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Evaluation of physico-chemical water quality and its suitability for domestic and irrigation purpose using AquaChem in around Aonla, Bareilly district Uttar Pradesh, India

Kusum Pandey and Dinesh Kumar Vishwakarma

Abstract
Ground water and surface water play a vital role in domestic usage and irrigation purpose. To assess the quality of groundwater & surface water and to characterize the hydro chemical characteristics of the groundwater in Bareilly Uttar Pradesh, water samples were collected from different villages Province and analysed for water quality parameters. The following ten parameters have been considered viz. pH, EC, TDS, Turbidity, Acidity, Alkalinity, Hardness, Ca^{++}, Mg^{++}, Cl, Cl_2, Na, K, P, SO_4, N, N-NO_2, N-NO_3 N-NH_3. These parameters are used to determine the quality of groundwater by comparing the quality of drinking water standards permissible limit. The study yielded that in most of villages of Bareilly District province area the water samples are suitable for irrigation and agriculture purposes.

Keywords: Aqua Chem, irrigation and drinking suitability, physico-chemical parameters, pollution, water quality

1. Introduction

Water with good quality and sufficient quantity is the backbone of a developing country. Ground water and surface water is primary source of Irrigation, and this quality of irrigation water is influence with yield and quality of crop. Determination of the physical and chemical quality of groundwater is essential for delineating the suitability of water for various purposes like drinking, irrigation, domestic and industrial. In the twenty first sanctuary increases in population and urbanization causes an increase in the demand for water and this in turn leads to over-pumping of ground and surface water**.** Land-use change for urbanization and agricultural activities commonly results in the deterioration of water quality**.**

Consequently, water quality issues like groundwater salinity is a major concern for water resources development projects (irrigation, floriculture) as well as for human health (drinking water supply). Hydrogeological conditions and chemical compositions of groundwater are important constraints and limiting factors for development, the type of materials used for water distribution systems, the quality of constructions and local ecological values (Berhane *et al*. 2015) [2]. It is essential to understand the hydro-geochemical processes and its evolution that take place in both ground and surface water resources (Subramani *et al*. 2005) [8]. The human health problems caused by inorganic element earlier reported from different part of India. These problem arise naturally and anthropogenically due to improper waste water management, groundwater contamination, unnecessary use of fertilizers, insecticides in agricultural area for high yield (Golekar *et al*. 2014) [5]. In India, wastewater from almost all industries is being discharged untreated either on land or into water courses which is the main causes of deterioration of water quality. Many studies has been proven that the quality of irrigation is one of them important parameters for yield, quality, soil productivity, environment protection (Vineesha Singh and Singh, 2008) [7]. The pollutant water is major caused of various disease human and plant life. In this study, hydrogeochemical parameters, some physical, chemical, biological, microbial water quality parameter in water sample were evaluated in the study area.

2. Materials and Methods

2.1 Study Area

The study area is located at Aonla, Bareilly district, Uttar Pradesh consisting of ten village; Khateta, Gulariya Gaurishankar, P. Uprala, Shivpuri, Gurgaon, Mughalpur, Anurudhpur, Motipura, Ramnagar and Sendha. IFFCO Aonla is situated at 790 9’ 0” E longitude and 28o

16’ 48” N latitude at 177 m elevation, about 28 km South-West at Bareilly on Bareilly-Aonla road. The area experiences moderate type of sub- tropical monsoon climate i.e in summer it is dry and hot and in winter it is mild but not frost free. The maximum mean monthly temperature of 41.80 C was found for the month of May and lowest mean monthly temperature of 5.50 C was found for the month of the January. The monsoon starts from June and lasts till October. The rainfall during July, August and September month contributes the major part of the monsoon rainfall. The area receives minimum average rainfall of about 560 mm and maximum annual rainfall if about 1256 mm.

