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Hydro-Chemical Analysis of the Ground Water Surrounding DCM Industrial area and its nearby Places, Kota, Rajasthan, India

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Abstract

Evaluation of major ions and water quality classification of ground water in DCM Industrial area and its adjoining areas, ground water samples were collected and experimented for various Physico-chemical parameters like Temp, pH, TDS,EC, TA, TH, DO, Cations and Anions by standard methods recommended by APHA. The order of all major distributed ions is - CO_3^{2-} >> Cl^- > HCO_3^- >Ca^{2+}>SO_4^{-2}> Na^+ >> NO_3^- > Mg^{2+} >K^+ >> F^- . Majority of samples are considered unsuitable for drinking purposes (TDS > 500 mg /L). For classifying ground water, quality parameters like SAR, RSC, % Na, PI and CAI are calculated. Classification based on SAR and Salinity Hazard by Wilcox analysis found that samples diagram were under excellent (S1, 100 %), good (C2, 86.66%) and doubtful (C3, 6.66%) categories respectively.

Keywords: Ground water, physico-chemical parameters, SAR, Wilcox, salinity hazard.

Introduction

Water resources have played and are still playing immense role in the financial development of all the prevalent societies. Water resources have to be the focus for economic growth in the countries like India is neglected from the point of view of optimum management But recent year's unscientific conditions and exploitation of resources has been instrumental in creating problems like water logging and salinity in agricultural use and environment pollutions beyond alarming limits due to mining, industries and municipal use[1].

The challenging problem is to study the quality resources specially those which takes place in the future. Initial attempts of our studies indicated that situation is going from bad to worse[2]. This prompted us to carry out hydro geochemical analysis of ground water samples collected from same sources during post-monsoon (December 2014) period also.

Materials and Methods

Study Area: On the eastern bank of Chambal River, the place famous for industrializations and educational hub is Kota, Rajasthan, India. Kota's cartographic coordinates are 25°11′N 75°50′E/ 25.18°N 75.83°E. The area covers 318 km^2 (3.63 per cent of the Rajasthan State) with an average elevation of 271 meters (889 ft). In the North and North West, it is by surrounded by Sawai Madhopur, Tonk and Bundi districts. In particular, DCM industrial area and its adjoining areas have been chosen as area of study having approximately 10 square Kilometres.

Sampling and Analytical Methods: A total of 15 groundwater samples were gathered from various sources like hand pumps at different spots nearby DCM Industrial area during post-monsoon season in the month of December, 2014. These spots were specifically identified on the basis of frequent use and probability of contamination and were mapped.

The season was selected owing to contamination which increases at the end of rainy season which accumulates of ions. When water samples were collected all necessary precaution were taken. The water samples were collected in sterilized and pre cleaned plastic bottles. After collection, all water samples were analyzed within 12 to 24 hrs using standard methods of analyses to judge as per APHA and WHO norms. Some parameters like temperature, color, and pH were measured on site. Water sample were analyzed by standard methods for physicochemical parameters like water temp (^{0}C), TDS, TA, conductivity, turbidity, odor, sulphate, nitrate, phosphate, Dissolved Oxygen, hardness, chlorides, fluorides, nitrate, sodium, potassium, calcium, magnesium and chemical oxygen demand (COD), Biological Oxygen Demand (BOD), free NH_4, Coli form Organism, heavy metals like Fe^{+2}, As, Cu, Zn [2].

The physico-chemical analyses of the samples were carried out by standard methods. Temperature, pH, TDS and conductivity were determined by using water analysis Kit. Hardness, DO, chloride, CO_2 and all such parameters were analyzed by standard procedure mentioned in APHA[3]. Na and K analysis was carried out by digital Flame Photometer.

