Correlation Study and Regression Analysis of Ground Water Quality Assessment of Nagaon Town of Assam, India

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Abstract **- In this study, the Nagaon district of the state Assam, India is selected as the study area to assess the groundwater quality for drinking purpose. Therefore efforts have been made to evaluate the status of potability of 77 groundwater samples from boring or tube wells representing groundwater resource that have been collected from September 2017 to January 2018 from different locations in the Nagaon town. 12 physical, chemical and biological water quality parameters, viz. fluoride, iron, manganese, nitrate, pH, turbidity, alkalinity, chloride, total hardness, calcium hardness, magnesium hardness and bacteria test are selected for analysis and to study whether the groundwater of the study area is potable for use or not. There is a relationship between variables which shows that one variable actually causes changes in another variable. In this paper, a statistical regression analysis method of the drinking water samples is carried out. This technique is based on the study and calculating the correlation coefficients between various physicochemical parameters of drinking water. The results were further compared with drinking water quality standards as per BIS (I.S. 10500:2012) and it was deduced that most of the water samples are potable. The results proved to be a useful mean for rapid monitoring of water quality with the help of systematic calculations of correlation coefficient.**

Index Terms- Statistical regression analysis method, Water quality parameters, Correlation coefficient.

1. INTRODUCTION

Water is a public good and every person has the right to demand drinking water. Human life, as with all animal and plant life on the planet, is dependent upon water. Not only do we need water to grow our food, generate our power and run our industries, but we need it as a basic part of our daily lives. Water, sanitation and health are closely inter-related. In wealthier communities this connection is taken for granted but in poor developing communities the connection is a stark daily reality.

Water and health are related in a number of ways. Firstly, there is the direct impact of consuming contaminated water - this is known as 'waterborne and there is chemically contaminated water such as water containing excessive amounts of arsenic or fluoride. Some contaminants are added to drinking water as a result of natural processes and some due to human activities such as industry and mining. Poor communities, especially in urban fringe areas, are particularly susceptible to dangers from polluted water from a variety of sources due to lack of or poorly enforced regulation of water pollution. The most prominent factors that elevates the level of water pollution are exploding population, increasing industrialization and urbanization. Various treatment methods are adopted to raise the quality of drinking water. Water should be free from the various detoxifications such as Organic and Inorganic pollutants, Pesticides, Heavy metals etc. As well as all its parameter like fluoride, iron, manganese, nitrate, pH, turbidity, alkalinity, chloride, total hardness, calcium hardness, magnesium hardness should be within acceptable limit. A novel approach of regression method is adopted to assess quality of water.

2. STUDY AREA

Nagaon town is selected as the study area since it is a developing town in Assam and much work has not been done in assessing the potability of the groundwater source. Parts of the Nagaon town are affected with contamination of groundwater by water quality entities or parameters with very high concentrations due to human interference.

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TABLE 1: NAGAON DISTRICT AT A GLANCE

SL NO	ITEMS	STATISTICS
1.	GENERAL INFORMATION i) Geographical Area (in sq.km AS PER 2011 CENSUS) ii) Population iii) Average Annual Rainfall (mm) iv) No of sub division	 411030 2826006 1541 03
2.	GEOMORPHOLOGY (i) Major Physiographic units (ii) Major drainage	Piedment plain, flat alluvial plain (older and younger alluvial) and Inselberges (Granites & Gneisses) Brahmaputra and its tributaries mainly Kolong, Kopili, Sonai and Diyang.
3.	LAND USE (sq. km.) as on 2011 i) Forest Area ii) Net Area Sown iii) Total cropped area iv) Area sown more than once	 88024 235626 291339 55713
4.	Major soil types	Alluvial soil
5.	PREDOMINANT GEOLOGICAL FORMATIONS	Vast river borne sediment, Older and Younger alluvium.
6.	HYDROGEOLOGY i) Major water bearing formation ii) Pre-monsoon water level iii) Post monsoon water level iv) Long term water level trend	 i) Sand and pebble aquifer zone down to 300 m depth and weathered and fracture zones up to 100 m depth in consolidated rocks ii) 2.23 – 4.48 mbgl iii) 1.861 - 4.07 mbgl iv) No significant change observed
7.	MAJOR GROUND WATER PROBLEMS AND ISSUES	Higher conc. of iron in ground water and Arsenic & Fluoride in some pockets.

3. MATERIALS AND METHODS

Drinking ground water samples were collected from different sampling locations covering the entire Nagaon town as in Table 2. The collected samples were analyzed in Kaliabor and Nagaon Public Health Engineering Department as per convenience.

3.1 Collection, Preparation of Water Samples and Analysis

For sampling in the study area, groundwater samples were collected by grab sampling from different pinpoint locations representing the actual groundwater resource of the study area. The samples were collected in plastic PET bottles to get representative samples. 500 ml of each of the samples were collected for groundwater quality analysis. All the sampling bottles were filled to the top with the groundwater samples and tightly capped. After that the filled sample bottles were transported to the laboratory of PHED. Samples were protected from direct sunlight during transportation. The samples were stored in the laboratory at room temperature until analyzed.

3.2 Water Quality Analysis

The water samples were analyzed for physicochemical parameters with the help of equipment that have been used in the limits of precise accuracy and chemicals used were of analytical grade as mentioned in the table 2 below.

TABLE 2: The physico-chemical parameters, their units and the methods/equipment of analysis

Parameter	Unit	Method/Instrument
Fluoride, F	mg/l	Spectroquant Pharo 100 Spectrophotometer
Iron, Fe	mg/l	Spectroquant Pharo 100 Spectrophotometer
Manganese, Mn	mg/l	Spectroquant Pharo 100 Spectrophotometer
Nitrate, NO_3	mg/l	Spectroquant Pharo 100 Spectrophotometer
Total Hardness, TH	mg/l	Titration
Calcium Hardness, $CaCO_3$	mg/l	Titration
Magnesium Hardness, $MgCO_3$	mg/l	Titration
Alkalinity	mg/l	Titration
Chloride	mg/l	Titration
pH		Field Water Testing Kit
Turbidity	NTU	Field Water Testing Kit
Bacteria test		Blue Bacta Vial

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TABLE 3: Analysis results of 77 groundwater samples collected from the Nagaon town of Nagaon district, Assam

