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INTERPRETATION OF GROUND AND SURFACE WATER QUALITY USING PRINCIPAL COMPONENT ANALYSIS IN GOHPUR SUB-DIVISION OF SONITPUR DISTRICT, ASSAM, INIDA

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ABSTRACT

Water is necessary for both; sustainable human development and healthy functioning of the planet's eco-system. The modern civilization, industrialization, urbanization and increase in population have led fast degradation of water resources. According to W. H. O., about 80% of all the diseases of human beings are caused by water. Since it is directly related with human health, it is necessary to bring awareness among the present and future generation about consequences of water pollution. A total of 34 numbers of samples from different sources such as dug wells, bore wells, hand pumps and ponds, where no information is available, were collected during year 2008. Samples were analyzed for different physico-chemical parameters like chloride, sulphate, nitrate, sodium, potassium, calcium, magnesium and iron using standard methods. The results indicated that chloride and nitrate concentration in all the sources were within the permissible limit and ponds contain higher amount of it than the other sources. The concentration of sulphate, sodium in dug well and bore well were very high and the concentration of sulphate, calcium were within the permissible limit. In case of calcium, its concentration in ponds was higher than the other sources. The iron concentration in all the sources exceeded the W.H.O. value and dug well and bore well contain higher amount of it. Magnesium content were greater than potassium and less than sodium in dug well and bore well, but in ponds, its concentration were greater than the other sources. In these investigations, the results indicate that TDS, EC, DO were found very high. The interpretation and evaluation, quality data, that was observed, were made very easier by utilizing the wide scope of spectacular statistical software, SPSS 17 through their principal component analysis. The main and ultimate aim of this study is to reveal and categorize the key parameters of the Gohpur sub-division for the pollution sources to ecosystem so that their inputs can be perceived. Box plots were derived from

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the PCA data and were graphically represented. The variance was observed to be above 67.28 % from the original data. Overall analysis reflected that 11 numbers of samples are fit for drinking purpose with respect to the parameters studied.

Key words: Drinking water, Physico-chemical parameters, Sonitpur district, Gohpur sub-division, WHO value, Metals, Physico-chemical.

INTRODCUTION

From the time immemorial, water is being considered as most important raw material of civilization. It is one of the vital resources for all kinds of life. Comprising over 71 % of the earth' surface, water is unquestionably the most precious natural resources that exists on our planet[1].

Ground water has historically been considered as reliable and safe source of water protected from surface contamination by geological filters that remove pollutants from water as it percolates through the soil[2]. Still ground water is not absolutely free from pollutants. In India, research on the qualitative studies of groundwater, specially with reference to fluoride, has been carried out by various workers[3,4]. Due to limited and confined study of groundwater, interpretations of the quality of groundwater in the area are incomplete for taking any measures for sustainable development[5]. The most common forms of diseases prevailing around rural and urban area of India till date has its root in the quality of drinking water facility in surrounding areas.

Increased in number of human population, the demand for water has increased to the extent that it has brought tremendous pressure on water resources, which has led to the disturbance of the status of water in the overall environment on the earth. If this pressure of degradation of water resource is not reduced, it may seriously impair the capacity of resource to meet the demand of the future generation and the present civilization. Pollution of fresh water occurs due to three major reasons, which are excess nutrients from sewage, wastes from industries[6], mining and agriculture. Groundwater is threatened with pollution from the sources of domestic waste, industrial wastes, run off from urban areas, suspended and dissolved soils, organics and pathogens. Other potential sources of groundwater contamination are waste water treatment lagoons, mine spills, urban and rural garbage's, earthen septic tanks, refuse dumps, barnyard etc. The problem of drinking water contamination, water conservation and water quality management has assumed a very complex shape[7]. Attention on water contamination and its management has become a need of the hour because of its far reaching impact on human health[8].

