids etc. High concentration of nitrate in drinking water can harm a human body by reducing the ability of blood to transport oxygen. In babies, “blue-baby syndrome,” can result from oxygen deprivation caused by high nitrate in drinking water. Death may occur in extreme cases.

Phosphate

The sources of phosphate in groundwater is overlying soils, dissolution of minerals, agricultural fertilizers detergents, industrial waste waters, animal wastes, and leakage in septic systems or infiltration of wastewater. During the years of investigations the quantity of phosphate has been found in range from 0.18 mg/L to 0.30 mg/L. During study period, the maximum phosphate value was recorded 0.31 mg/L in pre-monsoon season of the year 2012 and the minimum phosphate value was recorded 0.18 mg/L in post-monsoon season of the year 2011.Concentrations of phosphates in groundwater are very low because phosphate is not readily transported to groundwater[14].

Correlation

Correlation matrix is the mathematical model used to indicate the relationship between chosen independent and dependent variables. In this study, the relationships in between groundwater quality parameters of waters analyzed have been indicated by calculating correlation coefficients, R, by using the formula as given, [15ss].

$$R = \frac{\eta \sum (XiYi) - (\sum Xi).(\sum Yi)}{\sqrt{[\eta \sum Xi^2 - (\sum Xi)^2][\eta \sum Yi^2 - (\sum yi^2)]}} \tag{1}$$

Where, x (x=values of x-variable) and y (y=values of y-variable) represents two different water quality parameters. N=number of datum.
To determine the straight linear regression, following equation of straight line is used

$$y = a\,x + b \tag{2}$$

Where, y and x are the dependent and independent variable respectively a is the slope for the line, b is intercept on *y*-axis. With the slope a, and y-intercept, b can be determined using the following formulas;

$$a = \frac{\eta \sum XY - \sum X \sum Y}{\eta \sum X^2 - (\sum X)^2} \tag{3}$$

$$b = \frac{\sum Y - a\sum x}{\eta} \quad (4)$$

Correlation is the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter[16]. The regression analysis showed the pattern of the relationship between the variables. In the present study the correlation matrix (Table 3) describes the interrelationship between 15 hydro-chemical parameters. The values of correlation matrix show that very high positive correlations exit between HCO_3–TH (r = 0.997), Na–HCO_3 (r = 0.991), K–HCO_3 (r = 0.990), Na–K (r = 0.988), Na–SO_4, (r = 0.986), HCO_3–SO_4 (r = 0.983), K–SO_4 (r = 0.973), Na–Cl (r = 0.969), HCO_3 – Cl (r = 0.959), Cl – SO_4 (r = 0.947) and K – Cl (r = 0.936). High positive correlation exit between Mg – SO_4 (r = 0.895), Mg – K (r = 0.884), Mg–HCO_3 (r = 0.865), Mg – Na (r = 0.852), Ca – Cl (r = 0.871), Ca – HCO_3 (r = 0.748), Mg – Cl (r = 0.720), K – Ca (r = 0.695), Ca – SO_4 (r = 0.687). TDS have very high correlation with K, NO_3, Mg, HCO_3 and SO_4 (r = 0.940, 0.930, 0.929, 0.907 and 0.906), respectively. These investigations suggest that TDS is controlled by these ions. The correlation value in Table 3 shows that most of the parameters are significantly correlated with HCO_3^-.

Table 3. Correlation between various physicochemical parameters

	pH	TDS	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
pH	1	0.7866	0.9441	0.9492	0.7097	0.8262	0.9280	0.9183	0.9127	0.9311	0.8952	0.9408
TDS		1	0.9078	0.8938	0.4810	0.9293	0.8966	0.9406	0.7916	0.9061	0.9306	0.8387
HCO_3^-			1	0.9974	0.7484	0.8659	0.9917	0.9908	0.9595	0.9830	0.9696	0.9719
TH				1	0.7668	0.8549	0.9863	0.9811	0.9663	0.9838	0.9625	0.9678
Ca^{2+}					1	0.3225	0.7452	0.6952	0.8717	0.6874	0.6448	0.7538
Mg^{2+}						1	0.8522	0.8849	0.7204	0.8951	0.8983	0.8179
Na^+							1	0.9889	0.9696	0.9866	0.9833	0.9722
K^+								1	0.9366	0.9736	0.9831	0.9631
Cl^-									1	0.9475	0.9295	0.9522
SO_4^{2-}										1	0.9794	0.9465
NO_3^-											1	0.9539
F^-												1

Seasonal variations

The seasonal effect does change the concentration of various physicochemical parameters. The obtained results show that dilution effect from pre-monsoon to post-monsoon and concentrating effect from post-monsoon to winter, spring and pre-monsoon are observed during study period (2011-2013)[17].

Conclusion

Physicochemical characteristics of groundwater of Digod tehsil were analyzed to evaluate factors, influencing the groundwater chemistry of the study area. During study period (2011-2013), 144 groundwater samples collected for Physicochemical analysis of Digod tehsil in morning and evening hours of pre-monsoon, post-monsoon, winter and spring seasons. Out of 15 Physicochemical parameters, the average values of 2 parameter's (Fluoride and Nitrate) were exceeding contamination the maximum permissible limit set by IS10050[18]. It is concluded that nitrate concentration in groundwater exceeded due to agricultural practices in nearby area and other anthropogenic activities in Digod tehsil. The nitrate contaminated groundwater can never be put into fit category for drinking purpose[19]. On the other hand concentration of fluoride in groundwater is based on the breakdown of rocks, runoff and infiltration of chemical fertilizers in agricultural areas and liquid waste from industrial sources. Hence, the quality of groundwater cannot be said absolutely fit for drinking purpose. At some of the sites of the study area some essential treatment method's needed to apply so that groundwater can be utilized for drinking. Therefore the population intend of the rural areas is at higher potential risk of related diseases. It is recommended that groundwater analysis should be carried out at definite time intervals to monitor the quality and to explore the rate and type of contamination. Awareness among people of the rural areas is needed to maintain the cleanliness and purity of water to achieve a healthy life[20].

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