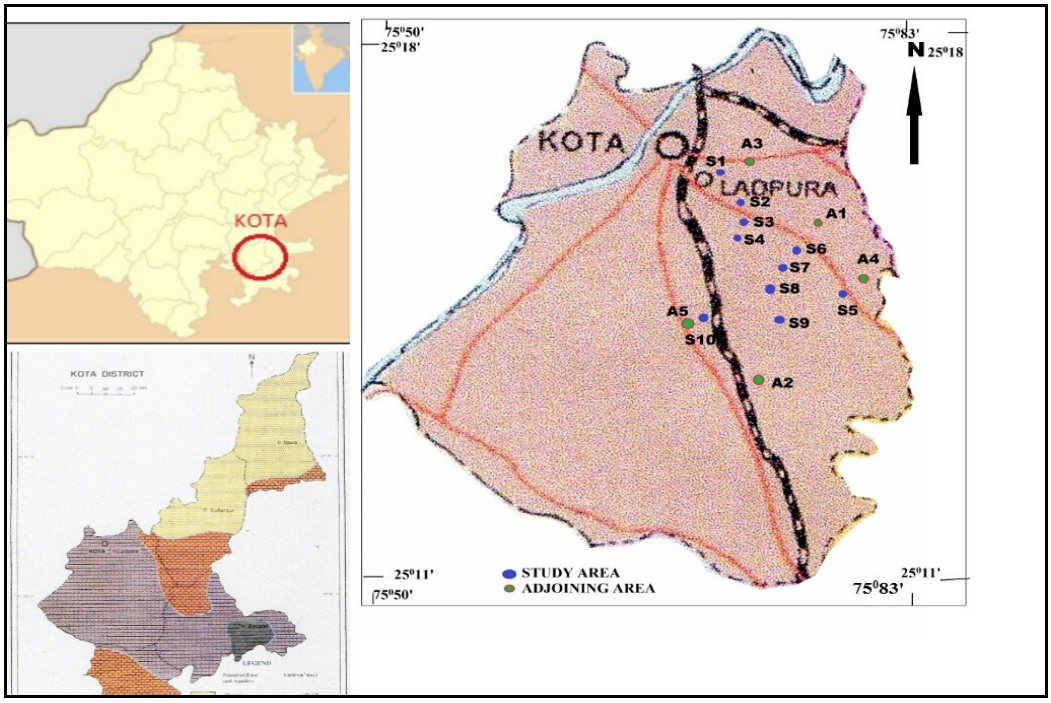

Figure-1
Location of sampling site at DCM industrial area, Kota

Results and Discussion

The results of physico chemical analysis are summarized in table-1 and 2 and are according to the standard suggested by the World Health Organization (WHO) [4]. The order of important cations and anions in ground water of DCM Industrial Area are distributed as: Ca^{2+} >> Na^{+} > Mg^{2+} >>K^{+} and CO_3^{2-} >> Cl^{-} > HCO_3^{-} >SO_4^{-2}> NO_3^{-} >> F^{-} respectively (mg/L). Overall, the main ions may be ranged as: CO_3^{2-} >> Cl^{-} > HCO_3^{-} >Ca^{2+}>SO_4^{-2}> Na^{+} >> NO_3^{-} > Mg^{2+} >K^{+} >> F^{-} .

Physico-chemical Parameters of Ground Water: The pH concentration varied from 6.93 to 8.10 with a mean value of 7.51 and these are in the permissible limit prescribed by WHO (6.5-9.5). Many samples were observed to give electrical conductivity value high and the values vary from 121.67 and 813.33 µS/cm and the average value is 517.53 µS /cm and these are according to standard WHO (1400 µS/cm)[5]. On the basis of Wilcox classification electrical conductivity of ground water, sample number A-3 is found in permissible category while sample numbers S-2, S-3, S-4, S-5, S-6, S-7, S-8, S-9, S-10, A-1, A-2, A-4 and A-5 ranged into good and sample number S-1 in excellent categories for agricultural uses as shown in table-1,2 and 3. TDS lies are in range between 390 to 826.67 mg /L with an average value of 612.44 mg/ L. The TDS concentration of the sample numbers S-3, S-4, S-5, S-6, S-7, S-8 and S-9 is high according to the standards of WHO (as 600 mg/ L)[6].

Hardness is representing calcium and magnesium ions concentrations[6]. Minimum value of hardness is 178.67 and maximum is 453.33 mg /L and mean value is 315.71 mg/L which are lies in standard range according to WHO (as 500 mg/ L). The TA (total alkalinity) values maximum are 306.67mg /L and minimum is 162 mg/L and mean is 223.27 mg /L.DO content in ranged from 3.47 to 4.83 mg /L with an average value of 4.17 mg/ L[7].

Calcium concentrations in water samples are lies between 49.25 and 122.79 mg /L and these are in standard value of WHO (as 100 mg/ L) accept some samples of S-3, S-5, S-6, S-8 and S-9. Magnesium is lies between 7.92 to 40.84 mg/ L which under according to ICMR (as 200 mg/L). The sodium concentration in the ground water samples are lies between 36.45 to 99.93 mg /L. Potassium concentrations are vary from 1.35 to 9.45 mg/L .

