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The Maiganga Coal Mine Drainage and Its Effects on Water Quality, North Eastern Nigeria

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Abstract

A hydrogeological study was carried out in Maiganga and environ, Gombe State. The aim of the research was to determine the major, trace, and rare earth elements content in effluent discharge from the coal mine and its effect on groundwater and surface water bodies used for drinking and other uses. Twenty five water samples from different sources (2-hand dug wells, 1-Formation water, 1-mine pond, 2- boreholes and 20 drainage channel samples) were collected and analyzed. Analyses of the samples were done at ACME Laboratories Vancouver, Canada and Geology and Mining Department, University of Jos. The combined ICPAES/ICPMS were used to analyze the major cations, trace and rare earth elements; Ion Chromatography was used to detect the anions and bicarbonate by titration method. Analysis of coal shows the following results of trace and rare earth elements: Cu – 1.4 mg/l, Zr – 0.54 mg/l, Zn – 0.2 mg/ l, Ni – 0.08 mg/l, V – 0.34 mg/l, Rb – 0.05 mg/l, Fe – 0.054 mg/l, while the results of As, Sn, Th, Te W, and the others trace and rare earth elements are below detectable limits. Low values of these elements in both the groundwater and the stream channel around Maiganga village shows little or no influences of effluent discharge on these water bodies. The pH range of 7.3 – 9.2 in the drainage channel indicates that the water is neutral to alkaline; and this was due to the neutralization effect of calcium carbonate on sulphate from the pyrite mineral in the coal, whose sulfur and iron content are very low. All values for physical and chemical parameters in the other sources of water are within the W.H.O maximum permissible limit for drinking and livestock uses.

Introduction

Mine drainage often comes from areas where ore or coal mining activities have exposed rocks containing pyrite and sulfur bearing minerals. This includes the mining of copper, gold, silver, zinc, lead and uranium. The resulting runoff is usually acidic and is expressed by

$(2FeS_{2(s)} + 7O_{2(g)} + 2H_2O_{(l)} = 2Fe^{2+}_{(aq)} + 4SO_4^{2-}{}_{(aq)})$.

The runoffcan further dissolve heavy metals such as copper, lead, mercury, and manganese into surface and ground water. Hence, acid mine drainage may contain elevated levels of potentially toxic metals, especially nickel, and copper, lead, arsenic, aluminum, and manganese. In addition, liquids that drained from coal stocks, coal handling facilities, and even coal wastes can be highly acidic, and in such case they may be treated as acid mine drainage. Acid mine drainage can occur long after mines have been abandoned, if piles of wastes are in contact with air and water. The red color often seen in streams receiving acid mine drainage is actually a stain on the rocks or water.The coal mine at maiganga, Gombe State – Nigeria has been in operation for close to twenty years now. The coal is used to

Location, Areal Extent and Accessibility of the Study Area

The study area is in Akko Local Government Area of Gombe State (Fig.1) and lies within Latitudes 11^o 08^0 47^{00} and $11^0 12^0$ 18^{00} and Longitudes 9^0 50^1 13^{11} and 10^0 oo^0 00^{00} on a scale of 1:50,000 Kaltungo NW, sheet 173.The study area cover an area of $10km^2$. The area was generally accessible by a major road from Gombe to Kumo and a secondary road from Kumo to the Maiganga coal mine (Fig.2). Minor roads and footpaths link the various villages, settlements and farm locations.