Sample No.	Fluoride (F) in mg/l	Iron (Fe) in mg/l	Manganese (Mn) in mg/l	Nitrate (NO_3) in mg/l	Total Hardness (TH) in mg/l	Calcium Hardness ($CaCO_3$) in mg/l	Magnesium Hardness ($MgCO_3$) in mg/l	Alkalinity in mg/l	Chloride (Cl) in mg/l	pH	Turbidity in NTU	Bacterial test	Well Depth in feet
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.16	0.21	0.45	2.7	272	200	17.57	50	96	6.5	4	negative	23
2	0.24	1.25	0.28	2.1	280	220	14.64	40	74	7	6	negative	30
3	0.17	0.87	0.44	2.7	236	180	13.66	40	46	6.5	4	negative	23
4	0	0.26	0.37	1.3	192	120	17.57	40	26	7	5	negative	30
5	0	0.36	0.85	4.4	244	200	10.74	36	88	6	5	negative	26
6	0.30	1.12	0.45	1.6	256	200	13.66	58	78	6.5	4	negative	26
7	0.17	0.25	0.46	6.1	252	200	12.69	42	50	6.5	5	negative	26
8	1.03	4.73	0.63	1.9	236	150	20.98	52	66	6.5	10	negative	26
9	0.14	1.26	0.54	1.2	240	190	12.20	38	60	7	8	negative	30
10	0.21	0.80	0.57	1.6	300	190	26.84	68	96	6	5	negative	23
11	0.43	0.11	0.46	3.1	184	150	8.30	130	40	6.5	3	negative	25
12	0.10	0.11	0.34	4.6	252	185	16.35	210	58	6.5	6	negative	40
13	0.24	0.12	0.29	2.7	268	200	16.59	204	78	6.5	3	negative	30
14	0.30	0.19	0.30	1.5	124	95	7.08	110	18	6	5	positive	30
15	0.22	0.29	0.45	2.2	160	140	4.88	90	32	6	5	positive	20
16	0.31	0.34	0.48	2.5	232	125	26.11	180	46	6	4	negative	30
17	0.44	0.12	0.79	8.4	260	175	20.74	140	112	6	5	negative	20
18	0.20	0.06	0.35	7.3	256	190	16.10	150	106	6	5	negative	25
19	0.27	0.09	0.29	6.6	164	105	14.40	100	76	6	4	negative	25
20	0.43	0.08	0.45	3.1	224	110	27.82	250	28	7.5	5	positive	20
21	1.24	1.26	0.68	2.5	176	150	6.34	148	14	6.5	25	negative	25
22	0.54	0.19	0.54	2.4	204	175	7.08	160	14	6	5	negative	33
23	0.10	0.22	0.63	2.2	128	95	8.05	154	50	6	5	negative	30
24	0.36	0.24	0.35	1.9	160	95	15.86	138	28	7	6	negative	25
25	0.28	0.32	0.36	1.7	220	75	35.38	198	30	6.5	5	negative	44
26	0.10	0.26	0.32	3	316	115	49.04	204	74	6	5	negative	25
27	0.19	0.21	0.33	2.6	312	115	48.07	236	76	6.5	5	negative	25
28	0.21	0.52	0.37	3.1	312	115	48.07	168	60	6	6	negative	25
29	0.22	0.21	0.31	2.6	236	110	30.74	222	70	6.5	5	negative	33
30	0.21	0.81	0.46	3.1	204	70	32.70	162	66	6.5	10	negative	25
31	0.35	1.14	0.57	1.9	236	200	8.78	230	34	6	10	negative	80
32	0	0.27	0.36	1.8	308	170	33.67	306	80	7	5	negative	40
33	0.70	0.38	0.32	1.8	176	80	23.42	116	16	6	5	negative	30
34	0.09	0.37	0.35	2.1	244	120	30.26	186	86	6.5	5	negative	25
35	0	0.34	0.32	2.3	296	120	42.94	220	78	7	5	negative	25
36	0.25	0.25	0.34	2.4	172	80	22.45	190	8	7.5	6	negative	30
37	0.10	0.21	0.53	2.9	252	100	37.09	240	72	6.5	6	negative	25
38	0	0.20	0.29	2	208	75	32.45	250	6	7.5	5	negative	30
39	0.14	0.28	0.37	2.4	188	80	26.35	126	54	6	6	negative	30
40	0.12	0.74	0.44	2.4	164	100	15.62	190	68	6.5	10	negative	25
41	0.21	0.22	1.14	2.7	240	175	15.86	36	92	6	5	negative	30
42	0.16	0.45	0.87	2.2	208	140	16.59	76	32	6	5	negative	26
43	0.05	0.20	0.50	2.4	132	40	22.45	46	18	6	5	negative	30
44	0.06	5	1.88	2.7	352	120	56.61	74	96	6	25	negative	26
45	0.11	0.54	1.40	2.7	212	100	27.33	50	76	6	5	negative	25
46	0.11	0.73	0.75	2.6	208	125	20.25	56	46	6	6	negative	25
47	0.94	4.77	1.57	2.1	248	105	34.89	60	38	6	30	negative	26
48	0.42	4.34	1.24	2.3	196	75	29.52	58	44	6	10	negative	26
49	0.22	1.14	0.50	3.9	180	90	21.96	36	78	6	5	negative	26
50	0.15	0.22	0.36	2.5	208	110	23.91	90	10	6.5	5	negative	30
51	0.10	4.54	1.15	2.8	288	105	44.65	106	120	6	25	negative	26
52	0.41	3.98	1.37	3.5	304	90	52.22	90	110	6	25	negative	26
53	0.25	0.22	0.79	5.3	308	150	38.55	272	104	6	5	negative	30
54	0.12	3.81	1.31	3.9	400	175	54.90	342	128	6	30	negative	150
55	0.11	0.58	0.44	3.2	280	75	50.02	286	70	7	5	negative	30
56	0	2.03	0.73	2.1	360	120	58.56	280	78	6	10	negative	55