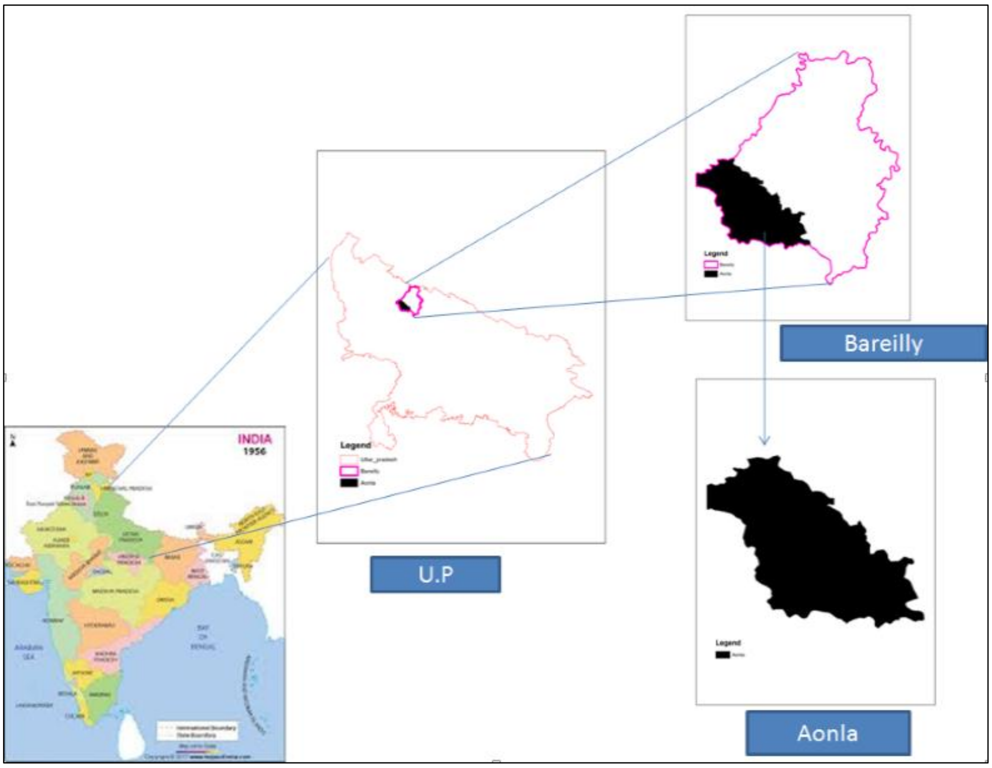

Fig 1: Location map of the study area

2.2 Graphical analysis of geochemical data by Aqua Chem software

Aqua Chem (v. 2014.1) is a fully-integrated software package developed by Schlumberger water services specifically for graphical analysis of geochemical data sets. It features a powerful database that can be customized and configured to include an unlimited number of attributes per sample, and a built-in database of inorganic chemicals that are commonly used for geochemical analyses, calculations and plotting. These powerful analytical capabilities are complimented by a comprehensive selection of commonly used graphical techniques to portray the chemical characteristics of geochemical and water quality data for single samples and groups of samples. Aqua Chem's graphical plotting techniques include Piper, Stiff, Durov, Langelier-Ludwig, Schoeller and ternary diagrams, radial plots, scatter graphs, frequency histograms, pie charts, geothermo meter plots and time series graphs. Data management built around a customizable MS Access database that can be configured to include more than 1000 alphanumeric parameters per sample. Parameters are divided into the following parameter groups: station description parameters, sample description parameters, measured parameters, and modelled parameters. Each parameter group contains predefined parameters which can be used to create a customized data structure for different sampling and reporting requirements. Data may be imported and exported in various formats including MS Access, MS Excel and Txt files. For the current work the data management has been accomplished using MS Excel. Data analysis through Aqua Chem uses the common measured values (cations and anions) for each sample to calculate additional geochemical values such as water type, sum of anions, sum of cations, ion balance, TDS, hardness, alkalinity, common ion ratios, sodium adsorption ratio, magnesium hazard and oxygen saturation. This includes a selection of more than 23 industry-standard plots including: Piper, Schoeller, Scatter, Stiff, Box & Wisker, time series, histogram, Stiff, Radial and Pie chart etc. For the current work data analysis by plot of Piper diagram, Durov diagram, Stiff diagram and series plot.

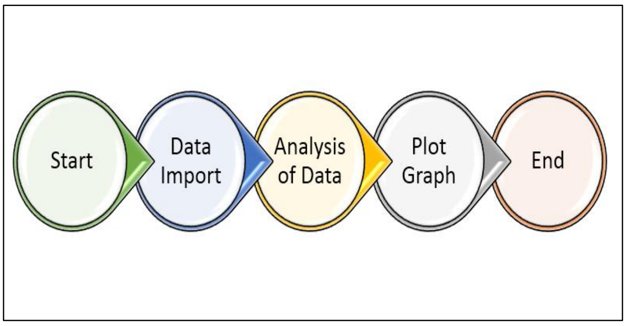

Fig 1.1: Flow diagram of data analysis of Aqua Chem software

3. Restuls and Discussion

In this study, the parameters are classified is a major chemical element that is (Ca, Mg, Na, K, HCO^3, SO^4, Cl) and physico-chemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS). From these data can be analysed descriptively about the feasibility and usefulness of water for consumption and the suitability of water for agricultural irrigation and domestic use (APHA, 1992). Physico-chemical parameters and chemical composition of major ions analysis were performed to compare the composition of water samples in the field with the standards which has been specified by the World Health Organization and the Indian Standard. This analysis will determine percentage of water suitable for consumption and irrigation.