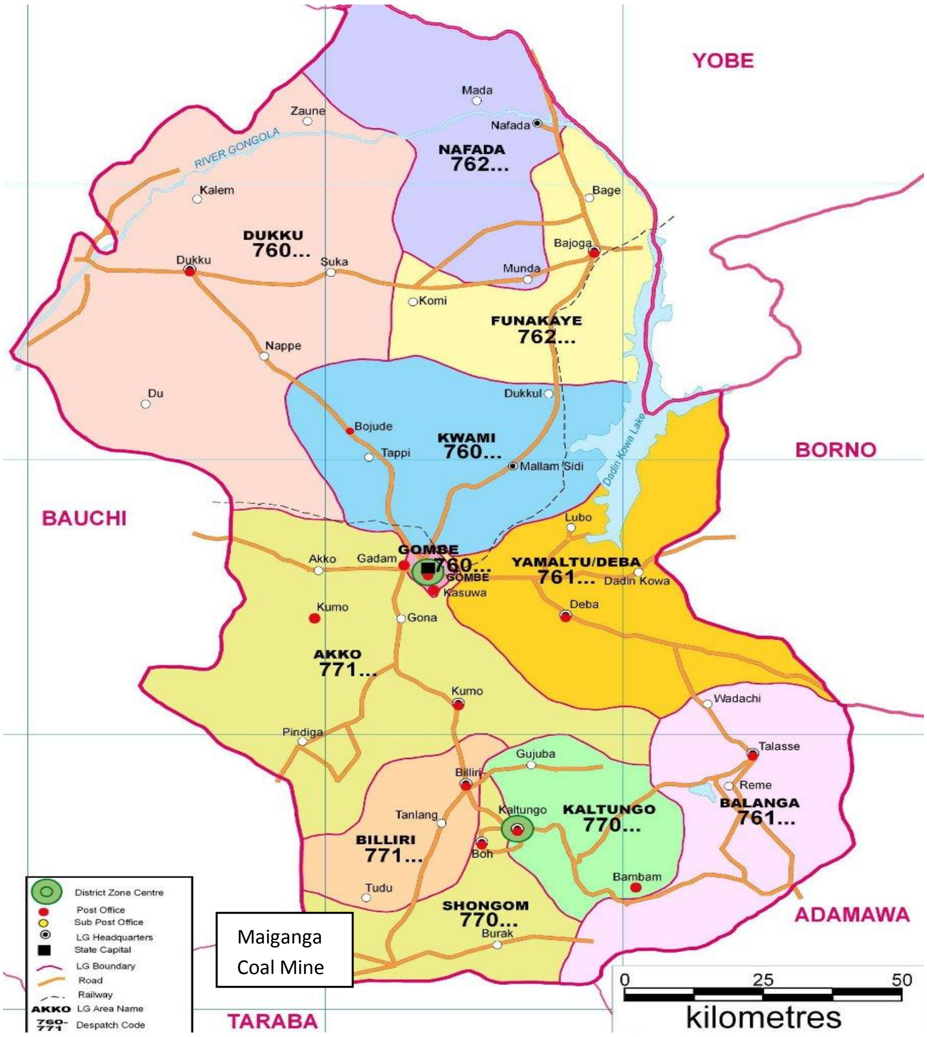

Fig1: Location Map of Gombe State showing Local Government Areas.

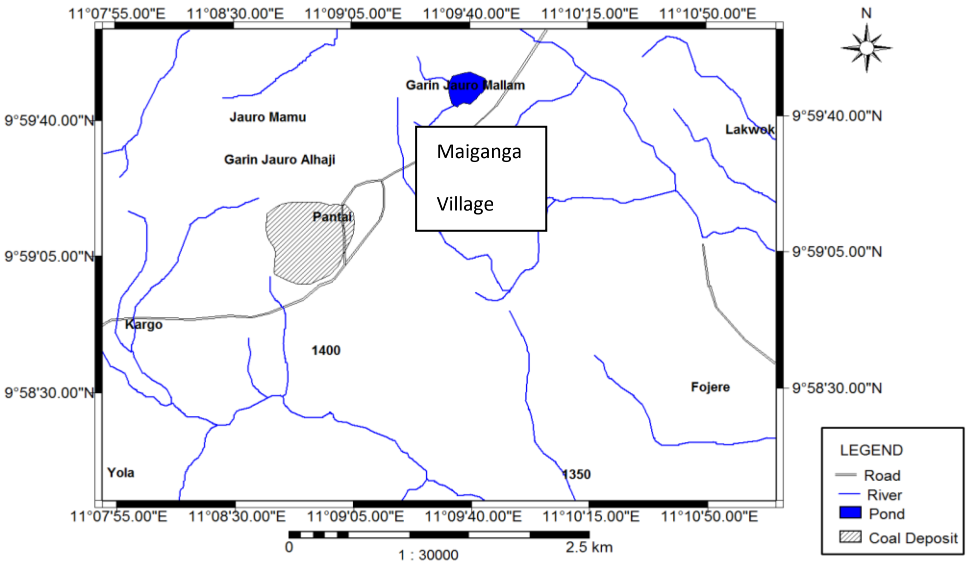

Fig.2: Location, Accessibility and Drainage Map of the Study Area

Geology of the study area

The study area is part of the eastern NE-SW trending Gongola arm of the Upper Benue Trough. There are two major rock formations in the study area; these are Gombe sandstones which occupies NE-SW part of the area and the Pindiga Formation which is on the southern part of the study area. The Pindiga Formation forms the plain on which the Gombe sandstone is resting unconformably (Fig.3). There were no noticeable outcrops andstructural features as the area has been ploughed for farming activities.

