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Assessment of ground water quality with special emphasis on As, F and Fe: A case study in Morigaon District, Assam, India

Bijoy Sankar Goswami*, Munmi Sarma and Hrishikesh Sarma

Department of Chemistry, B. Borooah College, Guwahati 781 007, Assam, India

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ABSTRACT

One of the main concern and a global challenge is the assessment of the quality of ground water. In the present work, water samples were collected from 23 different locations and the source was tube-wells, Dug wells respectively. The collected samples were analyzed with respect to general physico- chemical parameters, heavy metals and coliform bacterial contamination using established standard procedures. Most of the parameters are well within the specified limit as suggested by WHO, USEPA and IS:10500 except fluoride, iron, arsenic, manganese and lead content respectively. The fluoride content (1.66 mg/l - 4.2 mg/l) exceeded the tolerable limit (1.5 mg/l) at all the locations while iron concentration was ranged from 0.002 mg/l to 5.2 mg/l and tolerance limit (1.0 mg/l) prescribed by WHO was exceeded in six locations. The concentration of arsenic (2.22 µg/l to 19.77 µg/l) crossed the permissible limit (10 µg/l) fixed by US-EPA in only one site. Similarly the mean values of Mn and Pb exceeded their respective tolerance limit at specific locations prescribed by various organizations. The coliform bacterial contamination (0 – 450 per 100 mL) was also obtained in few of the water samples. Additionally, it was revealed by SAR studies that for irrigation purposes most of the ground water samples were excellent (<10). The present study revealed that the ground water quality was significantly contaminated with fluoride; iron, lead and to some extent manganese and bacterial load.

Key words : *Fluoride, Arsenic, Iron, Lead, Contamination, SAR*

Introduction

Water is one of the most important resources which are needed almost in all the aspects of human and ecosystem existence and health. After glaciers the largest resource for freshwater is the ground water. Vital role is played by ground water in the in socio-economic life of the people in Assam for horticulture, agriculture and domestic purposes. Normally it is considered that ground water is safe for drinking and its contamination is really a matter of concern because people drink ground water without any hesitation. Now a days it is not safe for drinking as the contamination causes epidemics of cholera, dysentery and other diseases.There are basically four categories in which humans are contaminating the ground water: (a)waste disposal practices (b)storage and handling of materials and wastes (c)agricultural activities and (d) saline water intrusion (Dalzell *et al.*, 1999). In India, one of the main and essential sources of ground water is sedimentary aquifers. Adverse effects of the pollution of water resources can be seen both on the human health as well as the Environment (Emmanuel *et al.*, 2009 ; Muhammad *et al.*, 2011).

Johnson (1979) and Sastri (1994) reported that unwanted along with soluble elements present in water are uncontrollable once they enter the ground. The hydrogeochemical differences in the groundwater occur due to percolation of surficial salts, Ion – exchange processes as well as the groundwater's residential time in the aquifer (S Krishna *et al.,* 2009; Sami, 1992).

The various chemical parameters associated with drinking water quality have considerable bad impact on the health of human beings either due to excessive intake or it can be due to deficiency. Though, the naturally occurring anions in water are nitrate (NO_3) and nitrites (NO_2) (Jordao *et al*., 2002) however, nitrate (NO_3) become toxic when it is reduced to nitrite. The nitrite toxicity in human health causes oxidation of the hemoglobin which is normal to methaemoglobin that reduces the oxygen's transportation to the tissues (Abdolmajid and Mehraban, 2014). Concentration of the heavy metals found in water can be in indorsed to both the sources like anthropogenic and geogenic. The primary considerable source of metals which actually finds a way to enter water or water bodies are ore deposits, weathering of rocks and various volcanic activities that results in release of metal (Muhammad *et al*., 2015). All the heavy metals like Cd, Cr, Co, Hg, Ni, Pb and Zn when have excessive assimilation in drinking water may cause cancer on human health (Abdolmajid and Mehraban, 2014; Muhammad *et al*., 2011; Muhammad *et al*., 2015). In order to assess the groundwater's geochemical effects, many studies were carried out and experiments were done in India along with few other countries across the globe (Kumar *et al.,* 2008; Krishna *et al.,* 2009; Garniel *et al*., 1999; Umar and Sami Ahmed, 2000). The present scenario showed that there is a dearth of study about the ground water quality in the different villages of Morigaon District. Therefore, this particular study is an endeavor to understand the potability status of water in different villages.