57	0.09	0.51	0.39	8.6	196	85	27.08	176	52	6	5	negative	26
58	0	0.95	0.45	5.1	164	70	22.94	146	58	6	5	negative	30
59	0.14	3.77	0.69	2.8	240	60	43.92	244	46	6.5	6	negative	26
60	0.16	4.55	0.80	2.4	420	125	71.98	414	124	6	25	negative	26
61	0.07	1.72	0.54	1.8	180	90	21.96	198	10	6.5	5	negative	190
62	0.05	0.36	0.33	5.1	200	75	30.50	196	58	6	5	negative	30
63	0.08	1.07	1.71	2.3	68	45	5.61	342	88	6	5	negative	30
64	0.07	0.39	1.74	2.5	212	155	13.91	308	86	6	5	negative	26
65	0	0.62	0.76	8.5	280	75	50.02	120	44	6	5	negative	30
66	0.22	1.23	0.74	4.5	420	225	47.58	348	164	6	5	negative	30
67	0.10	1.28	0.48	2.9	216	130	20.98	226	4	6.5	6	negative	30
68	0.18	0.70	0.31	6.1	276	120	38.06	198	52	6	5	negative	30
69	0.19	0.84	0.41	2.8	192	85	26.12	202	56	6	5	negative	26
70	0.07	0.88	0.43	6.4	284	90	47.34	208	56	6	5	negative	26
71	0.76	0.72	0.38	12.1	212	110	24.89	152	70	6.5	5	negative	30
72	0.49	0.94	0.33	4.9	208	95	27.57	160	58	6	5	negative	26
73	0.09	0.71	0.35	8.4	272	125	35.87	202	32	6	5	negative	26
74	0.52	0.92	0.34	2.8	168	80	21.47	162	20	6	5	negative	30
75	0.45	2.52	0.82	2.2	260	115	35.38	204	34	6	5	negative	26
76	0.53	0.67	0.62	3.4	484	185	72.96	602	166	6	5	negative	30
77	0.29	0.68	1.13	2.5	144	90	13.18	102	20	6	5	negative	30

TABLE 4: Statistics of the analytical results

Sl. No.	Water quality parameter	Minimum value	Maximum value	Mean	Standard deviation
1	Fluoride (F) in mg/l	0	1.24	0.24	0.24
2	Iron (Fe) in mg/l	0.06	5	1.04	1.32
3	Manganese (Mn) in mg/l	0.28	1.88	0.61	0.38
4	Nitrate (NO_3) in mg/l	1.2	12.1	3.37	2.04
5	Total Hardness (TH) in mg/l	68	484	238.49	71.36
6	Calcium Hardness ($CaCO_3$) in mg/l	40	225	124.54	45.31
7	Magnesium Hardness ($MgCO_3$) in mg/l	4.88	72.96	27.80	15.62
8	Alkalinity in mg/l	36	602	165.45	101.69
9	Chloride (Cl) in mg/l	4	166	60.99	34.83
10	pH	6	7.5	6.28	0.41
11	Turbidity in NTU	3	30	7.39	6.27

3.3 Linear Regression Model

The relationship of water quality parameters on each other in the samples of water analyzed was determined by determining correlation coefficients (r) by using the mathematical formula as given below. Let x and y be any two variables (water quality parameters in the present investigation) and n = number of observations. Then the correlation coefficient (r), between the variables x and y is given by the relation.

$$R = \frac{n\sum(x*y)-\sum x*\sum y}{\sqrt{f(x)*f(y)}}$$

Where,

$f(x) = n\sum(x^2) - (\sum x)^2$; $f(y) = n\sum(y^2) - (\sum y)^2$ and all the summations are to be taken from 1 to n. If the numerical value of the correlation coefficient between two variables x and y is fairly large, it implies that these two variables are highly correlated. In such cases, it is feasible to try a linear relation of the form

$$y = Ax + B$$

To correlate x and y, the constant A and B are to be determined by fitting the experimental data on the variables x and y. According to the well-known method of least squares, the value of constants A and B are given by the relations

And $B = y_{mean} - Ax_{mean}$

Where, $x_{mean} = \frac{\sum x}{n}$; $y_{mean} = \frac{\sum y}{n}$

$$A = \frac{n\sum(x*y)-\sum x*\sum y}{n\sum(x-x_{mean})^2}$$

By using these relations, with the help of Microsoft Excel the values of correlation coefficients (R) are found which has been given below in Table 5.

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TABLE 5: Correlation coefficients (R) among various water quality parameters

	Depth	F	Fe	Mn	NO_3	TH	$CaCO_3$	$MgCO_3$	Alkalinity	Cl	pH	Turbidity
Depth	1											
F	-0.118	1										
Fe	0.174	0.247	1									
Mn	0.082	0.047	0.576	1								
NO_3	-0.095	0.004	-0.154	-0.117	1							
TH	0.099	-0.088	0.323	0.119	0.106	1						
$CaCO_3$	0.043	0.091	-0.088	-0.026	0.003	0.471	1					
$MgCO_3$	0.08	-0.162	0.422	0.151	0.116	0.781	-0.182	1				
Alkalinity	0.215	-0.098	-0.009	-0.007	0.046	0.47	-0.021	0.539	1			
Cl	-0.038	-0.138	0.232	0.316	0.193	0.687	0.411	0.476	0.361	1		
pH	-0.011	-0.04	-0.199	-0.383	-0.244	-0.079	0.036	-0.113	0.032	-0.273	1	
Turbidity	0.203	0.284	0.778	0.552	-0.124	0.324	-0.014	0.371	0.036	0.243	-0.154	1

The correlation coefficient (R) measures the degree of association that exists between two variables, one taken as dependent variable. The greater the value of regression coefficient, the better is the fit and more useful the regression variables (Daraigan Sami G.,2011). 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. In this study, the numerical values of correlation coefficient (R) for the eleven water quality parameters and depth are tabulated in Table 5.

4. RESULT AND DISCUSSIONS

In the studied area, water used for drinking purposes should be colourless, odourless and free from slight turbidity and excess salts. The important physico-chemical characteristics of analyzed water samples viz., Mean and Standard Deviation (SD) have been presented in Table 4. It shows that variation among the measured values of these parameters at different locations is not too high and variation range is very narrow.

The regression equation was used as a mathematical tool to calculate different dependent characteristics of water quality by substituting the values for the independent parameters in the equations. The regression analysis carried out for which the water quality parameters found to have better and higher level of significance in their correlation coefficient are studied below.