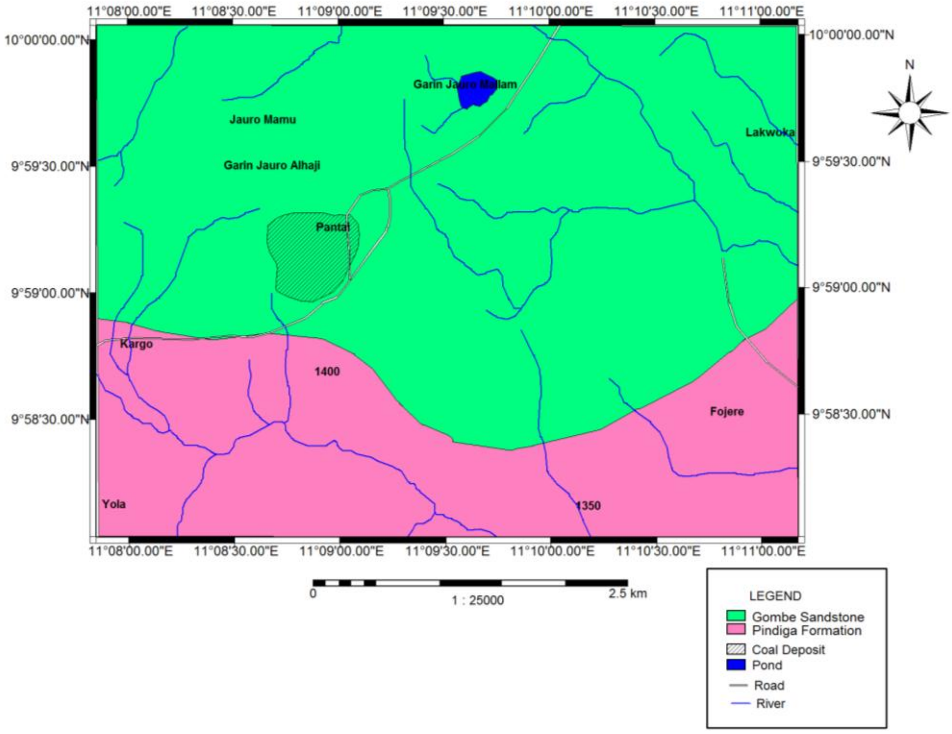

Fig.3: Geologic Map of Maiganga Coal

Methodology

Field sampling: Water samples were collected from different sources (wells, stream channels and bore holes) depending on availability. Water samples were collected within the coal mine and along the drainage channels. Water samples were collected at 300meters interval along the major drainage channels (Fig.4). Before the water sampling exercises 25ml plastic bottles were washed thoroughly with distilled water and with sample water severally before taking the water samples in order to ensure that sampling bottles were not contaminated. Two samples each were collected at every sampling point. The samples were filtered with a UNICEF standard filter to make samples free from suspended particles. One sample was acidified with two drops of concentrated pure nitric acid to a pH of < 2 for the samples that were used for the detection of cations. This is to help prevent or minimize precipitation and adsorption of certain cations on the wall of the containers and to hinder bacterial growth. Water samples were also collected in wells and boreholes in the surrounding Villages and in water pits dug along the drainage channel with a clean plastic container tied to a plastic rope (Davies, 1994). Boreholes samples were pumped for several minutes with the view that existing water standing in the holes should be pumped out so as to sample water freshly coming within the aquifer. At every sampling point co-ordinates of water sources were taken accordingly as the case may be using Geographical Positioning System (GPS). Well depths were measured using a graduated plastic tape; this was not possible for the borehole as there was no depth probe for the exercise. Physical parameters- temperature, total dissolved solid (TDS), electrical conductivity

(EC), and pH for all the samples were determined in the field using Oakton 5/6 pH/temperature meter and TDS and EC meter. Information on age of the water points (well, boreholes), water usage were obtained through careful interactions with the communities. Few samples were also collected from another stream channel which has no connection with the drainage channel to serve as control.