The quality of water is described by its physical, chemical and microbiological characteristics. These characteristics are many and interlinked[9]. In India, where groundwater is used extensively for irrigation and industrial purposes, a variety of land and water based activities are causing pollution of this precious resource. Its overexploitation is causing aquifer contamination in certain instance[10]. Information on groundwater quality of North East India is still scanty[11]. Available literature shows that ground water of north east valleys are highly ferriginous[12]. The incidence of high fluoride[13] and arsenic[14] in groundwater of Karbi Anglong and Nagaon districts of Assam and its manifestation in the form of fluorosis was already reported. These alarming pictures of the water quality and their continuous consumption have the potentional of posing serious health hazard to the local population. With increasing complexity and vastness of the observation and to grasp the whole scenario of the area, the data recorded were interpreted and inference of seasonal variation effect of the waters were made through statistical analysis, which is a handy tool in this kind of water pollution studies.

This interpretation of data can provide useful information needed by resource managers to exercise adequate environmental management. A literature review on principal component analysis, a technique that was formally used in the filed of hydrology, has shown its appropriateness for water quality data, as confirmed by some case studies in the literature[15-17]. In this study, it was attempted to determine the factors that cause variation in water quality of Gohpur sub-division by using PCA. There is no earlier statistics for various water quality parameters in Gohpur sub-division, and hence, the present research is undertaken with specific view to strengthen the national regional water quality data base.

Study area

The sonitpur district is stituated at the middle part of Assam and is located on the right bank of river Brahmaputra within 26.242 and 26.529N latitude and 92.182 and 93.482 E longitude. Land use in the district is divided primarily among tropical semi evergreen, moist deciduous, grass land, agricultural land and tea garden. The temperature ranges for 7^{o}C in January and 38^{o}C in July. Sonitpur district falls in 9A and 9B biogeography zone. The district is economically backward and practically has no large scale industry. The district is largely plain. There are three sub-divisions (Tezpur sub-division, Biswanath sub-division and Gohpur sub-division). The Gohpur sub-division belongs to low lying water logged, foot ravaged region. People of rural area generally use dug well, bore well, hand pump and pond as the sources of water for drinking purpose. Lifestyle of the inhabitants and their economic positions effect the water used within the home in different parts of the sub-division.

EXPERIMENTAL

Materials and methods

The water samples were collected form the various sources in separate container for physico-chemical analysis from all the 34 stations during winter, summer, monsoon and post-monsoon season. The water samples were collected from dug wells (DW), bore wells (BW), ponds and hand pumps. The depths of both; dug wells and bore wells varies from 30-350 feet in the month of July-August in the year 2008. Tube wells were operated at least 10 minutes before collecting to flash out the stagnant water inside the tube and to get fresh groundwater. The water samples were collected in plastic bottle (pvc 1 ltr.) and sealed preservative (1 : 1 HNO_3) solution to pH < 2, about 3 mL/L sample were added to each water sample for estimation of heavy metals. Sampling sources are arranged as shown in Table 1.

Table 1: Water sampling location

Name of block	S. No.	Source	Location (Gaon Panchayat)	Name of block	S. No.	Source	Location (Gaon Panchayat)
Pub-chaiduar	1	DW	Bartamuli	Chaiduar	18	Pond	Chatrang
	2	BW	Kharoi Paria		29	HP	Krishnapur
	3	DW	Raonamukh		20	DW	Rangalial
	4	Pond	Ghogra		21	Pond	Balijan
	5	DW	Luhitmukh		22	HP	Bakoridalani
	6	BW	Pachim Kalabari		23	DW	Kalyanpur
	7	BW	Pichal subansiri		24	BW	Jalpukbari
	8	DW	Solengi guri		25	BW	Tetonbari
	9	BW	Sonapur		26	DW	Amtola
	10	BW	Alupara		27	HP	Gamiri
	11	Pond	Uttar Kalabari		28	DW	Misamari
	12	DW	Dubia		29	BW	Helem
	13	DW	Kalabari		30	BW	Takoubari
	14	BW	Pub-Kalabari		31	Pond	Karibil
	15	BW	Gopalpur		32	HP	Kekurijan
	16	DW	Dakhin Kalabari		33	DW	Amjaroni
	17	BW	Pub-Dubia		34	DW	Nalanbari