In present Scenario the nitrate also increases ground water pollution[8]. The main sources of nitrate pollution are agriculture waste and leakage from septic tanks etc.[9] in our findings, nitrate range varied from 14.34 to 72.96 mg/L. The sample numbers S-3, S-4, S-6, S-8, S-9, A-1, A-2 and A-3 crossed acceptable limit decided by WHO (50 mg L-1 as NO_3^{-}). F^{-} Concentration < 1 mg/L is not acceptable and causes various diseases like flurosis. The F^{-} concentration is varies from 0.25 and 1.57 mg/L and sample number A-3 has higher value than the standard decided by WHO (1.5 mg/L).

Carbonate and bicarbonate contents varied from 176.67 to 360 and 0.00 to 291.33 mg/L with a mean value of 251.44 and 99.71 mg/L respectively. Chloride concentration present in the range between 66 to 168.67 mg/ L with a mean value of 117.73 mg/ L which is in the standard limit suggested by WHO (as 250 mg/ L).

Table-1
Analytical results of ground water sample in the DCM Industrial Area, Kota (Post Monsoon)

Sample ID	General parameters											
	EC	pH	TDS	TA	TH	Ca H	Mg H	Free NH_4^+	Coli-form organism	Fe^{+2}	DO	BOD
S1	121.67	7.27	523.33	188.33	263.33	185	78.33	4.17	1166.67	0.22	4.36	0.45
S2	363	7.1	543.33	231.67	288.33	161.67	126.67	3.9	633.33	0.35	4.83	0.47
S3	480	7.4	663	226.67	360	290	70	1.34	416.67	1.65	4.45	0.58
S4	456.67	7.36	662.67	188.33	370	220	150	1.56	660	1.23	4.37	0.8
S5	505	7.43	715.67	270	393.33	306.67	86.67	1.78	150	1.6	4.59	0.97
S6	590	7.47	826.67	306.67	446.67	293.67	153	1.15	166.67	1.18	3.6	0.71
S7	546.67	7.37	770	175	380	212.33	167.67	1.14	633.33	0.8	3.98	1.63
S8	570	6.93	780	162	453.33	293.33	160	1.37	150	1.57	4.27	1.52
S9	426.67	7.27	635	227.67	370	266	104	1.53	93.33	1.65	4.1	0.9
S10	433.33	7.33	583.33	231.67	310	247.67	62.33	2.85	566.67	1.23	4.27	1.13
A1	590	7.73	390	216	226.67	170	56.67	2.88	196.67	1.63	4.37	0.8
A2	713.33	7.8	490	168.33	185.33	146	39.33	2.13	360	1.91	3.47	1.85
A3	813.33	8.1	595	195	178.67	123	55.67	2.43	416.67	0.9	3.73	1.28
A4	720	8.1	426.67	290	200	167.33	32.67	2.5	466.67	1.63	4.27	0.95
A5	433.33	7.97	590	271.67	310	202.67	107.33	3.28	600	1.27	3.9	0.9

Note: The values of parameters are shows in mg /L except EC (µS/cm), pH, Coli-form Organism (MPN/100 ml).

Table-2
Major Cations and Anions result of ground water sample in the DCM Industrial Area, Kota (Post Monsoon)

Sample ID	Major Cations				Major Anions						
	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	F^-	SO_4^{2-}	NO_3^-	PO_4^{3-}
S1	0.37	0.16	0.3	0.01	0.71	0.12	77.33	0.25	52.67	17.67	1.52
S2	0.32	0.26	0.33	0.01	0.84	0.09	85	0.39	61.67	22.33	0.59
S3	0.58	0.14	0.16	0.01	0.87	0.22	126.67	0.29	81.67	55	0.79
S4	0.44	0.3	0.31	0.02	0.82	0.3	168.67	0.52	72.67	56.67	1.27
S5	0.61	0.18	0.21	0.01	1.04	0.2	153.33	0.43	55	25	0.65
S6	0.59	0.31	0.24	0.01	1.2	0.23	141.67	0.46	85	66	0.82
S7	0.43	0.34	0.25	0.01	0.81	0.34	130	0.33	115	48	0.56
S8	0.59	0.32	0.41	0.02	0.86	0.48	135	0.33	85.33	54.33	0.61
S9	0.53	0.21	0.22	0.02	0.94	0.23	153.67	0.42	118.33	66.67	0.69
S10	0.5	0.13	0.43	0.01	0.86	0.13	138.33	0.29	66	20	0.92
A1	0.34	0.11	0.26	0.01	0.71	0.02	66	0.51	67.67	72.96	1.84
A2	0.29	0.08	0.35	0	0.59	0.03	68.33	0.43	81.67	71.58	1.5
A3	0.25	0.11	0.43	0	0.61	0	115.67	1.57	45.11	72.78	0.63
A4	0.34	0.07	0.29	0.01	0.77	0	69.67	1.37	31.98	23.93	1.51
A5	0.41	0.22	0.43	0.01	0.94	0.06	136.67	0.45	51.67	14.34	0.63