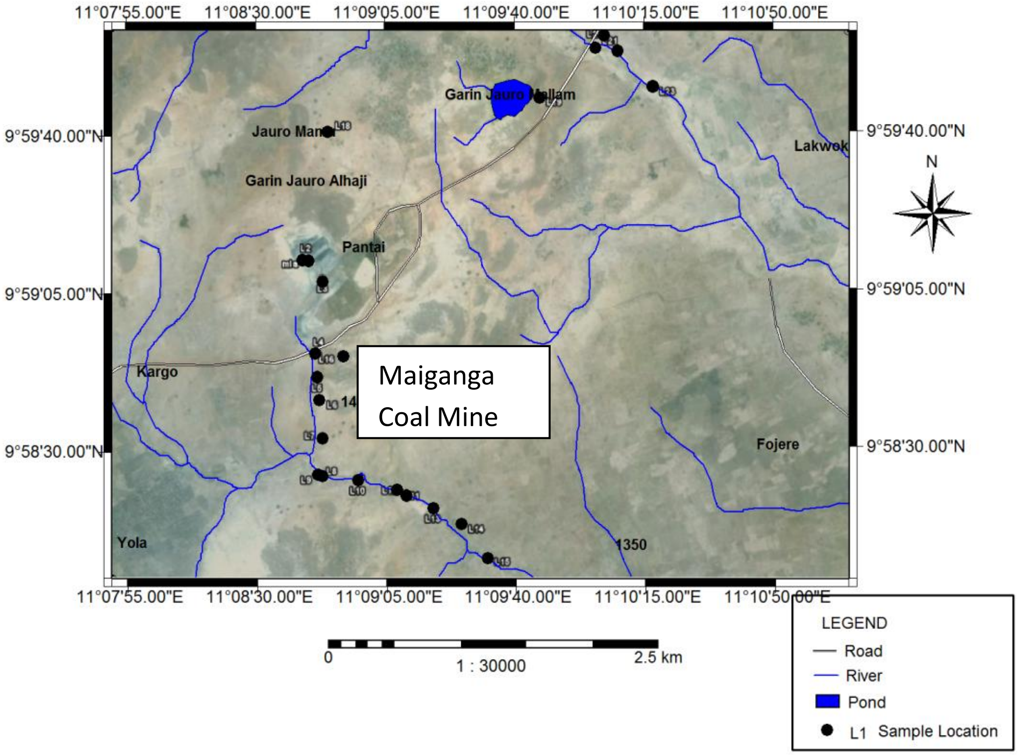

Fig.4: satellite image of sample location

There are some areas where we exceeded these intervals because of the dry nature of the area. At times, 1 to 2 meters depth of hand dug holes along the stream channels were also sampled in addition to two bore holes and two hands dug well.

Results and Discussion

The results of physico-chemical parameters of the various water sources in the study area are presented in table I and summarize into Minimum, Maximum, Mean, Range, Standard Deviation, and Variance in table II.While the graphical presentation of the data are in Fig.5 to Fig.24.

Concentration of Major Elements and Physical Parameter

Electrical Conductivity (EC) measured in the Water issuing out of quarried Gombe Formation was 210 μs/cm at the mine, 241 μs/cm in the mine pond and 1,058 μs/cm at the mine drainage channel. The Borehole water in the Maiganga Village has 117 μs/cm, hand dug well was 339 μs/cm and water holes along the stream channel range between 171 – 443 μs/cm. Fig.5 shows the plot of total dissolved solid (TDS) against sample location points. TDS ranges from 103 – 537 mg/l between locations 1 to 12, with the highest TDS of 537 mg/l at location 9. The Borehole water has TDS value of 55 μs/cm and the Earth Dam was 85 μs/cm. Water Samples from water holes along the stream channel has TDS values ranging from 72 – 220 μs/cm. There was no much variation in temperatures in the study area since the highest temperatures measured in water in all sources reflecting the ambient temperature of the study area. The pH of 9.2 (table 1) was observed in the Formation water located at the Mine (L1), and this value decreases to 8.9 at the mine pond (L2). pH of water of water holes along the stream channel was 8.2. There was no significant variation in pH along the mine drainage as it ranges from 7.4 – 7.9 indicating a slightly alkaline condition. Concentration of NO_3 was generally low in all water sources investigated namely: Borehole, well, Earth Dam, Formation water and water holes along the stream channel. For example, the range of NO_3 was 197 to 254 mg/l (table II) except water from the hand dug holes along the stream channel which was 43 mg/l in concentration. This show little human activities in the area. The concentration of SO_4 (table I) in the Formation water was 32 mg/l, and it rises steadily to 523 mg/l along the mine drainage channel. Cl concentration in the Formation water was 7.09 mg/l, while the mine drainage has the highest concentration of 120.05 mg/l and it decreases to below detectable level at location 9 toward the end of mine drainage channel. The highest concentration of HCO_3 (404 mg/l) was gotten at location 13 along the mine drainage (table I); Formation water has concentration of 66.66 mg/l while the highest concentration of 52.52 mg/l was observed in water holes along the stream channel. The concentration of Ca was plotted against sampling location as shown in Fig.15. In the Formation water, the concentration of Ca was 17.17 mg/l, this value increases to 91.81 mg/l at location 13 along the mine drainage channel. Well water and Earth Dam have a concentration of 37.52 and 9.75 mg/l respectively, and the water hole along the stream channel was 39.25 mg/l. The concentration of K ranges between 6.75mg/l in Formation water to 23.7 mg/l in the mine drainage channel (table III). Mg concentration in the Formation water was 9.12 mg/l and it increases to a maximum value of 48.29 mg/l at location 13 along the mine drainage channel. The concentration of Mg in Borehole, well, and Earth Dam ranges between 2.73 to 7.32 mg/l (table II), while its value in waterhole along the stream channel was approximately 14.0 mg/l. The concentration of Na as shown in Fig.20 was 12.55 mg/l in the Formation water ranges between 22.75 to 166.5 mg/l in mine drainage at location 10 still along the mine drainage channel. The concentration of Na in borehole water at location 13 was 13.27 mg/l while its concentration in water from hand dug holes along the stream channel was fairly uniform (48.81 mg/l).