Correlation between magnesium hardness and total hardness
A graph of magnesium hardness and total hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

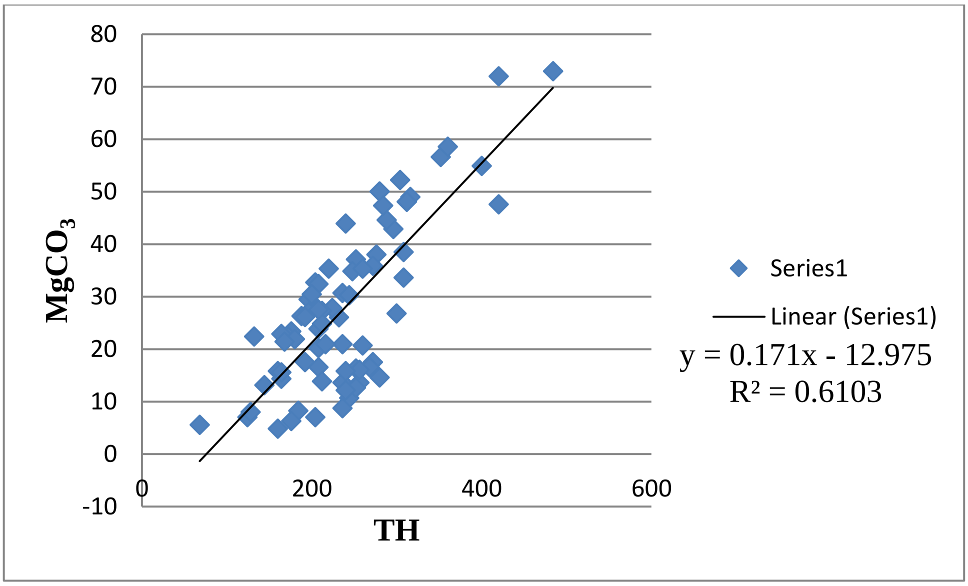

FIG.1: A graph of magnesium hardness and total hardness

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that the magnesium hardness are found dependent on the total hardness, such that an increase in total hardness related to an increase in magnesium hardness. This relation indicates the presence of stratum of high mineral content of limestone and chalk which are largely made up of calcium and magnesium carbonates and bicarbonates in the Nagaon town area.

Correlation between calcium hardness and total hardness

A graph of calcium and total hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

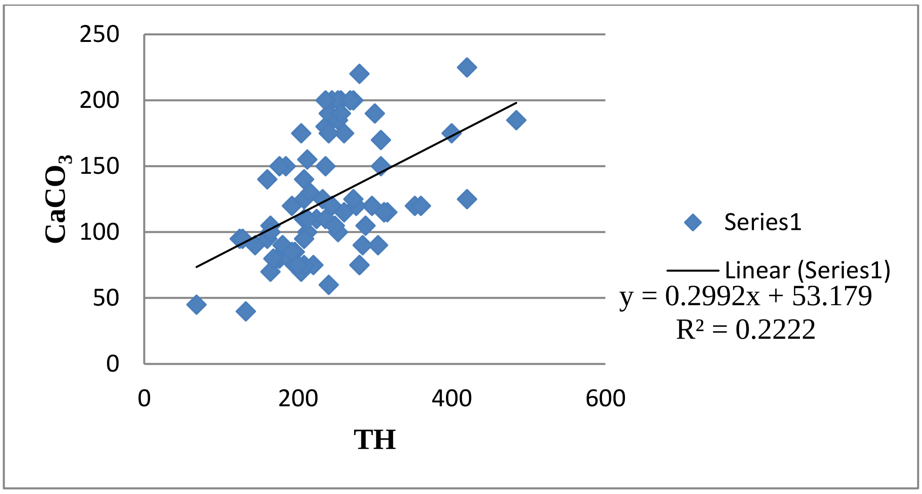

FIG.2: A graph of calcium hardness and total hardness

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that the calcium hardness are found dependent on the total hardness, such that an increase in total hardness related to an increase in calcium hardness. This relation indicates the presence of stratum of high mineral content of limestone and chalk which are largely made up of calcium and magnesium carbonates and bicarbonates; and also presence of calcium sulphate and calcium chloride in the geology of the Nagaon town area.

Correlation between chloride and total hardness

A graph of chloride and total hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

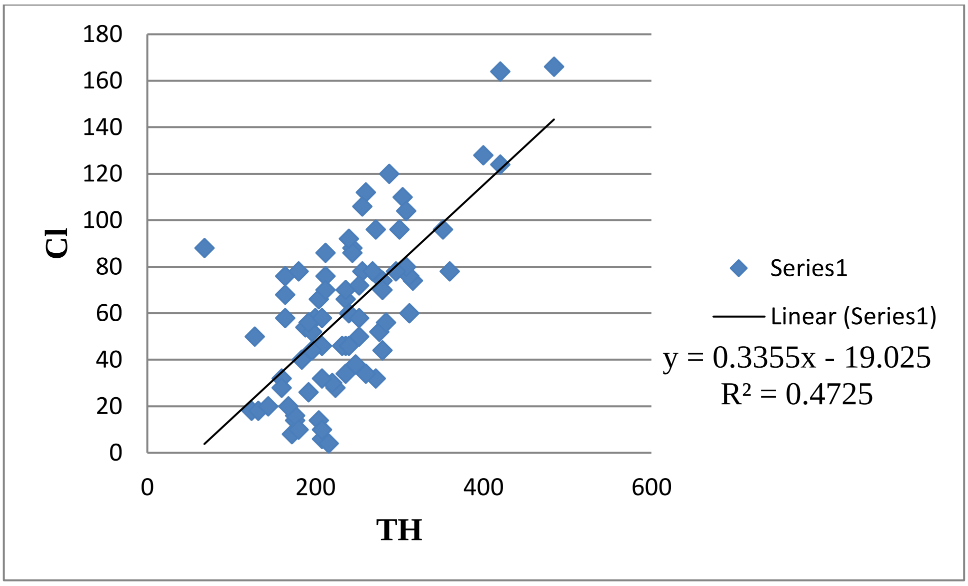

FIG.3: A graph of chloride and total hardness

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that chloride is found dependent on the total hardness, such that an increase in total hardness is related to an increase in chloride. This relation indicates the presence of stratum of high mineral content of limestone and chalk (carbonate or temporary

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hardness) and also presence of calcium sulphate, calcium chloride, magnesium sulphate, and magnesium chloride (non-carbonated or permanent hardness) in the Nagaon town area that adds to the total hardness and as a result the chloride also increases from chlorides of calcium and magnesium.