Materials and Methods

Study Area Description

Morigaon district in Assam is located at the geographic coordinate of 26°15'10.0"N latitude and 92°21'22.8"E longitudes. It is bounded by the mighty "*Brahmaputra on the North, Karbi Anglong district on the South, Nagaon District on the East and Kamrup District on the West*". The Pabitora wildlife sanctuary is also located in this district. The area occupied by the district is 1704 km^2 with a total population of 957853 that includes 485328 males and 472525 females (DCR 2011). The sex ratio of this district is 974 females for every 1000 males and 69.37% is the literacy rate. There are four seasons which are enjoyed by the inhabitants of this area and that are summer, autumn, winter and spring. The main profession of the people in this area is agriculture whereas few other professions considered in this study are livestock, scattered poultry, fish farms along with while bee. In terms of Industrial sectors, one small cements industry and significant number of brick fields are present in the study area. However, one paper mill is also close to the study area. In the present study the common sources for drinking water are Tube-wells, hand pumps and Dug wells.

Sampling of water samples

A meaningful chemical analysis largely depends on the sampling procedure. Tube-wells, hand pumps and dug wells were the various sources from where the water samples were gathered. Totally, 23 sites were selected for sampling (Fig. 1) and the sampling locations along with different ground water sources are shown in Table 1.

The samples for physical and chemical analysis were collected in pre-cleaned 1 L polyvinyl containers and brought immediately for the analysis. There were two ways of collecting sample at every point: i) when the water was filled in bottle having no air bubbles and acid. ii) Simultaneously, from the same site water was filled in another bottle and few drops of 5% HNO_3 were added to it in order to stop the microbial activities. In case of tube wells, for few minutes water was allowed to run and then was filled in bottle after reducing the flow and to get it done without splashing. Separate samples were collected at each point in sterilized bottle for microbial analysis. With all the important required precautions for sampling and preservation, samples were transported to laboratory and "analysis was done on the non- acidified samples for physical and chemical parameters while the acidified samples were actually used for the analysis of heavy metals.

Analytical Methods

All the chemical analysis was carried out as per standards procedure laid in APHA 21st Edition (2005). The basic parameters like pH content, electrical conductance (EC), total dissolved solids (TDS)