Note: The values of parameters are expressed in meq/L except F-, SO_4^{2-}, NO_3^- and PO_4^{3-} in mg/L.

Chloride concentrations of all samples are covered under brackish-salt categories as shown in table-1, 2 and 3. Sulfate concentration ranges from 31.98 to 118.33 mg/L with an average value of 71.43 mg/L which is in according to standards as WHO (as 250 mg/L).

Statistical approach of Ground Water Parameters: All the parameters are also calculated by using statistical approach as shown in table-1 and 2. The physico-chemical and statistical parameters based ground water classifications are summarized in table-3. Richard has classified water according to SAR[11]. SAR describes water quality for irrigation purposes [12]. The SAR value can be calculated by the following formula.

$$SAR = \frac{Na^+}{(\sqrt{Ca^{2+} + Mg^{2+}})/2}$$

Table 3
Irrigational water quality parameters of water samples from DCM Industrial Area, Kota (Post Monsoon)

Sample ID	Irrigation quality parameters				
	Na%	RSC	SAR	PI	CAI
S1	35.66	0.3	0.58	78.4	-0.4
S2	35.98	0.35	0.61	69.7	-0.4
S3	17.8	0.36	0.26	71.1	0.53
S4	28.47	0.38	0.5	81	0.31
S5	20.82	0.46	0.33	66	0.49
S6	20.67	0.53	0.35	63.1	0.38
S7	24.42	0.38	0.4	81.7	0.3
S8	30.49	0.43	0.61	83.3	-0.1
S9	22.72	0.43	0.37	73.1	0.44
S10	40.48	0.36	0.77	75	-0.1
A1	36	0.28	0.55	57.1	-0.5
A2	48.44	0.24	0.82	71.7	-0.9
A3	54.42	0.25	1.03	54.8	-0.4
A4	41.24	0.37	0.64	41.8	-0.5
A5	40.59	0.38	0.77	64.7	-0.2

Note: The values of parameters are expressed in meq/L.

PI indicates the long term use of irrigation water along with Na, Ca, Mg, HCO_3^- content of the soil. Doneen has developed a theorem for calculating permeability index (PI) [13]. It can be determined by following formula

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100$$

In the study area, eleven ground water samples(S-2, S-3,S-5, S-6, S-9,S10,A-1, A-2, A-3, A-4, A-5) are ranged into class-II and remaining 4 samples (S-1, S-4, S-7, S-8) are categorized into class-I as mentioned in table-4.

Schoeller has discovered the term CAI which indicate ion exchange between the ground water[14].
The CAI can be calculated as

$$CAI = \left[Cl^- - \left(Na^+ + K^+ \right) \right] / Cl^-$$

Table-4
Classifications of ground water in DCM Industrial Area, Kota

Classification of water	Water class	values	Number of Spots	%
Sodium Absorption Ratio (SAR) (Richard 1954)	Excellent (S1)	<10	15	100
	Good (S2)	10-18	0	0
	Doubtful (S3)	19-26	0	0
	Unsuitable (S4)	>26	0	0
Percent Sodium (% Na) (Wilcox 1955)	Excellent	<20	1	6.66
	Good	20-40	9	60
	Permissible	40-60	5	33.33
	Doubtful	60-80	0	0
	Unsuitable	>80	0	0
RSC (Richard 1954)	Good	<1.25	15	100
	Medium	1.25-2.5	0	0
	Bad	>2.5	0	0
EC (Salinity Hazard class) (Wilcox 1955)	Excellent (C1)	100-250	1	6.66
	Good(C2)	250-750	13	86.66
	Doubtful(C3)	750-2250	1	6.66
	Unsuitable (C4 and C5)	>2250	0	0
PI (Permeability Index) (Doneen 1964)	Class-I	>75	4	26.66
	Class-II	25-75	11	73.33
CAI (Chloro-Alkaline Indices) (Schoeller 1967)	Base Exchange Reactions	Negative Value	9	60
	Cation–Anion Exchange Reactions	Positive Value	6	40
Chloride (Cl^-)	Extremely-Fresh	<0.14	0	0
	Very- Fresh	0.14-0.85	0	0
	Fresh	0.85-4.23	0	0
	Fresh- Brackish	4.23-8.46	0	0
	Brackish	8.46-28.21	0	0
	Brackish- Salt	28.21-282.06	15	100
	Salt	282.06-564.13	0	0
	Hyper Saline	>564.13	0	0