Trace Elements in Water

The plot of Al against various sampling points is shown in Fig.17. The concentration of Al was 1,805 ppb at location 14 (mine drainage channel), while in the Borehole, Al concentration was 99 ppb, in hand dug well concentration was 257 ppb and waters sampled from waterholes along the stream channel ranges from 188 to 609 ppb in concentration (table II). The concentration of As, Te, Ti, Tl, U,W, Yb, Zr, Cs, Ga, Hf, Hg, Sb, Se, Sn, and Ta in various sources of water in the study area fall below detectable limits. The plot of B and Ba are presented in Fig.17 &18. The concentration of B in the Formation water at the mine was 26 ppb, and it increases to 301 ppb along the mine drainage. Sampled waters from Bore hole, well, and Earth Dam ranges from 29 – 65 ppb in B concentration, while waters from waterholes along the stream channel ranges from 10 – 151 ppb in concentration. The concentration of B in the Formation water at the mine was 114 ppb; water samples picked along the mine drainage at location 15 was 277ppb in B concentration. Furthermore, Borehole water was 119 ppb, well water and Earth Dam are 323 ppb and 71.5 ppb respectively in concentration. The concentration of B in water sampled from water holes along the stream channel ranges from 38.6 to 197 ppb (table I). The concentration of Co in the Formation water at location 1 was 0.2 ppb, while the mine drainage ranges in concentration from 0.2.0 to 12.0 ppb. Waters in the Earth Dam has concentration of 6.0 ppb, while in the waterholes along the stream channel ranges in concentration from 0.3 to 1.3 ppb. The concentration of Cr in all the water sources in the area ranges between 0.7 to 3.3 ppb. The concentration of Mn was generally below 100.0 ppb except at location 14 along the mine drainage where Mn concentration was 1948.0 ppb (Fig.22). The concentration of S in location I (mine) was 10 ppm. The highest value of 550 ppb of Mn was observed in the mine drainage while stream channel ranges between 3.0 to 12.0 ppm. Earth Dam at location 18 has Mn concentration of 17.0 ppm. At the mine in location 1, the concentration of Pb was 24.0 ppb while other source of water in the area ranges in concentration from 0.4 to 3.4 ppb.

Rare Earth Elements in Water

Table I shows the concentration of rare earth elements in water sources in the study area. These elements are Dy, Er, Eu, Gd, Ge, In, Lu, Pr, Sc, Sm, Tb, Tm and Y. Among these elements, only Sc ranges between 1.0 to 9.0 ppb, all other elements are far below these values and majority are < 0.01 ppb. The concentration of Fe in the Formation water in the Gombe Formation at location was 485.0 ppb (table I). It ranges from < 10.0 to 2,538.0 ppb at location 8 along the mine drainage, while the other sources of water range between 23.0 to 301.0 ppb (table 1).

Discussion

Coal mining activity in Maiganga area has led to the creation of mine drainage for the evacuation of mine waste and waste water so that mining activity can progress uninterrupted.

From the composition of the physical parameters (pH) and major cations and anions in the effluent discharge into the drainage channel, there seems not to be any case of acid mine drainage resulting from coal mining activities. Two factors have been identified as the main reasons for this.

1. Low content of Fe and S in the Maiganga Coal: The major ions which results in lowering the pH of the effluent discharge from most coal mine is the dissolution of Pyrite mineral (Zakari *et. al*, 2013). However, in the Maiganga coal sample analysed, the result revealed that the Fe and S content are quite low 597.78 and 21.77 ppb on average.

   Water issuing out from the Gombe Formation mixes with the debris of the coal: Water issuing out from the overlying Gombe Formation is alkaline in nature (pH 9.3), when this water comes in contact with the low Fe and S content of the debris from the coal mine, it neutralizes them and resulted in no acid mine drainage. Thus, alkaline water may probably be the result of dissolution of carbonate minerals from Gombe Formation.