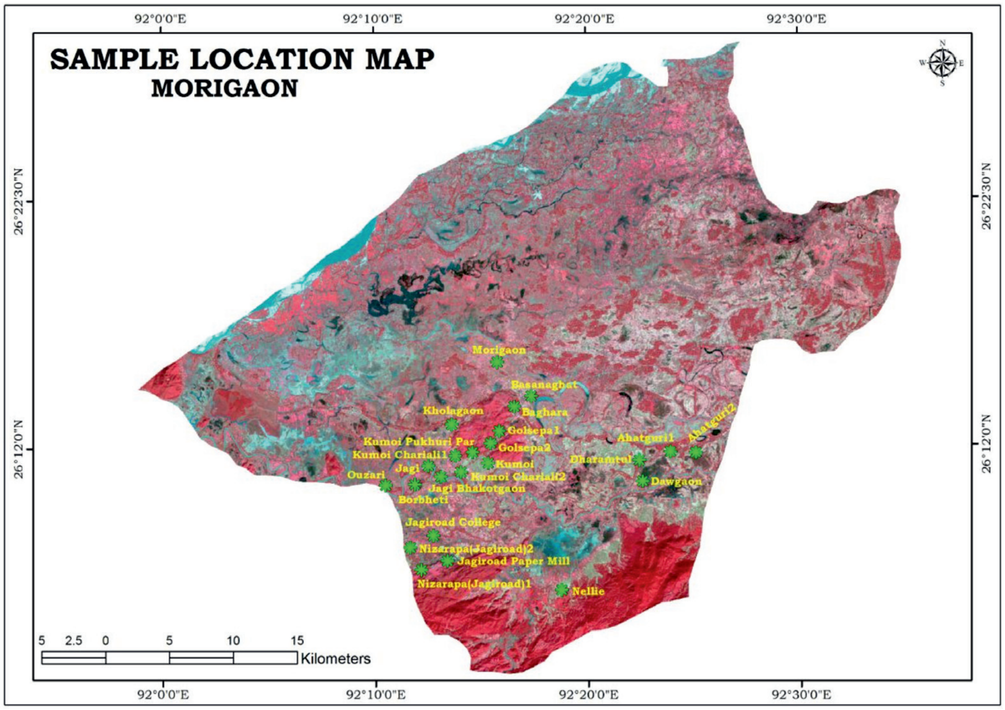

Fig. 1. Map of the Sampling Locations

were measured using Digital pH meter and conductivity meter (Hanna make). The titration method (APHA, 2005) was adopted for determining hardness and chloride (Cl^-) content. In the present study the anionic constituents such as sulphate, phosphate, nitrate and fluoride were measured in each water samples with UV-visible spectrophotometer (Agilent Cary-60). Major cations were measured with the help of digital flame photometer (Elico model CL -361). The heavy metal contents As, Fe, Cu, Pb and Mn were measured in atomic absorption spectrophotometer (Agilent Spectra AAS-240 with Hydride generation attachment). Standard method (MPN method) was used to count the Total coliform bacteria as maximum probability number (APHA, 2005).

Results and Discussion

General hydrogeochemistry: The outcomes of the general physico-chemical characteristics along with basic statistics and various drinking water standards were summarized in Table 2. The observed variation in the temperature ranged from 26^0C to 28

Table 1. Drinking Water Sampling Locations

S/ N	Locations	Sources	S/ N	Locations	Sources
S1	Ahatguri 1	Tubewell	S13	KumoiChariali 2	Ring Well
S2	Ahatguri 2	Tubewell	S14	Kholagaon	Tubewell
S3	Dawgaon	Tubewell	S15	Golsepa 1	Ring Well
S4	Dharamtul	Ring Well	S16	Golsepa 2	Ring Well
S5	Nellie	Tubewell	S17	Baghara	Tubewell
S6	Jagiroad Paper Mill	Tubewell	S18	Ouzari	Tubewell
S7	Nizarapar (Jagiroad) 1	Tubewell	S19	Basanaghat	Tubewell
S8	Jagiroad College	Tubewell	S20	Jagi	Tubewell
S9	Nizarapar (Jagiroad) 2	RingWell	S21	Morigaon	Tubewell
S10	KumoiPukhuri Par	Tubewell	S22	JagiBhakotgaon	Tubewell
S11	Kumoi	Tubewell	S23	Borbheti	Tubewell
S12	KumoiChariali 1	Tubewell			

°C. Almost all the samples were colour less excepting few brown in colour may be because of the presence of dissolved iron. Ground water becomes turbid in nature due to of the presence of slits and suspended solids, (Krishna Kumar *et al*., 2009). The pH values varied between 6.1 and 7.4 with 6.7 mean values along with standard deviation (SD) 0.39 showing slightly acidic to Alkaline. No significant relationship appeared between pH and any one of the other parameters in the present work. Even though there were no direct adverse effects of pH on the health of human but somehow it is associated with several other chemical components of water (Muhammad *et al*., 2015). It has been reported that on clay surface adsorbed of fluoride was noticeable particularly in acidic water while desorbed from solid phase in alkaline water (Narsimha and Sudarshan, 2017). It was observed that 21.7% sample below the permissible level and rest within the limit (6.5 – 8.5) as suggested by IS: 10500. The presence of ionic component is considered as conductance; it varied from 1.002 mS/cm to 1.149 mS/cm with 1.0mS/cm mean value and SD 0.03. Total dissolved solids (TDS) content widely varied from 62.2 mg/l to 633 mg/l with 361.2 mg/l as an average value and 131.6 SD. TDS was well within the specified limit of 500 mg/l excepting only one sample. If the TDS concentration exceeds the tolerance limit recommended by WHO, USEPA and ISI standards that declares the groundwater inappropriate for drinking as well as domestic purposes (S Krishna *et al*., 2009). Because of the presence of multivalent metallic cations, hardness of water is caused by the calcium and magnesium. Hard water is very useful in the overall growth of kids if within the tolerance limit. It varied from 44mg/l to 364 mg/l with 157.8 mg/l as an average value and SD 73.1. The hardness content in drinking water can be characterized on the basis of $CaCO_3$ concentration as soft if hardness <75 mg/l, medium if 75 – 150 mg/l, hard if 150 – 300 mg/l and very hard if hardness >300 mg/l. It was observed that only 8.7% exceeds the specified limit of 300 mg/l.