The physico-chemical parameters were analyzed with help of spectrophotometer Spectronic 120, Hanna pocket TDS meter, Century flame photometer, Century water testing kit, conductivity meter, atomic adsorbtion spectrometer (AAS). The parameters are analyzed as given in instrument manual, APHA[18], Trivedy et al.[19], Golterman et al.[20], Goldman and Home[21] and Welch[22]. The water quality data was processed by applying PCA. The PCA was carried out for factors having eigen factors greater than one (Kaiser criterion). Coefficient matrix was used in PCA. The principal components were extracted in decreasing order of importance so that the first PC accounts for, as much of the variations as possible and each successive component accounts are looser. The quality data for the factor analysis is confirmed with Kaiser-Meyer-Olkin test. The principal components loading of the season were analyzed and box plot were drawn between PC and time of sampling. The statistical package SPSS 17.0 was employed for doing the PCA on water quality data of Gohpur sub-division.

RESULTS AND DISCUSSION

The physico-chemical parameters of 34 water samples of both pub Chaiduar and Chaiduar blocks are tabulated in Table 2.

Table 2: Chemical composition of ground and surface water from different locations

SS	DO	Cl^-	SO_4^{2-}	NO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe^{3+}	TDS	EC
1	4.45	20.00	58	4.3	190	34.0	36	48	6.0	12	116	127
2	3.05	49.00	30	8.6	114	37.0	17	110	12	0.45	127	610
3	4.90	24.00	47	9.4	188	26.0	12	48	8.5	0.26	201	108
4	3.46	34.00	32	11.0	210	70.0	69	15	9.8	3.6	209	126
5	3.20	29.00	38	9.3	184	43.0	15	149	14	3.4	145	950
6	3.97	38.00	48	4.5	192	70.0	17	160	10	4.4	106	1028
7	5.70	27.00	54	7.5	162	19.0	34	16	30	2.6	98	124
8	5.50	35.00	47	6.3	328	28.0	9.8	110	32	0.42	77	137
9	5.20	42.00	40	3.5	372	49.0	13	130	24	0.36	68	615
10	7.90	48.00	38	2.5	364	39.0	6.7	16	3.6	0.54	52	120
11	6.90	72.00	30	1.7	318	49.0	8.0	10	6.5	4.6	35	160
12	8.00	30.00	60	7.3	468	33.0	38	48	6.2	7.9	37	180

Cont...

SS	DO	Cl^{-}	SO_4^{2-}	NO_3^{-}	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Fe^{3+}	TDS	EC
13	7.80	35.00	48	6.1	440	16.0	72	118	25	0.59	68	841
14	3.00	49.00	20	7.6	506	19.0	34	46	5.3	4.4	95	660
15	2.90	30.00	40	2.7	214	18.0	16	72	19	3.7	210	1025
16	2.50	29.0	28	6.2	394	6.40	15	87	4.9	0.54	207	142
17	5.70	40.00	54	10.0	302	6.90	12	45	5.6	0.34	108	186
18	5.60	15.00	40	10.0	498	38.0	53	15	8.8	5.3	25	1040
19	6.30	47.00	25	3.7	464	32.0	29	22	20	3.6	45	193
20	6.80	19.00	45	8.6	310	34.0	35	45	5.8	13	76	1047
21	7.50	25.00	39	12	412	20.0	68	15	7.5	5.0	88	120
22	7.80	39.00	28	5.4	176	36.0	17	26	26	2.7	97	199
23	7.70	31.00	37	6.5	140	43.0	13	116	8.0	3.4	235	890
24	6.00	50.00	45	3.8	388	19.0	19	16	17	5.6	210	137
25	5.30	25.00	50	6.0	288	40.0	30	45	12	0.68	207	120
26	4.00	28.00	46	8.8	330	32.0	11	80	30	8.0	102	156
27	3.10	40.00	27	11.0	470	40.0	26	21	15	2.7	197	140
28	3.90	35.00	59	2.7	342	18.0	38	48	25	0.67	119	156
29	6.10	34.00	21	6.2	441	19.0	30	150	6.5	4.5	241	143
30	7.50	45.00	41	8.9	405	12.0	20	45	18	0.53	136	164
31	6.80	68.00	40	13.0	497	40.0	48	10	10	4.5	95	170
32	3.00	50.00	25	4.2	385	31.0	16	30	25	1.9	30	1085
33	2.60	27.00	25	6.5	310	8.0	15	47	5.5	0.29	55	123
34	2.90	15.00	61	3.7	275	41.0	18	46	31	0.46	69	135