3.1 Hydrogen Ion Concentration (pH)

pH i.e. concentration of Hydrogen Ion in the solution and is used as the scale for determination of alkalinity and acidity status of water. The value of Hydrogen Ion concentration in the solution of site area were found in the range of 6.9 to 7.68. Thus sample were found slightly alkalinity in nature.

Table 1: Village wise pH level of Bareilly District

S. No.	Permissible limit for portable water	pH	Water Quality		
1	6.5 - 8.5	7	Natural i.e. neither saline nor alkaline		
2		7.5 to 8.0	Water contains carbonates of Ca and Mg		
3		8.5 or more	Water contains appreciable ESP		
S. No.	**Village**	**pH Level**	**S. No.**	**Village**	**pH Level**
1	Khateta	7.6	6	Mughalpur	7.46
2	G. Gaurishankar	7.68	7	Anrudhpur	7.23
3	P. Uprala	7.65	8	Motipura	6.93
4	Shivpuri	7.14	9	Ramnagar	6.95
5	Gurgaon	7.56	10	Sendha	6.9

3.2 Total Salt Concentration (Salinity)

Total Dissolved salts in the water is measure in the terms of Electrical conductivity, to convey current carrying capacity. High amount of salt increase the osmotic pressure of the soil water and produce conditions that keep the root from absorbing water. This results in a physiological drought conditions. Based on the EC, irrigation water can be classified into four categories.

Table 2: EC level of Bareilly District

Level	EC (µS/cm)	Hazard and limitations		Salt Concentration (g/L)	
C1	<250	Low hazard; no determinant effect on plants and no soil build up expected			Less than 0.16
C2	250-750	Sensitive plants may show stress; moderate leaching prevents salt accumulation in soil.			0.16 to 0.5
C3	750-2250	Salinity will adversely affect most plants; requires selection of salt- tolerant plants, carful irrigation, good drainage and leaching			0.5 to 1.5
C4	>2250	Generally unacceptable for irrigation; except for very salt tolerant plants, excellent drainage, frequent leaching and intensive management			1.5 to 3.0
S. No.	**Village**	**EC (µS/cm)**	**S. No.**	**Village**	**EC(µS/cm)**
1	Khateta	730	6	Mughalpur	500
2	G. Gaurishankar	870	7	Anrudhpur	1100
3	P. Uprala	640	8	Motipura	390
4	Shivpuri	1180	9	Ramnagar	190
5	Gurgaon	600	10	Sendha	370

3.3 Soluble Sodium Percentage

Sodium concentration is important in classifying the water for irrigation purposes because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980; Domenico and Schwartz, 1990) [3, 4] and this help little or no plant growth. So sodium is considered as a main factor for determining groundwater suitability for irrigation purposes. Presence of sodium is usually expressed in terms of sodium percentage calculated by the formula:

$$\textbf{\textit{Sodium Percentage}} = \left\{\frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}\right\} \times 100$$

Table 3: Village wise SSP level of Bareilly District

Water Class			SSP	EC (µS/cm)	
Excellent			<20	>250	
Good			20-40	250-750	
Permissible			40-60	750-2000	
Doubtful			60-80	2000-3000	
Unsuitable			>80	>3000	
S. No.	**Village**	**SSP**	**S. No.**	**Village**	**SSP**
1	Khateta	0	6	Mughalpur	20.98
2	G. Gaurishankar	37.60	7	Anrudhpur	18.04
3	P. Uprala	25.98	8	Motipura	61.11
4	Shivpuri	0	9	Ramnagar	40.22
5	Gurgaon	16.00	10	Sendha	22.18

Based on Na% the value of less than 60 in groundwater is suitable for irrigation purposes.