Major Cation Chemistry

Ca, Mg and Na concentration enrich in ground water due to the presence of clay minerals that includes montmorillonite, illite and chlorite (S Krishna *et al*., 2009). The calcium content was wide-ranging from 14 mg/l to 127 mg/l with 47.6 as an average value and 27.0 SD. The magnesium content ranged between 1.94 mg/l and 38.0 mg/l with 9.8 mg/l as mean value and SD 7.4. The existence of calcium along with magnesium ions particularly in groundwater is predominantly derived by percolation of limestone and dolomites; however the calcium ion may also be derived from cation exchange process (S Krishna *et al*., 2009). The calcium concentration

Table 2. Basic Statistics of the Drinking Water Quality [All parameters are in mg/l except conductance in mS/cm and As in µg/l]

Parameters	This Study			Drinking Water standards by different organizations			
	Min	Max	Mean	SD	WHO	US EPA	IS:10500
pH	6.1	7.4	6.7	0.39	6.5 -8.5	6.5 -8.5	6.5 -8.5
Conductance	1.0	1.1	1.0	0.03			
TDS	291.8	633	361.2	131.6	500	500	500
Hardness	44	354	157.8	73.1	500	-	200
SO_4^{2-}	4.4	64	19.0	15.9	200	250	150
PO_4^{3}	0.001	3.1	0.25	0.65	-	0.1	-
NO_3^-	0.01	0.87	0.19	0.19	45	10	45
F^-	1.66	4.2	2.07	0.57	1.5	1.0	1.5
Cl^-	8.52	156.2	38.9	37.4	200	250	250
Ca^{2+}	14.42	127.4	47.6	27.0	75	-	75
Mg^{2+}	1.9	38.5	9.8	7.4	<30	-	30
Na^+	8.3	215.5	56.2	52.6	200	-	-
K^+	3.2	90.6	21.0	27.4	12	-	-
As	BDL	19.8	1.9	4.2	10		10
Fe	0.002	5.3	1.1	1.6	0.3	0.3	0.3
Cu	0.006	0.26	0.03	0.05	1.0	1.0	0.05
Pb	0.14	0.46	0.27	0.07	0.01	0.05	0.1
Mn	BDL	3.78	0.47	0.81	0.05	0.05	0.1

was exceeded the maximum permissible limit of 75 mg/l in few locations while magnesium concentration was well within the specified limit (30 mg/l). Again the highest sodium content was appeared 215 mg/l while lowest 8.3 mg/l with an average value of 56.2 mg/l and SD 52.6 and in only one location exceeded the permissible limit (200 mg/l). Similarly the potassium concentration was also widely varied; it ranged between 3.2 mg/l and 90mg/L with 21.0 mg/l as mean value and 27.4 as SD. 34.8 % of total sample exceeded the permissible limit (12 mg/l). It is expected that the rock salt dissolution or weathering of sodium bearing minerals is the main source of increased concentration of sodium in ground water (S Krishna *et al.,* 2009; Narsimha and Sudarshan, 2017). Na/Cl ratio approximately should be 1 when the halite dissolution process is accountable for the sodium, whereas the Na/Cl ratio greater than 1 which actually shows that from silicate weathering, sodium was released (Krishna *et al*., 2009; Meyback, 1987). The current study shows that 74% samples have Na/Cl ratio is >1. However in Six samples such as Sample 4, 6, 14, 15, 17 and 20 have Na/Cl ratio < 1 and it may be concluded that because of ion exchange process there is a noteworthy reduction in concentration of Na (Krishna *et al*., 2009).