Cl^{-}, SO_4^{2-}, NO_3^{-}, Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Fe^{3+}, DO, TDS, TH are measured in mg/L and EC are measured in mmho/cm

Table 3: Descriptive statistics

Para-meter	Range	Min.	Max.	Mean	Std. Deviation	Variance	Skewness	Kurtosis
DO	5.50	2.50	8.00	5.2068	1.84698	3.411	0.045	-1.419
Cl^-	57.00	15.00	72.00	36.0000	13.16791	173.394	0.822	0.962
SO_4^{2-}	594.30	20.00	614.30	56.4500	99.19143	9.839E3	5.715	33.077
NO_3^-	11.30	1.70	13.00	6.8971	2.93345	8.605	0.112	-0.771
TH	392.00	114.00	506.00	3.2579E2	1.15811E2	1.341E4	-0.158	-1.132
Ca^{2+}	63.60	6.40	70.00	31.3618	15.45719	238.925	0.572	0.614
Mg^{2+}	65.30	6.70	72.00	26.7794	17.77662	316.008	1.281	0.964
Na^+	150.00	10.00	160.00	58.9706	45.25985	2.048E3	0.920	-0.346
K^+	28.40	3.60	32.00	14.5147	9.07414	82.340	0.636	-1.039
Fe^{3+}	12.74	0.26	13.00	3.3218	3.20926	10.299	1.446	2.291
TDS	216.00	25.00	241.00	1.1714E2	65.50206	4.296E3	0.514	-0.992
EC	977.00	108.00	1085.00	3.8697E2	3.67883E2	1.353E5	0.997	-0.826

Table 4: Total variance explained for the principal component

Component	Initial Eigen values			Extraction sums of squared loading		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.226	18.552	18.552	2.226	18.552	18.552
2	1.737	14.471	33.023	1.737	14.471	33.023
3	1.634	13.616	46.638	1.634	13.616	46.638
4	1.405	11.712	58.351	1.405	11712	58.351
5	1.072	8.937	67.288	1.072	8.937	67.288
6	0.912	7.600	74.888			
7	0.808	6.734	81.621			

Cont...

Component	Initial Eigen values			Extraction sums of squared loading		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
8	0.611	5.094	86.715			
9	0.535	4.457	91.172			
10	0.456	3.796	94.968			
11	0.359	2.994	97.962			
12	0.245	2.038	100.000			
Extraction method: Principal component analysis						

Table 5: Component score coefficient matrix

Parameters	Components				
	1	2	3	4	5
DO	0.248	-0.069	0.144	0.095	-0.097
Cl^-	0.109	-0.346	0.293	-0.008	-0.212
SO_4^{2-}	-0.117	-0.003	-0.434	0.274	-0.170
NO_3^-	0.139	0.294	-0.268	-0.145	-0.033
TH	0.308	-0.129	-0.026	0.033	0.396
Ca^{2+}	-0.080	0.185	0.164	0.324	-0.567
Mg^{2+}	0.267	0.281	-0.120	0.072	0.164
Na^+	-0.289	0.115	0.184	-0.013	0.353
K^+	-0.149	-0.205	-0.255	0.311	0.160
Fe^{3+}	0.153	0.322	0.162	0.172	-0.122
TDS	-0.153	0.160	0.008	-0.530	-0.119
EC	-0.131	0.222	0.280	0.297	0.405
Extraction method: Principal component analysis					

TDS: It indicates the general nature of salinity of water (Sing et al. 2004). The TDS fluctuated from 35 to 210 mg/L in pub-chaiduar block and ranges from 25 to 241 mg/L in chaiduar block. The fluctuation in TDS is largely because of dissolved organic matters. All 34 sources have TDS value below the desirable limit (500 mg/L).

DO: The DO values varied from 3.0-8.0 mg/L. The DO are major parameters to access the pollution load.

EC: Electrical conductivity varied from 108 to 1085 mmho/cm. Maximum EC was observed in hand pump of Kekurijan gaon panchayat.