3.4 Sodium Absorption Ratio (SAR)

Sodium Adsorption ratio is an index, basically used for assessing the sodium hazard because adsorption of sodium is directly related to the soil formation. SAR and EC reciprocally can be used to evaluate irrigation water quality. The SAR recommended by the salinity laboratory of the United States Department of Agriculture (Wilcox, 1955) [11] is calculated using the formula:

$$\textbf{Sodium Absorption Ratio} = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Table 4: Village wise SAR level of Bareilly District

Level	SAR	Hazard			
S1	<10	No harmful effect for sodium.			
S2	10-18	Appreciable sodium hazard in fine textured soil of high soil CEC, but could not be used for sandy soils with good permeability.			
S3	18-26	Harmful effects could be anticipated in most soils and amendment such as gypsum would be necessary to exchange sodium ions.			
S4	>26	Generally unsatisfactory for irrigation.			
S. No.	**Village**	**SAR Value**	**S. No.**	**Village**	**SAR Value**
1	Khateta	-	6	Mughalpur	3.43
2	G. Gaurishankar	8.76	7	Anrudhpur	4.86
3	P. Uprala	5.51	8	Motipura	15.64
4	Shivpuri	-	9	Ramnagar	9.25
5	Gurgaon	3.01	10	Sendha	5.74

In the study area the SAR values falls in the range of 0 to 15.64 (Table 4).

3.5 Magnesium Hazard

The most water calcium and magnesium maintains a state of equilibrium. A ratio namely index of magnesium hazard has been developed (Paliwal 1972) [6]. Accordingly, high magnesium hazard value (more 50%) has an adverse effect on the crop yield as the soil becomes more alkaline. In the study area the magnesium hazard values falls in the range of 23.5 to 48.4% (Table 5). In the study area, all the samples collected showed Magnesium hazard ratio Mg hazard calculated by following formula

$$\boldsymbol{Magnesium\ Hazard} = \left\{\frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}\right\} \times 100$$

Table 5: Village wise Magnesium Hazard level of Bareilly District

S. No.	Sample Village	Magnesium Hazard %	Type
1	Khateta	19.04	Sutaible
2	G. Gaurishankar	19.12	Sutaible
3	P. Uprala	20.40	Sutaible
4	Shivpuri	24.32	Sutaible
5	Gurgaon	20.65	Sutaible
6	Mughalpur	18.06	Sutaible
7	Anrudhpur	23.44	Sutaible
8	Motipura	12.48	Sutaible
9	Ramnagar	19.55	Sutaible
10	Sendha	22.96	Sutaible

3.6 Total hardness (TH)

It is the measure of presence of Ca and Mg ion in the water. The classification of groundwater based on total hardness (TH) shows that a majority of the ground water samples fall in the hard water category. The following formula can be used for computing TH of the groundwater

$$Total\ Hardness = \left(\frac{Ca\ CO_3}{Ca}\right) Ca + \left(\frac{Mg\ CO_3}{Mg}\right) Mg$$

The hardness values range from 120 to 900 mg/l with an average value of 259.4 mg/l. The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per the WHO standard (2004) [10]. Groundwater exceeding the limit of 300 mg/l is considered to be very hard. Sample from Shivpuri exceed the maximum allowable limit of 500 mg/l. The hardness of the water is due to the presence of alkaline earths such as calcium and magnesium.

Table 6: Village wise Total hardness level of Bareilly District

S. No.	Village	TH	S. No.	Village	TH
1	Khateta	170	6	Mughalpur	148
2	G. Gaurishankar	172	7	Anrudhpur	432
3	P. Uprala	212	8	Motipura	80
4	Shivpuri	600	9	Ramnagar	184
5	Gurgaon	222	10	Sendha	374

3.7 Total dissolved solids (TDS)
Total dissolved solids (TDS) have been calculated by summing up all the major cations and anions and the correlation between TDS and instrumentally determined EC excellent. TDS values for samples range from 120 to 900 mg/l, the average value for the samples being 454 mg/l. Drinking water becomes significantly unpalatable at TDS value more 1000 mg/l. From this point of view, therefore, groundwater in the study area is really ideal.

Table 7: Village wise Total dissolved solids level of Bareilly District

S. No.	Village	TDS	S. No.	Village	TDS
1	Khateta	490	6	Mughalpur	350
2	G. Gaurishankar	600	7	Anrudhpur	750
3	P. Uprala	430	8	Motipura	250
4	Shivpuri	900	9	Ramnagar	120
5	Gurgaon	420	10	Sendha	230

3.8 Residual Sodium Carbonate
According to the US Salinity Laboratory (1954) [9], RSC value less than 1.25 meq/L is good for irrigation, a value between 1.25 and 2.5 meq/L is of doubtful quality and a value more than 2.5 meq/L is unsuitable for irrigation. Hence, continued usage of high RSC waters will affect the yields of crop. The RSC is calculated by the following methods.