Correlation between alkalinity and total hardness
A graph of alkalinity and total hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

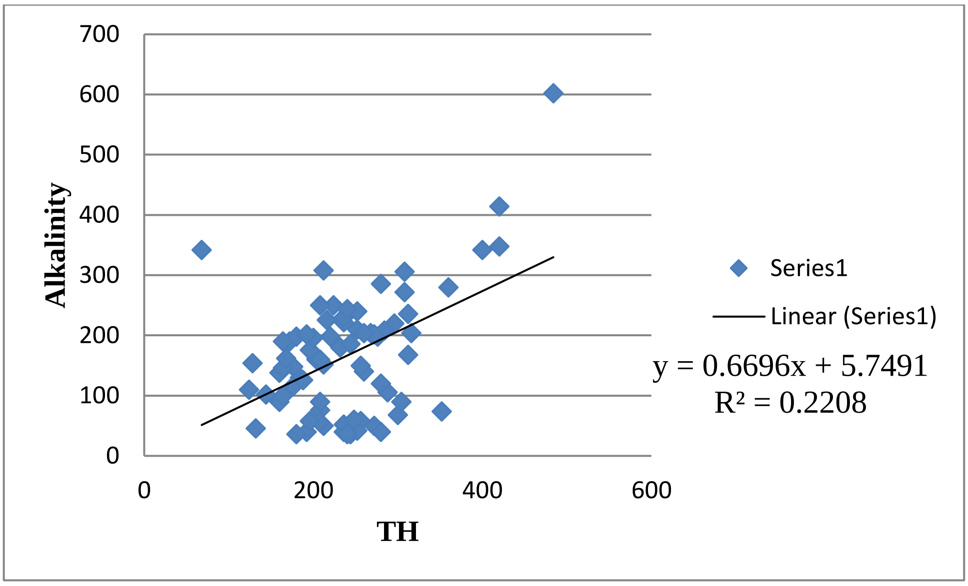

FIG.4: A graph of alkalinity and total hardness

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that alkalinity is found dependent on the total hardness, such that an increase in total hardness is related to an increase in alkalinity. This relation basically indicates that alkalinity and hardness changes depending on the pH or mineral content of the stratum.

Correlation between alkalinity and magnesium hardness
A graph of alkalinity and magnesium hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

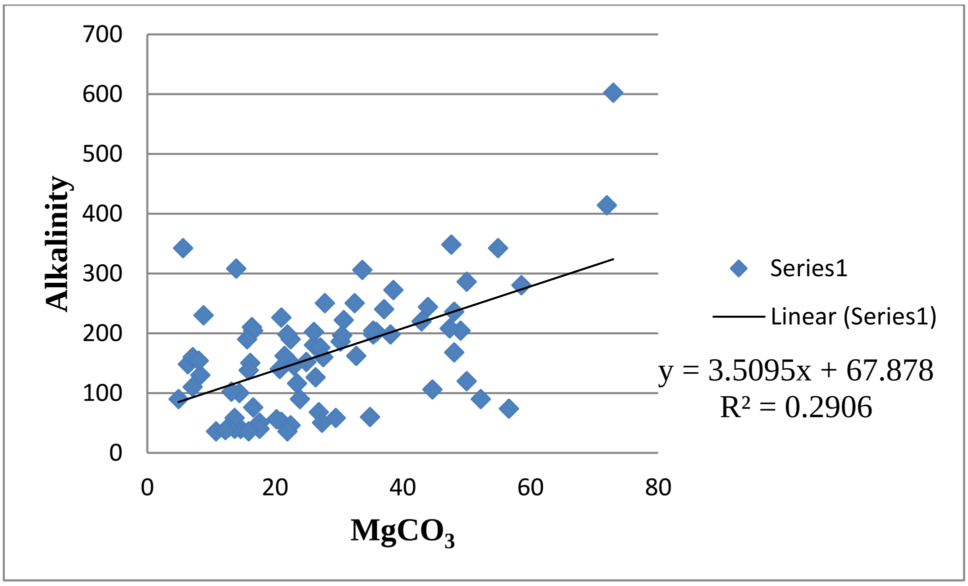

FIG.5: A graph of alkalinity and magnesium hardness

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that alkalinity is found dependent on the magnesium hardness, such that an increase in magnesium hardness is related to an increase in alkalinity.

This relation basically indicates that alkalinity and hardness changes depending on the pH or mineral content of the stratum.

Correlation between chloride and magnesium hardness

A graph of chloride and magnesium hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

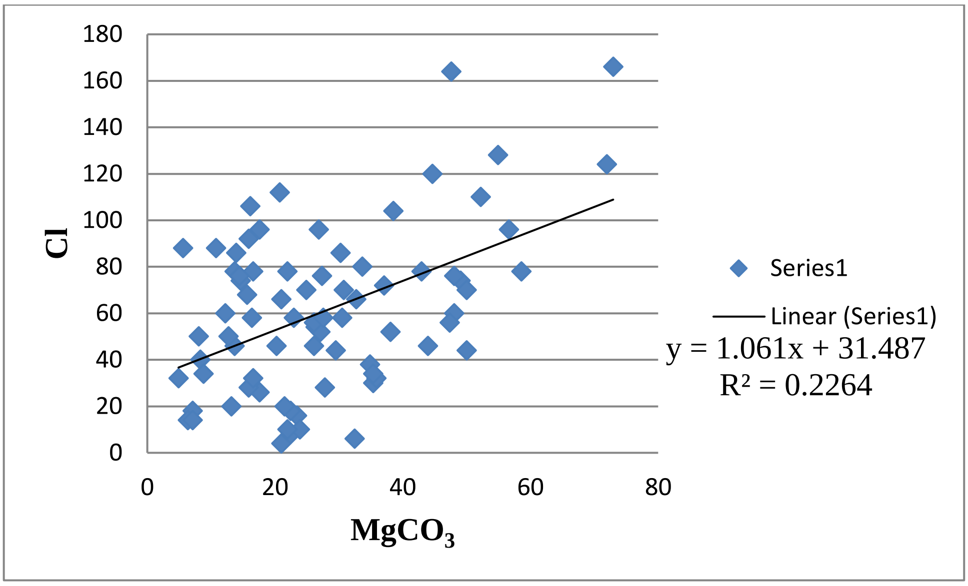

FIG.6: A graph of chloride and magnesium hardness

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that chloride is found dependent on the magnesium hardness, such that an increase in magnesium hardness is related to an increase in chloride.