In the study area, nine samples (S-1, S-2, S-8, S-10, A-1, A-2, A-3, A-4, A-5) have the negative value of CAI proving the base-exchange reactions while six samples (S-3, S-4, S-5, S-6, S-7, S-9) indicate the cation-anion exchange reaction as shown in table-4.

The classification shows that the samples are suitable for agricultural purposes shown in table-4.

Richard has developed a formula for calculating harmful effect of CO_3^{-2} and HCO_3^{-2} on water quality. It can be determined by formula:

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

The classification shows that the samples are suitable for agricultural purposes as summarized in table-4.

Wilcox developed a system for checking the agricultural waters based on % Na and EC[15].

The % Na is calculated by

$$\%Na = \frac{\left(Na^{+} + K^{+}\right)\times 100}{\left(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}\right)}$$

In the study area, only one water sample (S-3) is found in excellent and remaining nine samples (S-1, S-2, S-4, S-5, S-6, S-7, S-8, S-9, A-1) are good categories respectively but five samples (S-3, S-10, A-2, A-3, A-4, A-5) are present in standard limit for the agricultural purpose as shown in table-4.

Correlation Matrix: The correlation matrix explains interrelationship between two or more variables was carried out using SPSS 16.0[16]. The correlation matrix of analyzed groundwater quality parameters are presented in table-5 and it was found that samples showed the negative correlations in 33 cases between TDS and pH, EC and TDS, TH and EC, EC and Cl^-, Cl^- and pH , TDS and F^-, TH and F^-, Cl^- and F^-, EC and SO_4^{2-}, SO_4^{2-} and pH, SO_4^{2-} and TA, SO_4^{2-} and F^- , NO_3^- and TA, Ca^{2+} and EC, Ca^{2+} and pH, Ca^{2+} and F^- , Ca^{2+} and NO_3^- ,Mg^{+2} and EC, Mg^{2+} and pH, Mg^{2+} and TA, Mg^{2+} and F^- , Na^+ and TDS, Na^+ and TA, Na^+ and TH, Na^+ and Cl^- , Na^+ and SO_4^{2-} , Na^+ and NO_3^- , Na^+ and Ca^{2+} , Na^+ and Mg^{2+} , K^+ and EC, K^+ and pH, K^+ and TA, K^+ and F^-.

Some of the highly positively correlations were found between EC and pH, pH and TA, TDS and TH, Cl^- and TDS, EC and F^- , pH and F^-, TH and $Ca^{2+,}$ Ca^{2+} and Cl^- , TDS and $Mg^{2+,}$ Mg^{2+} and TH. Poor positive correlation was found between EC and TA, TA and TDS, NO_3^- and TH, NO_3^- and Cl^- , NO_3^- and $Mg^{2+,}$ K^+ and $Na^{+.}$

Table 5
Correlation Matrix

	EC	pH	TDS	TA	TH	Cl^-	F^-	SO_4^{-2}	NO_3^-	Ca^{+2}	Mg^{+2}	Na^+	K^+
EC	1	-	-	-	-	-	-	-	-	-	-	-	-
pH	.605*	1	-	-	-	-	-	-	-	-	-	-	-
TDS	-0.04	-0.5	1	-	-	-	-	-	-	-	-	-	-
TA	0.04	0.31	0.01	1	-	-	-	-	-	-	-	-	-
TH	-0.3	-.692**	.877**	0.12	1	-	-	-	-	-	-	-	-
Cl^-	-0.13	-0.35	.779**	0.12	.763**	1	-	-	-	-	-	-	-
F^-	.677**	.734**	-0.32	0.19	-.565*	-0.24	1	-	-	-	-	-	-
SO_4^{-2}	-0.08	-.522*	.520*	-0.4	.553*	0.39	-.537*	1	-	-	-	-	-
NO_3^-	.558*	0.1	0.13	-0.4	0	0.04	0.17	0.49	1	-	-	-	-
Ca^{+2}	-0.24	-.572*	.728**	0.27	.892**	.703**	-.524*	0.42	-0.03	1	-	-	-
Mg^{+2}	-0.26	-.615*	.774**	-0.1	.801**	.581*	-0.43	.536*	0.04	0.44	1	-	-
Na^+	0.15	0.21	-0.18	-0.3	-0.32	-0.07	0.25	-0.37	-0.19	-0.43	-0.07	1	-
K^+	-0.21	-.562*	0.42	-0.1	.655**	.576*	-0.26	0.32	0.1	.568*	.547*	0	1

*Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

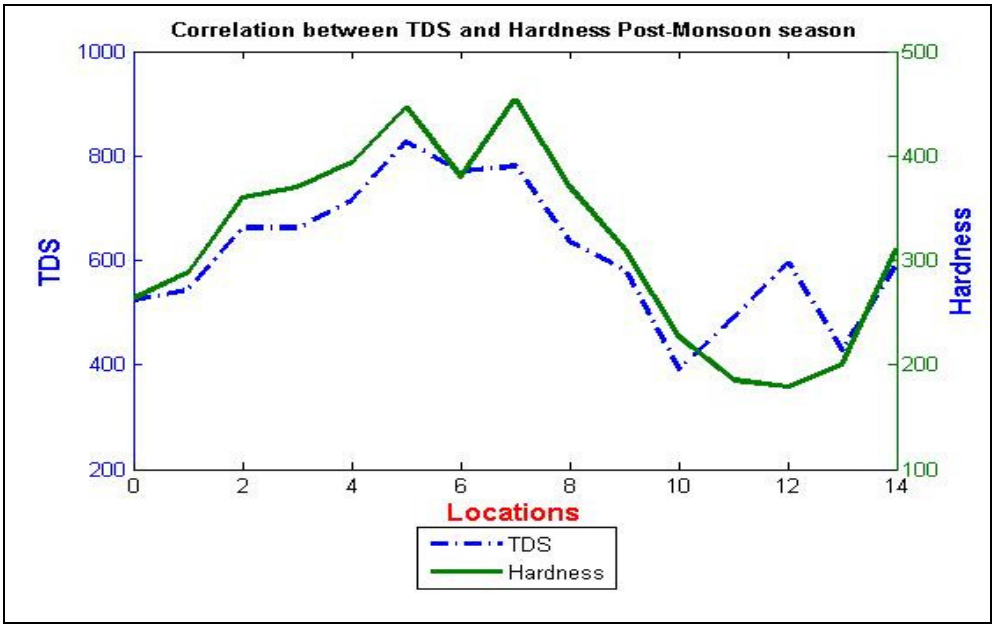

Figure-2
Correlations between TDS and Hardness during Post Monsoon season

Conclusion

The experiment has shown that many of the samples in the DCM Industrial Area are not suitable for drinking as well as irrigation purpose (TDS > 500 mg L-1). It is a bit alkaline and brackish salty. The order of all chief ions distributed is: CO_3^{2-} >> Cl^- > HCO_3^- >Ca^{2+}>SO_4^{-2}> Na^+ >> NO_3^- > Mg^{2+} >K^+ >> F^-. The other water quality parameters such as Mg^{2+}, CO_3^{-2}, HCO_3^- and Cl^- ranged within permissible limits. Nitrate value was exceeding (50 mg /L) indicating the need of awareness in the society owing to avoid ground water for drinking utilization. Approximately 93.33 percent samples have the fluoride level 1.5 mg /L. The SAR values shows excellent category of water for irrigation purposes. The Na% of samples shows that approximately 60% samples are good whereas, 33.33% reflects the presence of Na hazards for irrigation purposes. The 60% CAI values of samples are base- exchange type of reaction and remaining 40% samples are cation-anion exchange type of reactions. It is classified that one sample [A3, Soorsagar] in C3S1 class is not suitable for irrigation water under ordinary conditions due to high salinity hazard in the study area. The Results were found that the water samples taken from Kansuwa, Prem Nagar, and Soorsagar and DCM area are more contaminated as compared to their adjoin area. Growing industrialization and population is the reason behind recycling of polluted water due to which the variations in concentration appear.

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