   Comparing the composition of the mine drainage channel and other water sources in the area, there was no indication that water quality has been affected as a result of effluence discharge from the coal mine.

Water Quality: The main objectives following the hydrogeochemical assessment was to determine the ground water and surface water suitability for different uses based on different chemical indices. The suitability for drinking water and domestic consumption was evaluated by comparing the hydrogeochemical parameters of groundwater in the study area with a prescribed standard or specification by the W.H.O (2004).

Domestic Water Uses: The pH values of surface and groundwater vary between 7.3 and 9.3. According to the World Health organization (W.H.O, 2004) standards, the range of desirable pH values of water for drinking purposes is 6.5 – 8.5. In this study area, maximum pH of 9.3 was gotten from the mine drainage while 7.2 were observed in the other sources of water and all these are within the W.H.O standard. The pH of water in mine drainage was far above the maximum permissible limit and so it is not good for drinking. Although all other parameters analysed in the drainage channel are within the standard of W.H.O (2004) for drinking purpose. In addition, the cloudy nature of the water renders it unfit for drinking and other uses. The other water sources (Formation water, Well, Borehole and

Waterhole) in the area are good for drinking and other house hold uses.

Irrigation Water Uses: Classification of the groundwater samples for irrigation uses was based on Wilcox classification diagram (1955).In US salinity diagram, electrical conductivity (EC) was taken as salinity hazard and sodium adsorption ratio (SAR) as alkalinity hazard. The highest measured values of 1058 µs/cm (EC), and calculated SAR value of 4.39 was observed (table III). The plot of these and other data on the US salinity diagram shows that the samples were found to be confined to C1 - C2 & S1- S2 Class (Fig.25), indicating low to medium salinity and low – medium sodium (alkaline) hazard respectively. The waters with these compositions were found in Gombe Formation, water holes along the stream channel, borehole and well. This is due to low – medium concentration of sodium and low - medium EC content of the water and therefore can be used for irrigation on almost all soils with little danger of sodium problem. Few high salinity water (C3) and high sodium (alkaline) hazard (S3) were obtained in mine drainage which cannot be used for all cases of crops production without special practices for salinity control (US Department of Interior Geological Survey, 1948).

Table III: Concentration of Elements, % Na, SAR, and E.C at various locations.

Location	K	Na	Ca	Mg	% Na	SAR	EC
L1	0.17	0.55	0.75	0.98	29.00	0.59	210
L2	0.22	0.61	0.88	0.98	31.00	0.98	241
L3	0.20	0.64	1.13	1.20	26.00	0.58	284
L4	0.21	1.00	1.10	1.40	33.00	0.90	286
L5	0.22	1.00	1.04	1.40	33.33	0.90	280
L6	0.21	0.81	1.04	1.27	44	1.07	282
L7	0.20	0.60	1.10	1.30	27	0.60	275
L8	0.02	7.20	2.32	3.10	57	4.39	282
L9	0.40	3.70	2.58	2.05	47	243	1101
L10	0.10	0.06	0.22	0.55	17	0.10	360
L11	0.23	1.11	0.01	1.87	62	1.14	506
L12	0.27	0.67	0.32	0.49	54	0.86	521
L13	0.52	0.57	0.22	0.28	36	1.14	1058
L14	0.52	0.57	0.22	0.28	36	1.14	1058
L15	0.31	0.90	1.3	1.8	28	0.72	957
L16	0.50	1.12	1.7	2.3	29	1.56	715
L17	0.2	1.1	1.9	2.7	22	0.73	117
L18	0.60	3.70	1.6	3.2	47	2.39	172
L19	0.4	3.7	2.58	2.05	47	2.43	114
L20	0.10	0.06	0.22	0.55	17	0.10	443
L21	0.23	1.11	0.06	1.87	69	1.13	375
L22	0.27	0.67	0.32	0.49	54	1.12	4O5
L23	0.52	0.57	0.22	0.28	46	1.14	171

Concentration of elements are in milliequivalent/litre, EC in µs/cm.