Major Anion Chemistry

The current study shows that there was a variation in the concentration of sulphate (4.4 - 64 mg/l) with 19.0 mg/l as average value and 15.9 SD. It was well within the permissible limit of 200 mg/l. The primary means for the increase in non – point pollution is the usage of huge amount of fertilizer along with the pesticide which results in increased concentration of sulphate (Surindra *et al.,* 2009). The high value of sulphate could be due to fertilizer and the defuse leachates. Sulphate can also get into natural water due to chemical weathering of rocks and soils and biochemical oxidation of sulphur compounds in the water (Elango *et al*., 2003; Jeevanndam *et al*., 2006). The phosphate content was ranged from 0.001 mg/l to 3.1 mg/L with an average value of 0.25 mg/l along with SD 0.65. The presence of nitrate concentration ranged between 0.01 mg/l and 0.87 mg/l having the mean and SD value of 0.19 mg/l. Generally incomplete microbial reduction of nitrate generates nitrite while ammonia produced from the geogenic degradation of organic matter in the ground water (Jorg *et al*., 2017). The nitrate content was also appeared within specified limit of 45 mg/l. The key source of nitrates in soil is the nitrogen containing substances such as agro fertilizer and domestic waste (Krishna *et al*., 2009). Jorg *et al*. (2017) reported that nitrate toxicity can cause colorectal cancer, bladder cancer and adverse effect on various reproductive issues. The fluoride content was ranging between 0.98 mg/l and 4.2 mg/l with 2.07 mg/l average value and SD 0.57. There was no significant relationship observed between fluoride and any one of other parameters under study. Because of the presence of fluoride bearing minerals in the host rocks and interaction of theirs with ground water causes the presence of fluoride in ground water. Fluoride accumulation in ground water in different areas varies according to the geological formation of the area, amount of rain fall and quantity of water loss for evaporation. It has been observed that almost all the sample exceeds the WHO, IS10500 specified limit of 1.5 mg/l. It is widely accepted that persistent water – rock interaction may enrich the content of fluoride in ground water. There are many factors on which the concentration of fluoride in ground water depends – climate condition, evaporation, precipitation and geomorphology of the particular area. The excessive intake of fluoride contaminated water causes major health problems – dental fluorosis, skeletal fluorosis, bones distortion in adults and children (Narsimha and Sudarshan, 2017). Similarly the chloride concentration ranged (8.52 – 156 mg/l) with 38.9 mg/l as an average value and SD 37.4. Chloride increases with

Table 3. Water quality classification based on SAR and Na% values of the study area

SAR (Sodium Absorption Ratio)	Water Class	Sample Location Numbers
<10	Excellent	All Samples
Based on Na%		
20	Excellent	All samples except one
21 - 40	Good	13
41 - 55	Poor	
50 - 70	Very Poor	

the increasing degree of eutrophication (Mahananda *et al*., 2010). The locations which have higher values are indication of organic waste in higher quantities compared to other locations. The chloride content may enrich in ground water due to weathering or due to the flow of irrigation wastage and dissolution of salt deposits (Krishna *et al*., 2009). The excess of chloride content may harm the metallic pipes, or structures along with agriculture crops (Krishna *et al*., 2009). It was well within the specified limit of 250 mg/l.

Heavy Metal Contents

Table 2 revealed that arsenic (As) concentration was varied from below detectable level (BDL) to 19.8 $\mu g l^{-1}$ with a mean value of 1.9 $\mu g\ l^{-1}$ and SD 4.2. Almost all the sample was well within the specified limit (10 $\mu g l^{-1}$ as suggested by ISI 2012, WHO) except the sample 13 which was collected from the village Kumoi Chariali 2. It has been reported that even if the trace amount of arsenic, it causes various conditions of disease which may include dermatitis, stomach aches, nerve injury and cancer, diabetes and hearing loss (Tchounou *et al*., 2012; Izah *et al*., 2015; Maduabuch *et al*., 2007; Jarup, 2003). Higher concentration of As have adverse impact on organs like liver, skin, bladder as well as kidney (Izah *et al*., 2015; Jarup, 2003). The iron concentration was ranged (0.002 - 5.3 mgl^{-1}) with a mean value of 1.1 mgl^{-1} and SD 1.6. It has been observed that 21.7% sample exceeded the permissible level of 1 mgl^{-1}. The spatial variation of distribution of iron is exhibited in Fig. 2. At iron concentration more than 10 mgl^{-1}, insoluble suspension was created by Fe(III) with tannin along with phosphates called hazes or cases (Paleologos *et al*., 2002). Hemochromatosis is caused by iron contaminated drinking water and it has symptoms like chronic fatigue, cirrhosis, arthritis, diabetes, sterility, thyroid diseases, and heart diseases. Further, Fe toxicity can cause persistent hepatitis infection B or C. It can also cause "malignant tumors, colorectal, liver, lung, stomach and kidney cancers" (Huang, 2003). The lead (Pb) content varied from 0.14 mgl^{-1} to 0.46 mgl^{-1} with mean value 0.27 mg/l and SD 0.07. All the sample was exceeded the specified limit suggested by WHO and USEPA (0.01 mgl^{-1}; 0.05 mgl^{-1}). For the samples which were collected from village Ahatguri 2, the concentration of Pb was found to be Minimum (0.14