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

3.9 Hydro-Chemical Facies
Piper diagram: On the basis of chemical analysis, the groundwater is divided into four facies shown in Table 8, The dominant hydro chemical facies of the study area is Ca^{2+}-SO_4^{2-} (40%) > Mg^{2+}- SO_4^{2-} (30%) > Ca^{2+}- HCO_3^{2-} (20%) > Mg^{2+}- HCO_3^{2-} (10%). The Piper diagram as shown in Fig. 1.1 reveals that the dominant cation is Ca^{2+} and Mg^{2+} and the dominant anion is HCO_3^{2-} and SO_4^{2-}.It is observed that the majority of sample belongs to Ca^{2+} and Mg^{2+}, which indicates that the alkali earth is dominant over alkali (Na^+ and K^+) in our study area. It is inferred from Fig. 2 that the most of the samples of our study area comes under strong acid group (SO_4^{2-}).

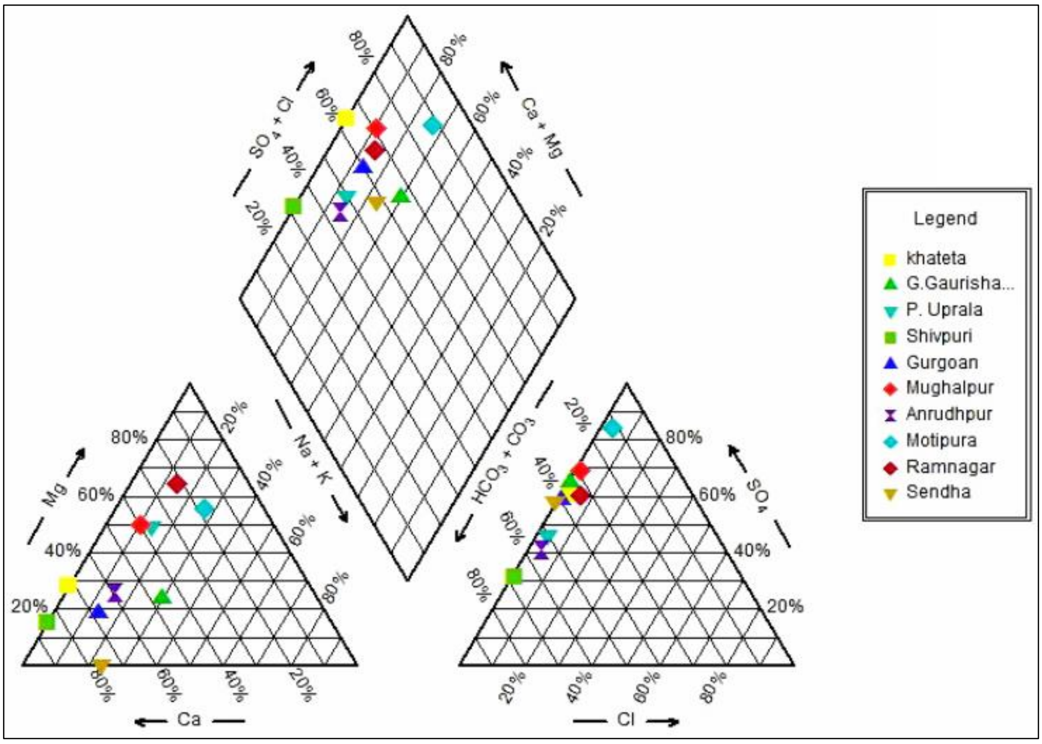

Fig 2: Piper diagram

Table 8: Classification of water based on Piper diagram

Facies type	No of samples	%
Ca-SO_4	M1 (khateta), M2 (G. Gaurishankar), M5 (Gurgaon), M10 (Sendha)	40
Mg-HCO_3	M3 (P. Uprala)	10
Mg-SO_4	M6 (Mughalpur), M8 (Motipura), M9 (Ramnagar)	30
Ca-HCO_3	M4 (Shivpuri), M7 (Anrudhpur)	20

Durov diagram: The Durov diagram shown in Fig. No. 3 shows that the 40% of the samples is along the dissolution or mixing line. It indicates that the fresh water exhibits simple dissolution or mixing with no dominant major anion or cation. Addition to this, 50% sample showing HCO_3 and Na are dominant, which indicates ion exchange water. In the remaining samples (10%) SO_4 is found to be dominant