This relation indicates the presence of magnesium carbonates and bicarbonates; and also magnesium chloride in the stratum of the study area.

Correlation between chloride and calcium hardness

A graph of chloride and calcium hardness in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

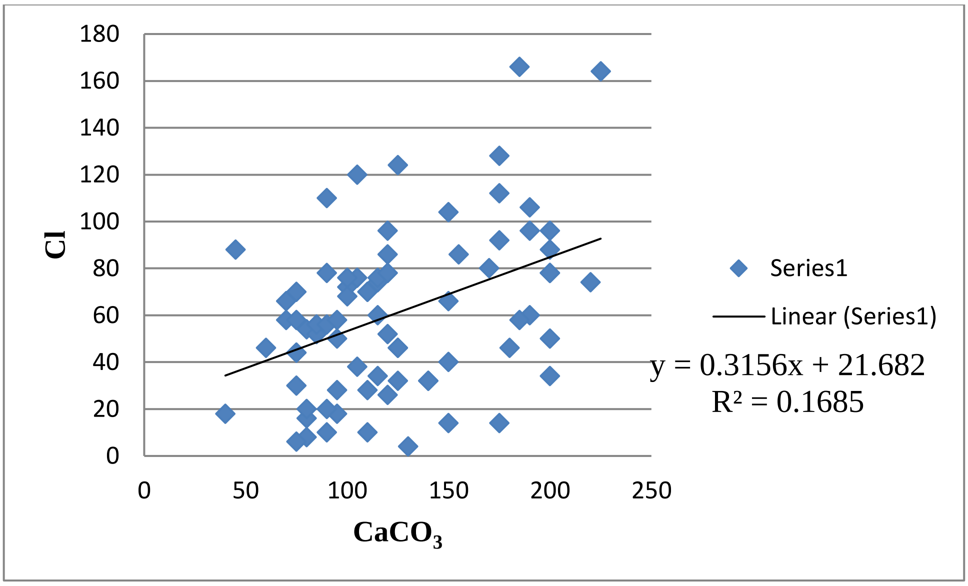

FIG.7: A graph of chloride and calcium hardness

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The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that chloride is found dependent on the calcium hardness, such that an increase in calcium hardness is related to an increase in chloride. This relation indicates the presence of calcium carbonates and bicarbonates; and also calcium chloride in the stratum of the study area.

Correlation between turbidity and iron contents

A graph of turbidity (NTU) and iron contents in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

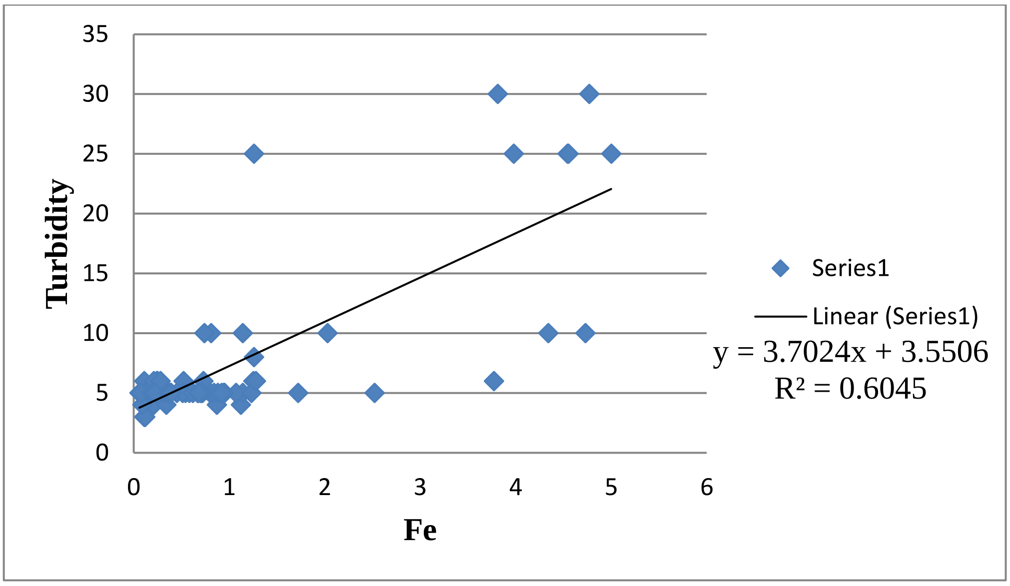

FIG.8: A graph of turbidity and iron contents

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that the turbidity is found dependent on the iron contents, such that an increase in iron contents related to an increase in turbidity. This relation indicates that iron in groundwater occurs in two forms Fe^{2+}, is very soluble and Fe^{3+}, will not dissolve appreciably may cause turbidity in the groundwater samples in the Nagaon town area.

Correlation between manganese and iron contents

A graph of manganese and iron contents in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

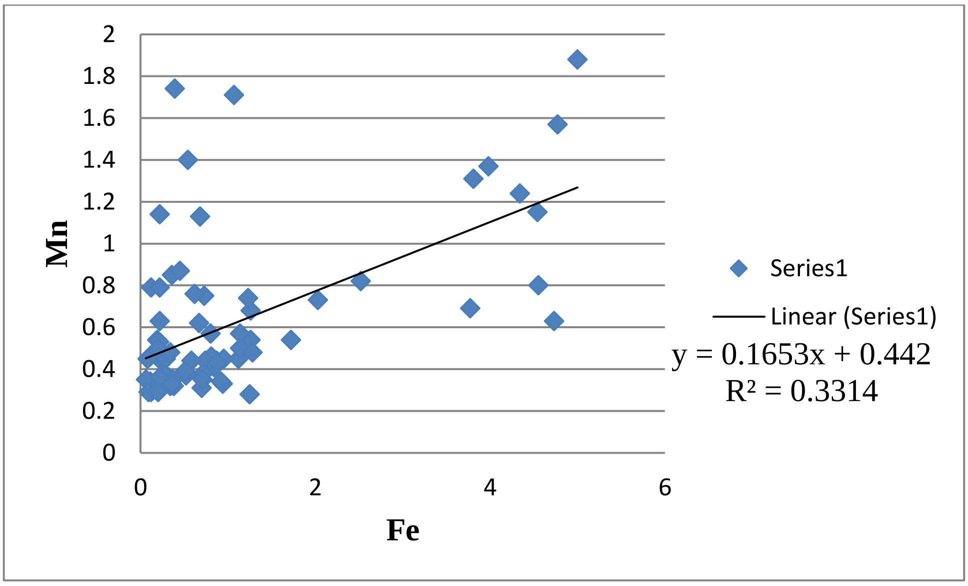

FIG.9: A graph of manganese and iron contents

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The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that Mn and Fe are correlated in the study area aquifer system. Since Mn is not found as a free element in nature; it is often found in minerals in combination with iron. From the analysis of the groundwater samples of the Nagaon town it is observed that the study area stratum have Fe and Mn minerals mostly so these two parameters in some sampling location have exceeded the permissible limits.