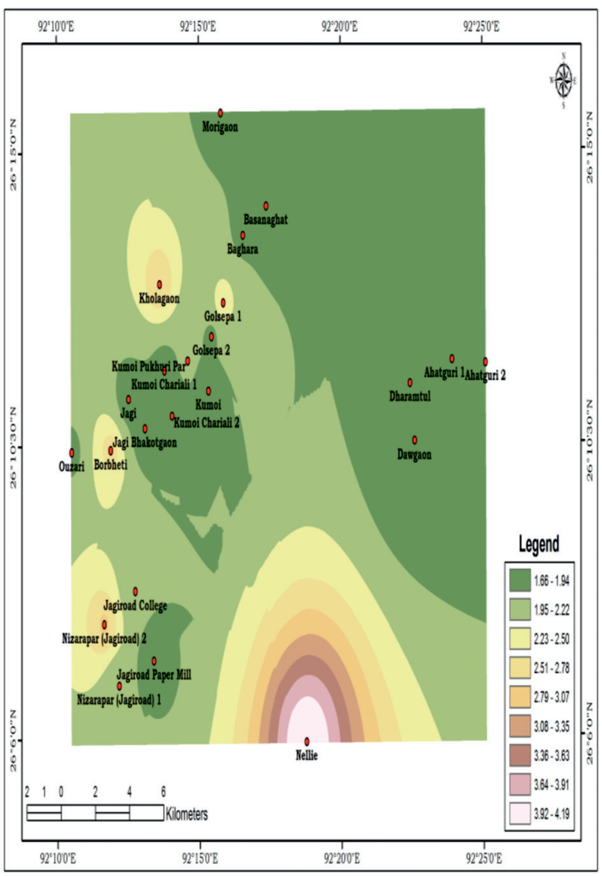

Fig. 2. Spatial Variation of Distribution of Fluoride

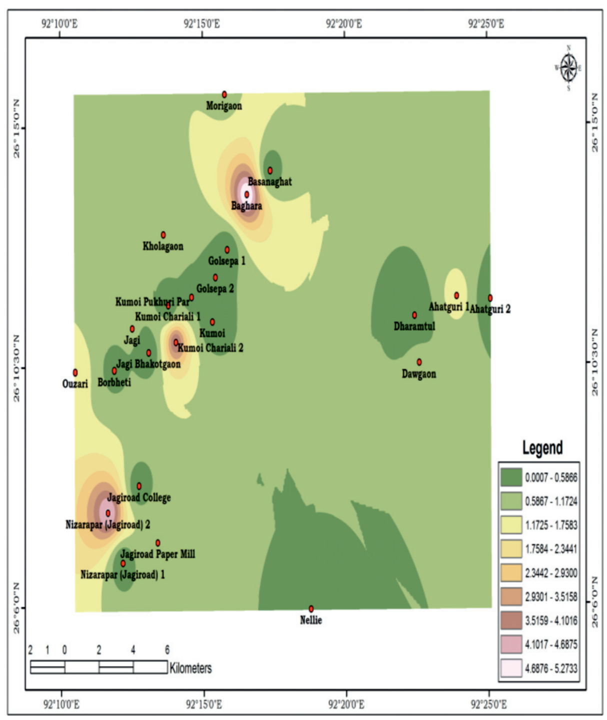

Fig. 3. Spatial Variation of Distribution of Iron

mgL^{-1}) while the maximum concentration (0.46 mgL^{-1}) was found in the village Golsepa 1. Fig 3 represents the spatial variation of distribution of lead. Leaching from plumbing system and transportation is mainly responsible for Pb contamination of drinking water especially in urban areas (WHO, 1996; Clement *et al*., 2000). The exceeding tolerance limit of Pb may cause several adverse impacts on human health such as neurological, behavioral, tiredness, slight abdominal discomfort effects (Lehloesa and Muyima, 2000; WHO, 1993; Gerlach *et al*., 2002). Acute Pb toxicity in child may cause major neurological injury, failure of organs, coma and finally death (Sardar Khan *et al*., 2013). USEPA (1991) reported that Pb accumulate in the various parts of the human body such as bones, kidneys, Brain and few other important organ. It is also reported that lead poisoning at times can have no symptoms or there can be few symptoms like vomiting, mimic flu, poor appetite, fatigue, constipation, gastrointestinal diseases, sleep disorder and irritability (Sardar Khan *et al*., 2013). The manganese concentration ranged (BDL - 3.8 mg l^{-1}) with 0.47 mg $^{-1}$ as a mean value and SD 0.81, where 47.8% exceeded the specified limit of 0.1 mgl^{-1}. Deficiency of Mn can cause osteoporosis, epilepsy and diabetes mellitus while excess manganese can result in neurological toxicity (Iweala *et al.*, 2014; Iwegbue *et al.*, 2013). The copper (Cu) content was lying between 0.006 mg/l and 0.264 mg/l with 0.03 mg l^{-1} as a mean value and SD 0.05. It was well within the specified limit of 0.5 mg l^{-1}. The spatial distribution of copper is shown in Fig. 4. Cu concentration exceeding the tolerance limit may leads to cause poisonous effects on humans body particularly to the gastrointestinal system (Salako *et al*., 2016) Whereas hypertension, hypercholesterolemia and increased low density lipoproteins can be the result due to deficiency of Cu (Iwegbue *et al*., 2013).