Chloride: The ranges of chloride content in different sources were 15 - 35 mg/L in dug well, 25- 50 mg/L in bore well, 39 - 50 mg/L in hand pump and 24 - 72 mg/L in ponds. In the present investigation, the chloride content of water samples does not exceed the BIS value of 250 mg/L. Ponds contain higher amount of chloride. Higher values i.e. 68 mg/L and 72 mg/L were observed in ponds of sources No. 11 and 31. The most important sources of chlorides in the water is the discharge of domestic sewage. Men and the other animals excrete high quantities of chlorides with nitrogenous compounds.

Sulphate: The ranges of sulphate content of water samples were 25 - 61 mg/L in dug well, 20 - 54 mg/L in bore wells, 3.9 - 40 mg/L in ponds and 25 - 28 mg/L in hand pump. The sulphate concentrations were higher than the corresponding chloride content in case of dug well and bore well, but the trend was reversed in case of ponds. This is due to the inflow of chloride rich waste water into the ponds. In present investigation, the sulphate concentrations of all the water samples were below the permissible limit of 200 mg/L.

Nitrate: The ranges of nitrate concentration of water samples were 2.7 - 8.8 mg/L in DW, 2.5 - 8.9 mg/L in BW, 10 - 13 mg/L in pond and 3.7-5.4 mg/L in HP. During the investigation, all the water samples were found to have nitrate content within the permissible limit of 45 mg/L.

Sodium: The ranges of sodium concentration were 45 - 149 mg/L in DW, 16 - 160 mg/L in BW, 10 - 15 mg/L in ponds and 21 - 26 mg/L in HP. In the present study, the maximum value of sodium was recorded at water sources at No. 5, 6, 7, 8, 9, 13, 23 and 29.

Potassium: The ranges of potassium concentration were 4.9-32 mg/L in DW, 3.6 - 30 mg/L in BW, 6.5 - 10 mg/L in ponds and 15 - 25 mg/L in HP. The highest concentration of potassium was observed in water source No. 8 and 26 of DW.

Calcium: The ranges of calcium concentration were 6.4 - 43 mg/L in DW, 6.9 – 30 mg/L in BW, 19 - 70 mg/L in ponds and 31 - 40 mg/L in HP. The values of calcium concentration in all the water samples during present investigation was below the permissible limit of 75 mg/L. Highest amount of calcium (70 mg/L) was found in sample No. 4 of pond.

Magnesium: The ranges of magnesium concentration were 9.8 - 72 mg/L in DW, 6.7 - 34 mg/L in BW, 48 - 80 mg/L in ponds and 16 - 29 mg/L in HP. During these investigations, it was found that Mg content was higher than those for Na, K and Ca.

Iron: The iron contents of water samples were 0.29 - 13 mg/L in DW, 0.34 - 5.6 mg/L in BW, 3.6 - 4.1 mg/L in ponds and 1.9 - 3.5 mg/L in HP. The maximum value of iron was observed in the source No. 23 (DW). In the present study, the iron contents of all the types of sources except the source No. 33 (DW) exceeded the WHO permissible value of 0.3 mg/L. The concentration of iron in DW and BW was found higher than the ponds. It may be due to soil origin and age-old iron pipes used.

During the investigation, PCA extracted five composite variables with Eigen value greater than one (Table 4). These composite variables capture a total of 67.28 % (Table 4) at the variance in the original data. Taking into consideration the most significant variables in evaluating the component, the first principal component (PC-I) explained 18.55 % variance and gives information about the Mg and DO. The Mg showed lowest value of 67 mg/L to highest value of 72 mg/L with a mean of 26.77 and DO value varied from lowest value of 2.5 mg/L to highest value of 8.0 mg/L with a mean of 5.20. The variation of Mg and DO are shown in Fig. 1. In the second principal component (PC-II), it explained 14.47 % of variance and gives information about the Fe and NO_3^-. The Fe showed lowest value of 0.26 mg/L to highest value of 13 mg/L with a mean of 3.32 and that of NO_3^- with lowest value of 1.7 mg/L to highest value of 13 mg/L with a mean of 6.89. The variation of Fe and NO_3^- are shown in Fig. 2.