Correlation between magnesium hardness and iron content

A graph of magnesium hardness and iron content in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

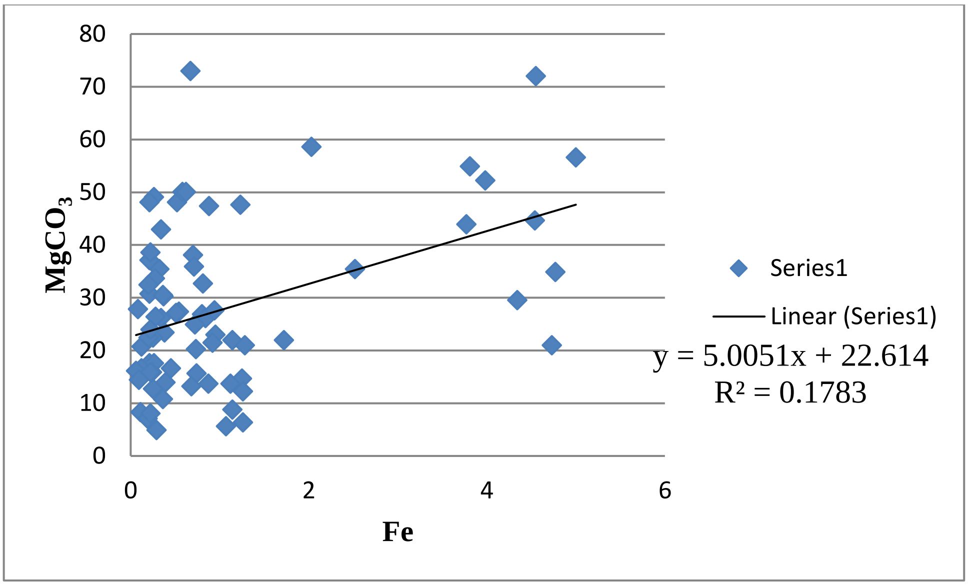

FIG.10: A Graph Of Magnesium Hardness And Iron Content

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.
From the graph, it can be seen that magnesium hardness and iron are correlated in the study area aquifer system. It is observed that an increase in iron is related to an increase in magnesium hardness.

Correlation between turbidity and manganese content
A graph of turbidity in NTU and manganese content in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

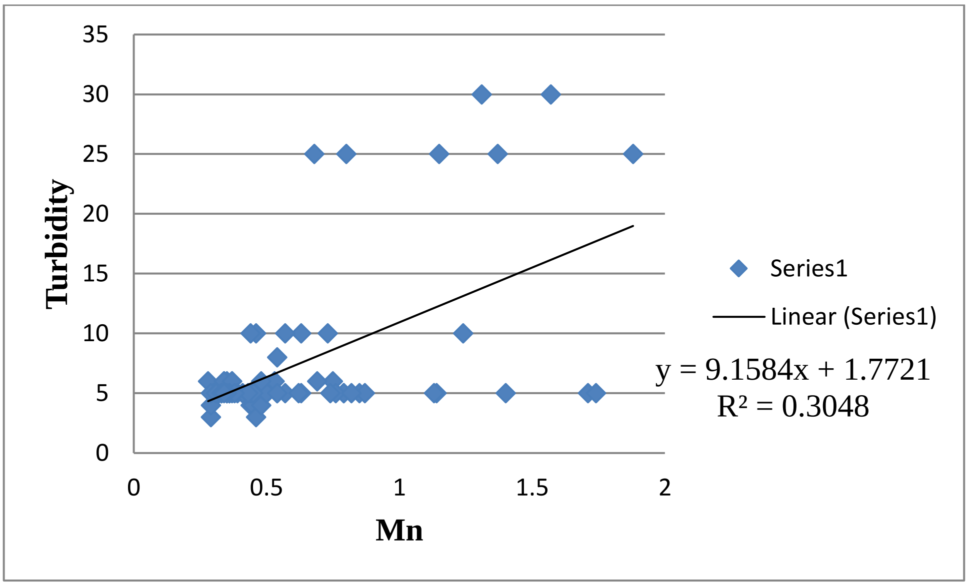

FIG.11: A graph of turbidity and manganese content

The plotted graph revealed a direct linear and positive relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

From the graph, it can be seen that turbidity and Mn are correlated in the study area aquifer system. It is observed that an increase in Mn is related to an increase in turbidity.

Correlation between pH and manganese content

A graph of pH and manganese content in mg/l of the groundwater samples is plotted to establish the relationship between the two variables.