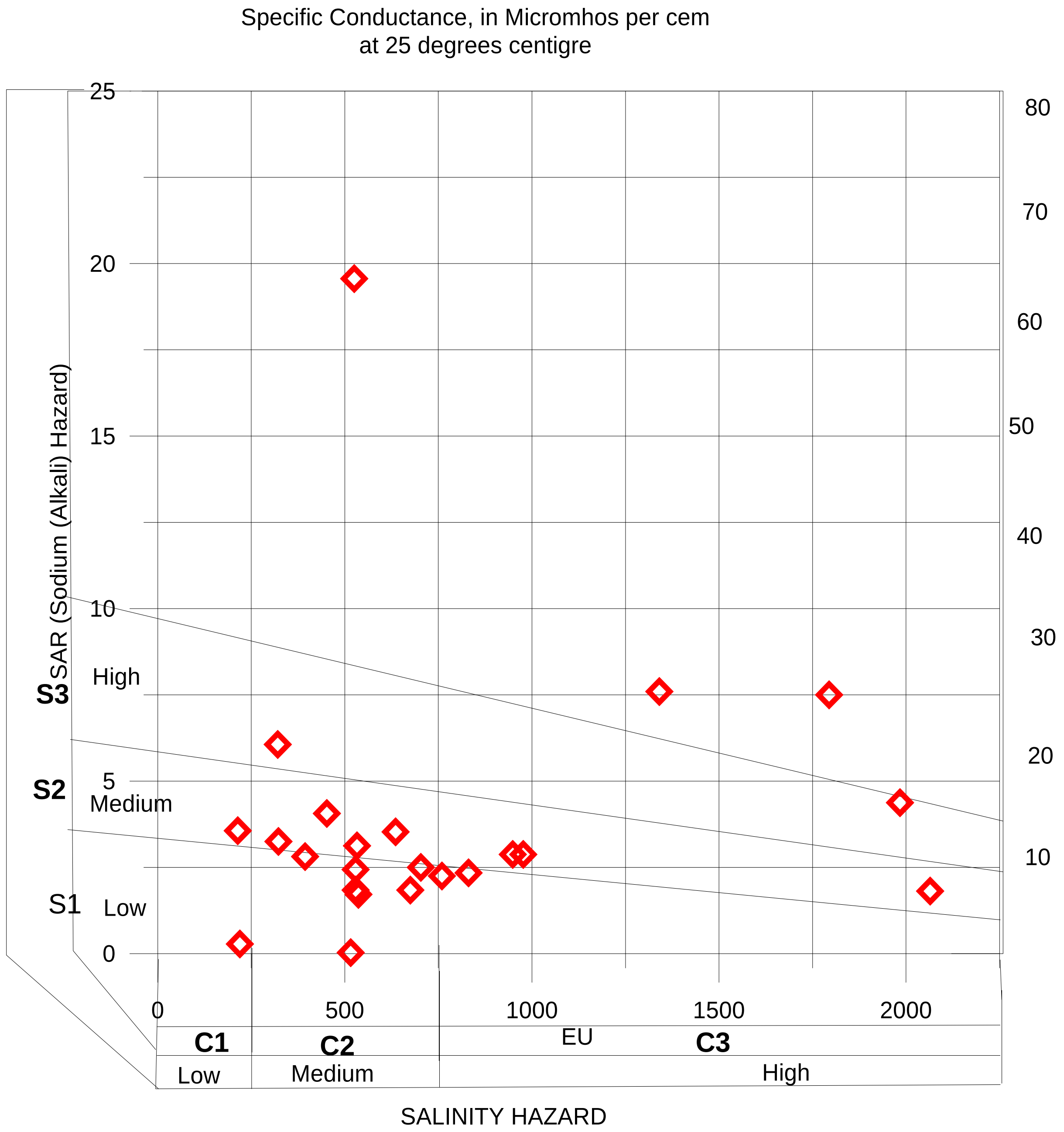

Fig. 25: Plot of Sodium Percentage and Electrical Conductivity (Based on Wilcox 1955) for Classification of Groundwater for Irrigation Uses.

Livestock Use: With regard to the TDS content of waters in the study area which was 537 mg/l and less than the 1000 mg/l recommended by Jewell, 1972 for raising livestock. The waters in this area are considered satisfactory for raising all livestock

Water types in the study area

The major water type in the study area as shown in Fig.26 was $MgSO_4$-Cl.While the minor ones are Ca-HCO_3, and Na+K-Cl. Both major and minor water types were found in water of the mine drainage channel.