In the third principal component (PC-III), it explained 13.61 % of variance and gives information about the Cl^-, which is negatively correlated with SO_4^{2-}. The Cl^- showed lowest value of 15 mg/L to highest value 72 mg/L with a mean of 36.00 and that of SO_4^{2-} range from 20 mg/L to highest value 58 mg/L with a mean of 26.77. The variation of Cl^- and SO_4^{2-} are shown in Fig. 3. In the forth principle component (PC-IV), it explained 11.71 % of variance with Ca^{2+} and K^+, which was found to be important. The value of Ca^{2+} varied from lowest value of 12 mg/L to highest value 70 mg/L with a mean of 31.36 and that of Ca^{2+}

ranged between 3.6 mg/L to 32 mg/L with a mean of 14.51. The variations of Ca^{2+} and K^{+} are shown in Fig. 4.

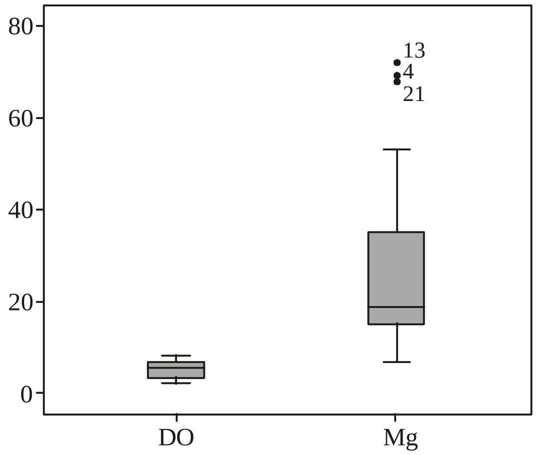

Fig. 1: Variation of DO and Mg^{2+}

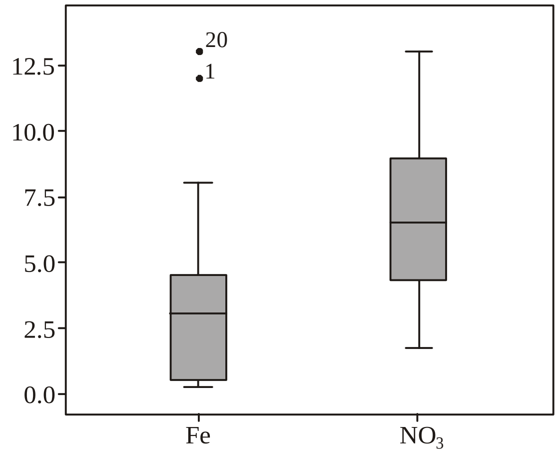

Fig. 2: Variation of Fe and NO_3

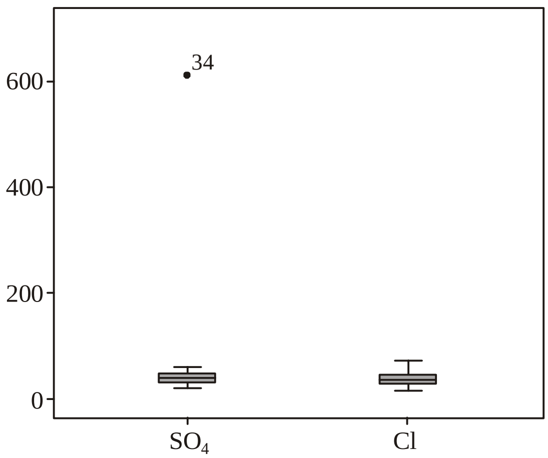

Fig. 3: Variation of SO_4^{2-} and Cl^{-}

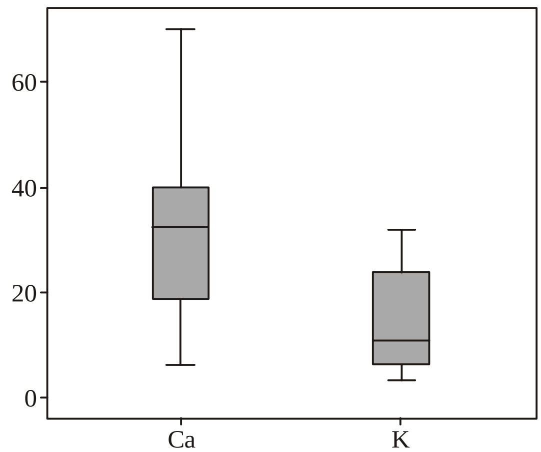

Fig. 4: Variation of Ca^{2+} and K^{+}

In the fifth principle component (PC-V), it explained 8.93 % of variance with EC and TH was found to the important. The value of EC varied from 108 mmho/cm to 1047 mmho/cm with a mean of 3.86E2 and that of TH value ranged from 114 to 506 with a mean of 3.25E2. The variation of EC and TH are shown in Fig. 5.

The number of Eigen value can be estimated from a Scree plot demonstrated in Fig. 6. As shown in this Fig., the Eigen values sharply decrease within the first five components and than slowly stabilized for the remaining ones.