Microbial contents

In the present work**,** out of 23 samples, only four samples (SN-7, 14, 16, and 17) had shown the positive confirmed coliform test by the appearance of typical coliform colonies with dark centers and metallic sheen (Fig. 5 - 6). Further production of acid and gas after incubated in lactose broth and presence of gram negative rod also clearly indicated that the samples were contaminated with coliform bacteria. The MPN coliform count for these samples was (SN 7: 150; SN 14: 250; SN16:460; SN17: 23 MPN/100 m l) and it was considerably exceeded the tolerance limit of drinking water (0 per 100 ml) set by Pak-EPA (2008) (Khan *et al*., 2013).

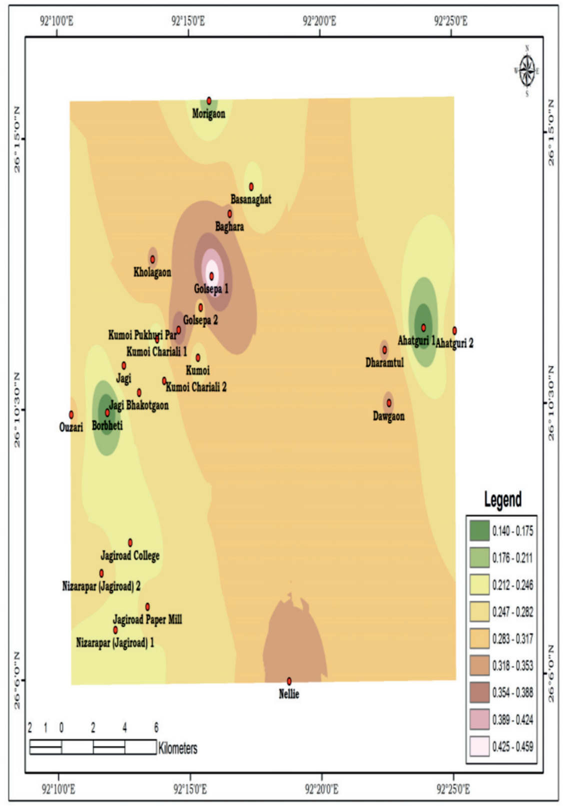

Fig. 4. Spatial Variation of Distribution of Lead

Correlation matrix

Correlation matrix study is used to find out the strength of the relationship between the two independent variables. The limits of the correlation coefficient (r) are +1 to -1 (r = +1, Perfect positive correlation; r = 0, no correlation and r = -1, perfect negative correlation). In this present study significant **(r** $\leq$ 5) positive correlations has been obtained for the following pairs using the mean values of physicochemical parameters as shown below-

Pair of Parameters	Linear Correlation Coefficient (r)
TDS and Hardness	+ 0.84
TDS and Calcium	+ 0.87
TDS and Chloride	+ 0.86
TDS and Sodium	+ 0.75
Phosphate and Nitrate	+ 0.55
Sodium and Chloride	+ 0.72
Hardness and Calcium	+ 0.83
Hardness and Sulphate	+ 0.52
Sodium and Calcium	+ 0.62