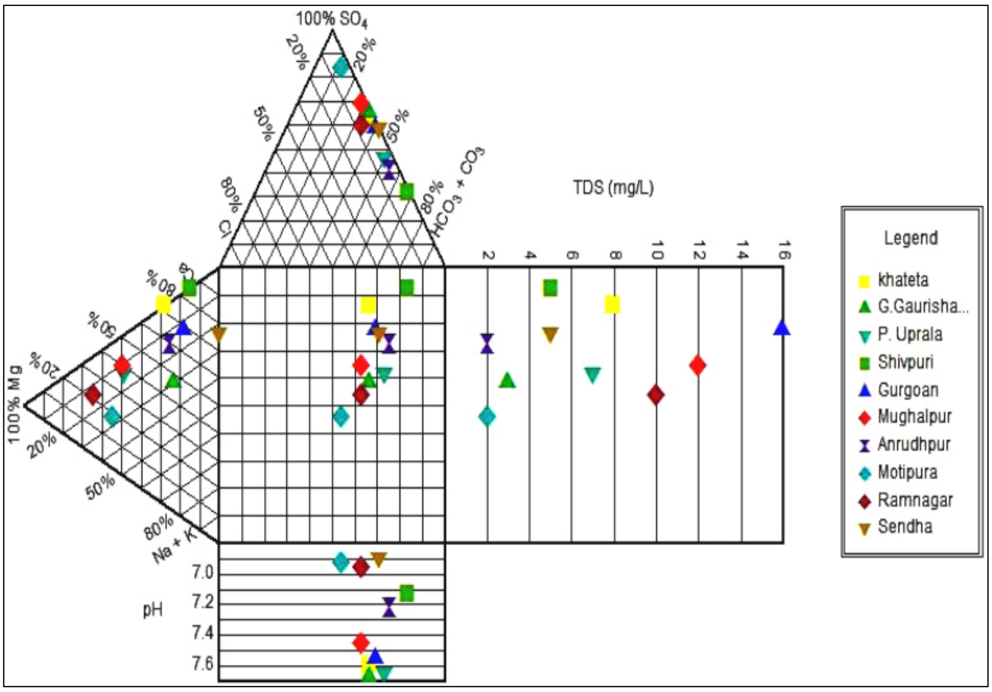

Fig 3: Durov diagram

Schoeller diagram: The Scholler diagram is shown in Fig. No. 4. This diagram indicates that in water sample of Khateta village, sulphate ion is dominant and chlorine ion is least in the following order: SO_4 >Ca>HCO_3 >Mg> Cl. In Gulariya Gaurishankar village, water sample contains calcium ion in highest concentration and chlorine in lowest concentration in the following order: Ca>Na+K> HCO_3+ CO_3>Cl. In water sample P. Uprala village, magnesium ion is dominant and mixture of sodium and potassium ion is least in the following order: Mg> HCO_3+ CO_3> SO_4> Na+K. In Shivpuri village, water sample contain calcium ion in highest concentration and chlorine ion is lowest concentration in the following order: Ca> HCO_3+ CO_3> SO_4>Mg>Cl. In water sample Gurgaon village, calcium ion is dominant and chlorine is least in the following order: Ca> HCO_3+ CO_3> SO_4>Mg>Na+K>Cl. In Mughalpur village, water sample contain sulphate in highest order and chlorine is lowest in the following order: SO_4>Mg>Ca> HCO_3+ CO_3> Na+K>Cl. In water sample Anurudhpur village, calcium ion is dominant and mixture of sodium and potassium ion is least in the following order: Ca> HCO_3+ CO_3> SO_4>Mg> Na+K. In Motipura village, water sample contain magnesium ion in highest concentration and chlorine ion is lowest concentration in the following order: Mg> SO_4> Na+K> Ca> HCO_3+ CO_3> Cl. In water sample Ramnagar village, magnesium is dominant and chlorine is least in the following order: Mg> SO_4> Ca> Na+K> HCO_3+ CO_3> Cl. In Sendha village, water sample contain calcium in highest concentration and chlorine is lowest concentration in the following order: Ca> SO_4> HCO_3+ CO_3> Na+K> Cl.