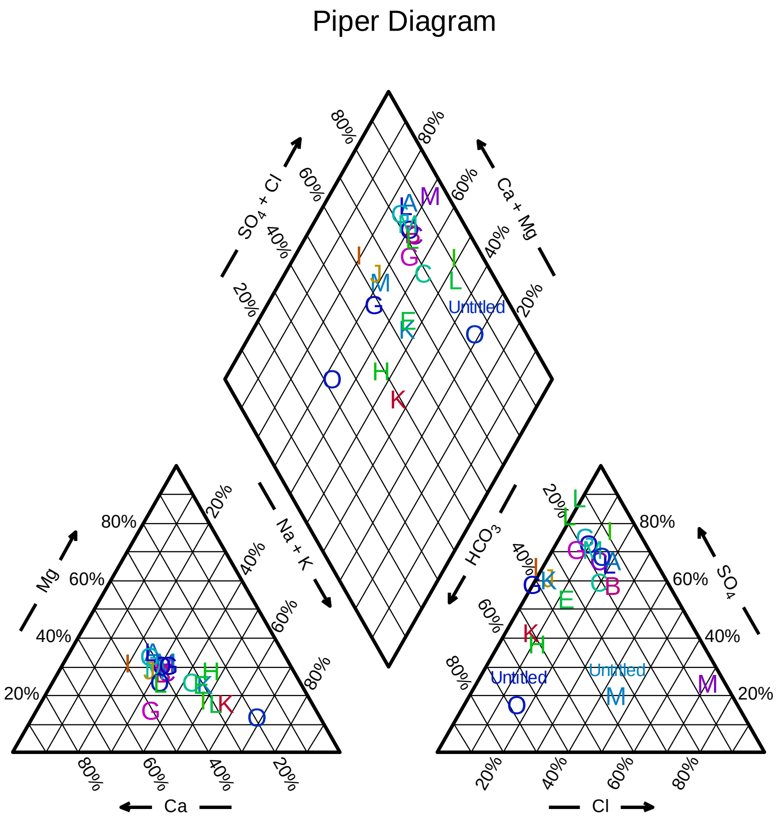

Fig. 26: Piper diagrams show water type in the study area.

Coal Mining and its Effects on Water Quality

From the analysis of the major elements, trace elements, rare earth elements plus the physical parameters, there are no any effects of coal mining on these constituents of the water. Also, the analysis has also shown that there was no acid mine drainage in Maiganga Coal Mine Area.

In addition, the analysis of waters samples by using US Salinity Diagram (1954) and Wilclox Classification Diagram (1955) shows that only water from mine drainage was not suitable for Irrigation but other sources of water are suitable for domestic, irrigation and livestock uses.

CONCLUSION AND RECOMMENDATION

Conclusion

The result of the analysis has shown that there is no acid mine drainage in Maiganga Coal mining area, because

1. The composition of Fe ans S are very low
2. The bicarbonate rich water from the Gombe Formation is continuously neutralizing the pyrite associated with the Coal Formation. The physical and Chemical constituents of waters in the area are within the W.H.O (2004) recommended limits. Therefore, the waters are of good quality for domestic, irrigation, and livestock uses. The only exception to this is water from the mine drainage channel which has high sodium absorption ratio and high alkaline content which render the water unsuitable for irrigation purposes.

The major water type was $MgSO_4$ – Cl while the minor ones are Ca-HCO_3 and Na+K - Cl, and all of these are found within the mine drainage channel.

The concentration of trace and rare earth elements are very small as to have any significant effect on the quality of waters in the area. This has confirmed the assertion of Ezeigbo and Ezeanyim (1993) that trace elements like arsenic, tungstein and lead that are presence in Onyeama coal in Enugu are absence in both Lafia Obi and Maiganga Coal.

Recommendation

Based on the study, the following are recommended:

1. Government should enact law that will make the company operating the mine to treat their mine waste in the mine pond before discharging it into the main drainage in the area.
2. The local populace should be educated to stop drinking water from waterhole dug by the side of mine drainage channel as this may contain harmful organisms.
3. Local Cattle – Rarer should be advised on the dangers of exposing their animal to drink water from the mine drainage channel.
4. I recommend additional research work on the plants and animals that depends on this water for survival since some of the trace elements may be harmful to them.

REFERENCE

1. Ezeigbo, H.I., Ezeigbo, B.N. (1993): *Environmental pollution from coal activities in Enugu area, Anambra State, Nigeria* .Mine water Environment, Vol. 12 pp 53 – 62.
2. U.S. Dept. of Interior Geological Survey. (1948): *Inventory of published and Unpublished Chemical Analysis of Surface Waters in the Western United.* Notes on Hydrologic Activities. Bull. No.2 pp.69 – 82.
3. Wilcox, L.V. (1955): *Classification and Uses of Irrigation Water.* 1stEdn.,United States Dept. of Agriculture, Washington, D.C. pp 19.
4. Zakiri, H.M., Islam, M. M., Arafat, M.Y., and Sharmin, S.(2013):*Hydrogeochemistry and Quality Assessment of an Open Coal Mine Area in a Developing Country: A Case study from Barapukuria, Bangladesh.* International Journal of Geosciences Research, Vol.1 (1) pp 2 – 24.