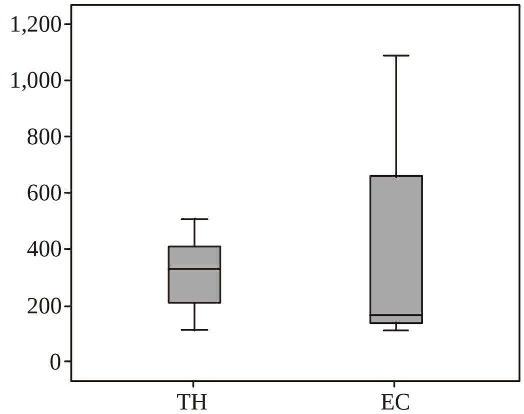

Fig. 5: Variation of TH and EC

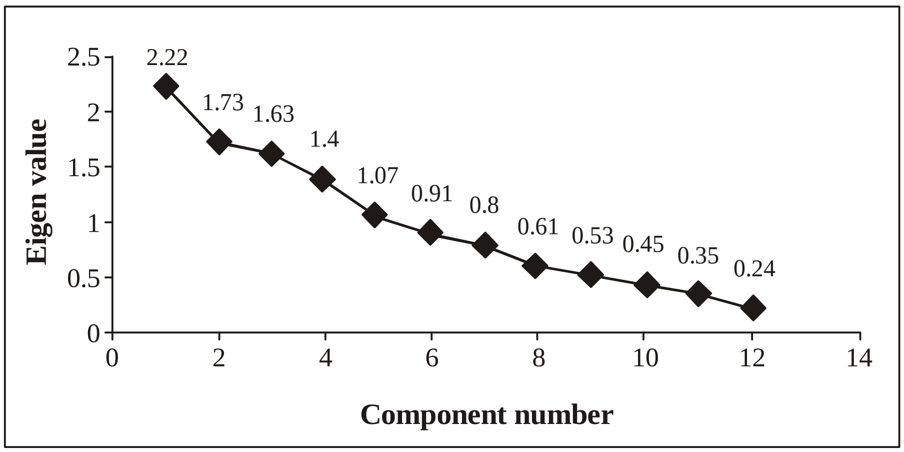

Fig. 6: Scree plot of groundwater

CONCLUSION

In the present study using PCA, it may be concluded that during these investigations, the variance was observed to be above 67.28 % from the original data. Sulphate concentration was found to be high. The concentration of iron was high. Regarding other parameters, their concentrations do not exceed the permissible limits. In case of ponds, most of the inorganic constituents like sulphate, nitrate and chloride did not have very high values although the nitrate values were higher in comparison to other sources. The water of ponds was having sufficient amounts of Na, K, Ca, Mg and Fe. It was found that many of the people of rural area of Gohpur sub-division have ordinary sand and stone filters as the only treatment given to water before using it for drinking and cooking. Disinfection is seldom done. Proper sanitation and sewage disposal systems do not exist in the sub-division. Since the groundwater is being more or less contaminated, so the people awareness regarding water disinfection, hygienic condition and prevention and remedial measures with respect to water quality and causes are of prime importance. In addition, water quality surveillance programs infrastructure set up and public participation is the need of the hour.

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