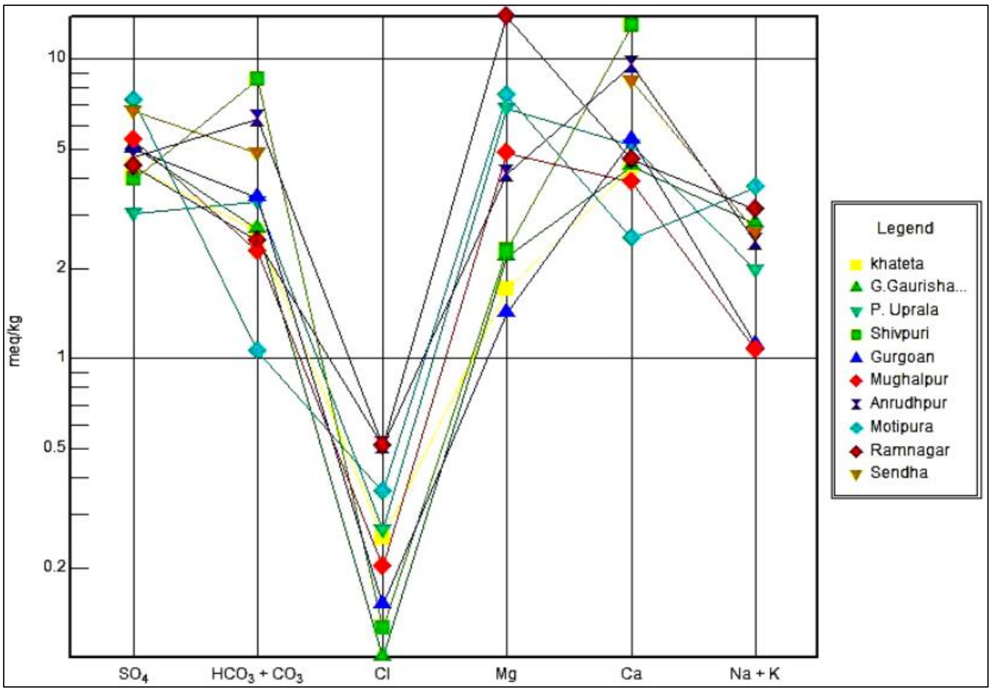

Fig 4: Schoeller diagram

Series plot: Series plot diagram shown in Fig. No. 5 indicates that the chlorine content of Gulariya Gaurishankar and Motipura village are found to be beyond the permissible limit while all other are within the range. The magnesium content is found to be under the permissible limit at all the places except Ramnagar. It is observed that the bicarbonate and calcium content of Shivpuri village exceeds permissible limit. The sodium, sulphate and potassium content are found to be within the safe limit at all the locations.

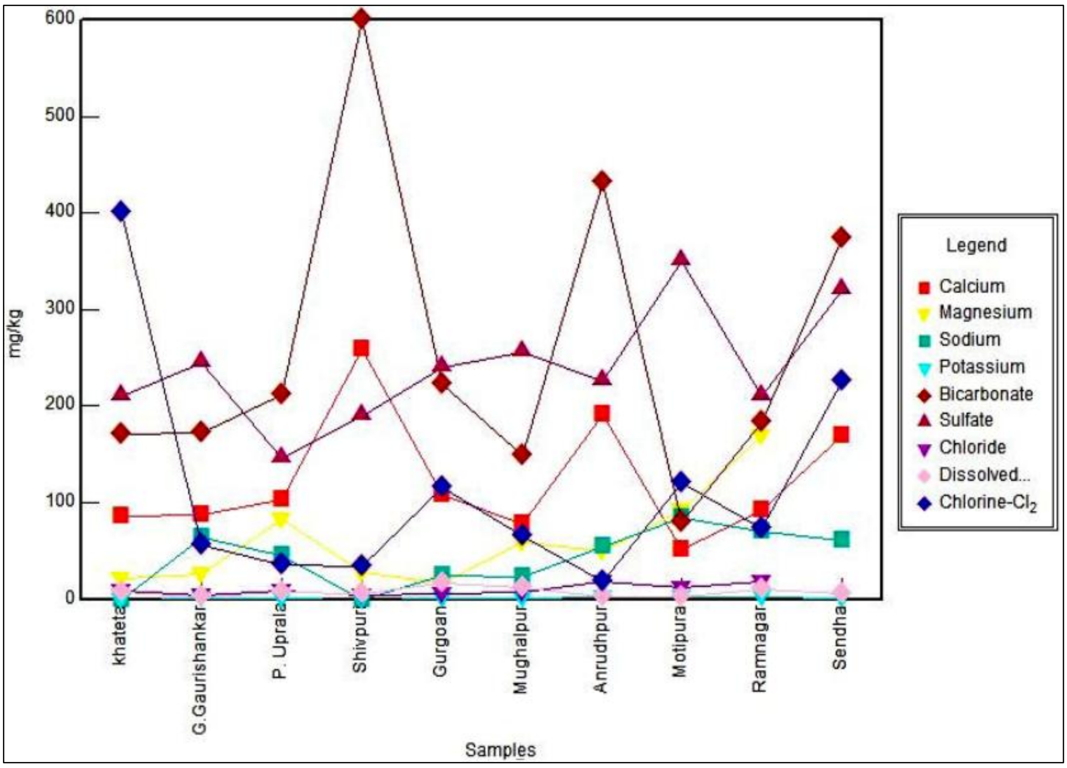

Fig 5: Series plot diagram

Table 9: Village wise cooperative parameters of water sample of Bareilly District