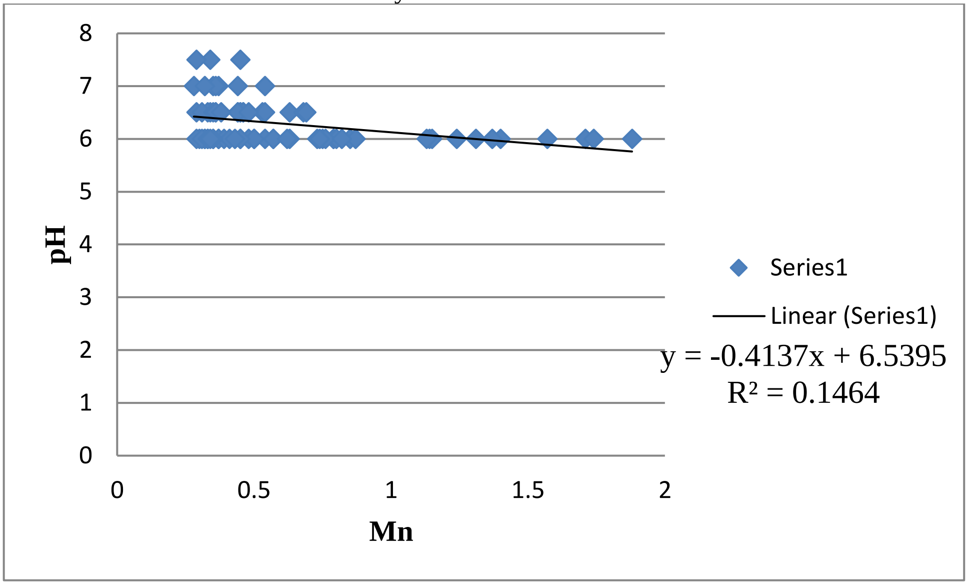

FIG.12: A graph of pH and manganese content

The plotted graph revealed a direct linear and negative relationship between the two variables. Linear regression was carried out to find the regression coefficient (R) value for the relationship.

As a negative correlation is found to exist between pH and Mn values, it can be said empirically that when Mn content in the groundwater increases, the value of pH decreases i.e. the water is acidic mainly in the study area.

In the current study it is evident from Table 5 that distribution of magnesium hardness $MgCO_3$, calcium hardness $CaCO_3$, chloride and alkalinity were significantly correlated ($R > .46$) with total hardness (TH). Alkalinity and chloride were significantly correlated ($R > 0.47$) with magnesium hardness $MgCO_3$. Turbidity, manganese Mn and magnesium hardness $MgCO_3$ were also significantly correlated ($R > 0.42$) with iron Fe. A high correlation value was observed between $MgCO_3$ and TH (R=0.78). A low negative correlation was observed between pH and Mn (R=0.38). A considerably low correlation was observed between turbidity and $MgCO_3$ (R=0.37) and Chloride and alkalinity (R=0.36). Fluoride F is negatively correlated with most of the water parameters and some parameters like nitrate NO_3 and F; $CaCO_3$ and NO_3 are insignificantly correlated. This is perhaps due to highly variable nature of chemical concentrations and minerals in the stratum of the study area. Finally, it can be concluded that the correlation studies of the water quality parameters have great significance in the study of water resources.

5. CONCLUSION

The statistical regression analysis has been found to be a highly useful technique. Finding linear correlation between various physicochemical water parameters can be treated as a unique step ahead towards the drinking water quality management. The mathematical models used to access water quality involve two parameters to describe realistic groundwater situations. This technique has been proven as a very useful tool for monitoring drinking water and has a good accuracy. A significant relationship obtained from a systematic correlation and regression in this study has been established among different pairs of physicochemical parameters. The method of linear correlation has been found to a significant approach to get an idea of quality of the ground water by determining a few parameters experimentally. It can be concluded that the iron, manganese, alkalinity, chloride, turbidity, total hardness and magnesium hardness are important physicochemical parameters of drinking water, because they are correlated with most of the water quality parameters in the study area. This study has revealed the facts that all the physicochemical parameters of drinking water in Nagaon town of Assam are correlated in some or the other ways. But iron Fe, manganese Mn, turbidity and total hardness TH are the parameters exceeding the permissible limits of the drinking water quality parameters in the study area and since groundwater is available in the study area through boring or tube well in shallow depth of 20 feet onwards so significant correlation of Fe, Mn, turbidity and TH with depth could not be established. Thus the study could be more enhanced by studying groundwater quality in more depth in the near future.

TABLE 6: Linear correlation coefficient and regression equation for some pairs of parameters which have significant value of correlation

Pairs of parameters	Regression equation	R square
$MgCO_3$-TH	$MgCO_3$ = -12.98 + 0.17TH	61.03%
Turbidity-Fe	Turbidity = 3.55 + 3.7Fe	60.45%
Cl-TH	Cl = -19.02 + 0.34TH	47.25%
Mn-Fe	Mn = 0.44 + 0.16Fe	33.14%
Turbidity-Mn	Turbidity = 1.77 + 9.16Mn	30.48%
Alkalinity- $MgCO_3$	Alkalinity = 67.88 + 3.51$MgCO_3$	29.06%
Cl- $MgCO_3$	Cl = 31.49 + 1.06 $MgCO_3$	22.64%
$CaCO_3$-TH	$CaCO_3$ = 53.18 + 0.3TH	22.22%
Alkalinity-TH	Alkalinity = 5.75 + 0.67TH	22.08%
$MgCO_3$-Fe	$MgCO_3$= 22.61 +5.01Fe	17.82%
Cl-$CaCO_3$	Cl = 21.68 + 0.32$CaCO_3$	16.85%
pH-Mn	pH = 6.54 – 9.16Mn	14.64%

TABLE 7: Comparison of the analytical results of 77 groundwater samples with I.S. 10500:2012

Sl. No.	Water quality parameter	Desirable limit	Maximum permissible limit	Samples below the desirable limit	Samples exceeding the desirable limit but within the maximum permissible limit	Samples exceeding the maximum permissible limit
1	Fluoride (F) in mg/l	1	1.5	75, 97.4%	2, 2.6%	0
2	Iron (Fe) in mg/l	0.3	1.0	27, 35.1%	29, 37.7%	21, 27.2%
3	Manganese (Mn) in mg/l	0.1	0.3	0	5, 6.5%	72, 93.5%
4	Nitrate (NO_3) in mg/l	<45	45	77, 100%	0	0
5	Alkalinity in mg/l	200	600	51, 66.2%	25, 32.5%	1,1.3%
6	Chloride (Cl) in mg/l	250	1000	77, 100%	0	0
7	Total hardness (TH) in mg/l	200	600	23, 29.9%	54, 70.1%	0
8	Calcium hardness (as $CaCO_3$) in mg/l	75	200	11, 14.3%	64, 83.1%	2, 2.6%
9	Magnesium hardness (as $MgCO_3$) in mg/l	30	150	48, 62.3%	29, 37.7%	0
10	Hydrogen-ion concentration (pH)	6.5-8.5	6.5-8.5	46, 59.7%	31,40.3%	0
11	Turbidity in NTU	1	5	0	53, 68.8%	24, 31.2%
12	Bacteriological parameter	Absent	Absent	74, 96.1%	3, 3.9%	0

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