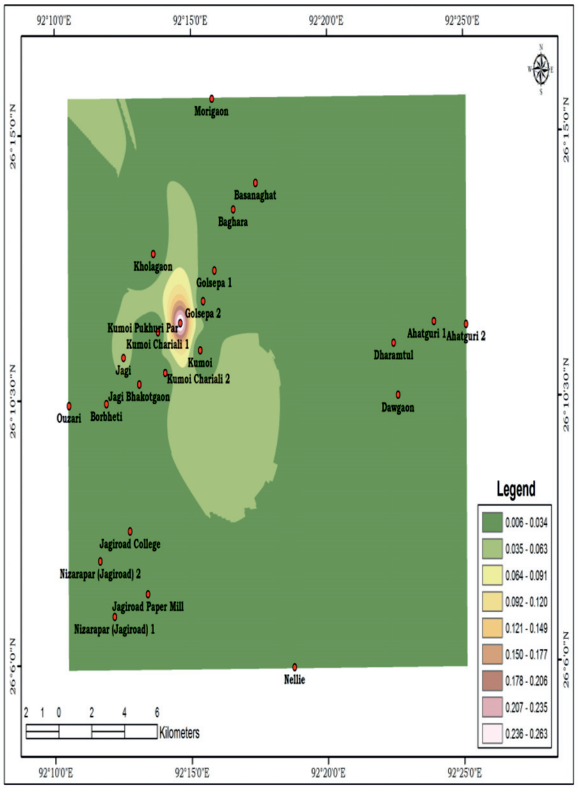

Fig. 5. Spatial Variation of Distribution of Copper

Calcium and Chloride	+ 0.67
Magnesium and Phosphate	+ 0.78

Good positive correlations between various parameters indicated that these constituents have a tendency to occur together and expected to have come from similar sources such as point sources (municipal and industrial waste) or non-point sources (agricultural runoff, soil leaching etc.).

Sodium Absorption Ratio (SAR) and Na%

Classification of ground water quality in terms of

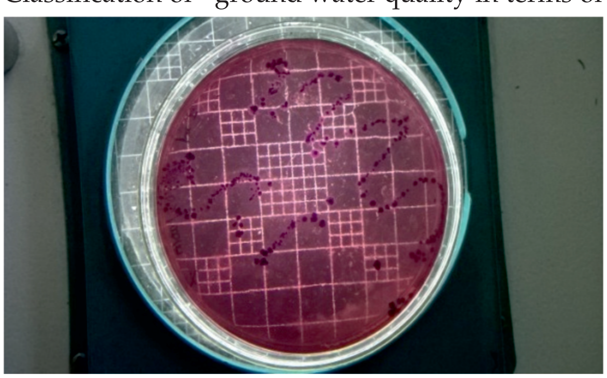

Fig. 6. Coliform colonies with dark centre

sodium absorption ratio (SAR) and sodium percentage (Na %) are presented in Table 3. The sodium absorption ratio as well as concentration of sodium is one of the essential parameters to assess quality of water being used for irrigation purpose (Krishna *et al.*, 2009; Todd 1980; Domenico and Schwartz, 1990). Under-given equation was used to calculate the SAR values:

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

Table 3 revealed that according to the SAR values all the ground water samples were excellent for irrigation purpose (SAR<10). Further, depending on Na%, the sodium hazards are very low, and all the ground water samples except one (sample no.13) can be used for irrigation on most crops .The spatial distribution of SAR is shown in Fig. 7.

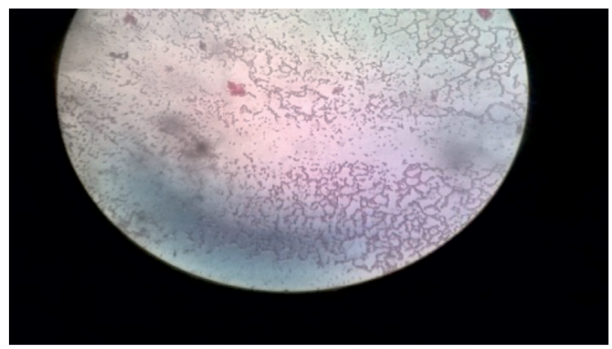

Fig. 7. Gram staining : negative rod of bacterium

Conclusion

Based on the findings, a good number of ground water sources are dominated by fluoride contamination. In case of heavy metals, arsenic was appreciably present in most of the samples but significant contamination appeared for lead concentration. The iron and manganese content were also considerably high in most of the cases. Coliform bacteria also played a significant part in the contamination of ground water in various locations. Almost all the samples were excellent in terms of SAR and Na% values. The results showed that the overall water quality of Morigaon district is not satisfactory for drinking purposes with respect to the fluoride, iron, manganese, lead and bacterial contamination. Improper sanitation, anthropogenic input, large use of agro fertilizer may alter the geochemical composition of ground water in the study area. Hence Morigaon district administration should initiate the activities in terms of creating awareness program, educating mass on toxicity of various water quality parameters, citing and care, use of boil water for drinking and improving general sanitation to safeguard the health of the residents.

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