Parameter	Permissible limit for portable water	Khateta	G. Gaurishankar	P. Uprala	Shivpuri	Gurgaon	Mughalpur	Anrudhpur	Motipura	Ramnagar	Sendha
PH	6.5-8.5	7.6	7.68	7.65	7.14	7.56	7.46	7.23	6.93	6.95	6.9
EC	-	730	870	640	1180	600	500	1100	390	190	370
TDS	500	490	600*	430	900*	420	350	750	250	120	230
Turbidity	25	8	3	7	5	16	12	2	2	10	5
Acidity	-	60	30	55	90	65	45	60	50	40	55
Alkalinity	200	100	100	150	220*	120	105	230*	200	200	510*
Hardness	500	170	172	212	600*	222	148	432	80	184	374
Ca^{++}	200	86.57	87.37	103.41	258.92*	107.41	77.76	191.58	50.50	92.18	168.34
Mg^{++}	150	20.36	20.65	26.50	83.22	27.96	17.14	58.66	7.20	22.4	50.18
Cl	5	8.88*	3.55	8.88*	4.45*	5.33*	7.1*	5.33*	18*	12.7*	18*
Cl_2	400	55.38	35.96	34.08	115.02	65.32	18.46	120.70	73	225	194
Na	200	-	64.4	44.4	-	24.8	23.6	54.4	84	70	60
K	-	-	0.7	1.2	-	1	1.6	0.7	6.7	7.1	2.3
P	-	1.6	0.9	0.85	0.95	1.75	0.65	0.7	0.31	1.4	0.7
SO^4	400	210	245	146	190	240	256	225	350	210	320
N	-	-	16.8	8.4	-	16.8	7	5.8	-	7.8	9.2
$N\text{-}NO^2$	3	5.7*	2	4.8*	2.4	2.5	3	1.15	1.7	1.6	4.6*
$N\text{-}NO^3$	50	2.5	0.4	9.9	9	5.3	2.34	5.5	9.5	0.28	0.5
$N\text{-}NH^3$	35	1.4	2.4	2.3	2.2	1.2	1.5	1	1.16	6	0

*Red colour in the table is indicate it cross the permissible limit of portable water

4. Conclusion

The study area is always under stress due to increasing population and more demand for water resources under irrigation and domestic use. Water were sampled and analysed for their hydro chemical characteristics and evaluation of the water quality for drinking and irrigation purposes. The values of thirteen parameters of ten places were used to study the effect of IFFCO factory waste on groundwater quality. The analysis was done by using Aqua chem. Software. On the basis of above study the following conclusions were drawn.

1. Geochemistry of water samples of study area displays Ca> Mg>Na>K and HCO_3>SO_4.
2. The dominant hydro chemical facies are Ca-SO_4 (40%), Mg-SO_4 (30%), Ca-HCO_3 (20%) and Mg-HCO_3, respectively.
3. On the basis of Durov diagram, the 40% of water samples was along the dissolution or mixing line. In 50% of the water samples the HCO_3 and Na was found to be dominant whereas in the remaining samples SO_4 was

found to be dominant.

4. From the above study, it was concluded that the SO_4 in anion and Ca in cation are dominant chemical in Khateta, Gulariya Gaurishankar, Gurgaon and Sendha village.
5. In the Mughalpur, Motipura and Ramnagar village, SO_4 and Mg were found to be dominant anion and cation respectively.
6. In the Shivpuri village, Ca and HCO_3 were found to be dominant cation and anion respectively.
7. In the P. Uprala village, Mg and HCO_3 were found to be dominant cation and anion respectively whereas in the Gurgaon village, Ca and SO_4 were found to be dominant cation and anion respectively.
8. As per WHO norms, the groundwater of Shivpuri, Motipura, Ramnagar and Gulariya Gaurishankar villages was not found suitable for drinking purposes.

5. Acknowledgement
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