Impact of Coal Mining on Water Quality in Maiganga, Akko Local Government Area, Gombe State

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Abstract

Mining sector is very important because it provides foreign exchange earnings, jobs and socio-economic development. It also serves as a source of energy or fuel to some industries. However, coal mining activities are often associated with environmental degradation (water, soil, air and even noise pollution). Maiganga coal mine is not an exception to the effect of coal mining activities. The study examines the impact of coal mining on water quality in Maiganga communities. The physical and chemical concentrations in water samples were analyzed for trace metals. The results were compared with World Health Organization (WHO) standard. Both primary and secondary sources were used to collect data. The collected data were analyzed using tables and graphs. The result shows that all the sources of water are acidic (from pH of 6.18 - 6.63). The Total Suspended Solid (TSS) exceed the permissible limit (10mg/l) and Total Solids (TS) is high and ranges from 173mg/l - 414mg/1. These indicates that the water has a lot of suspended solids and various metals, which are likely to cause ailment like nausea, vomiting, diarrhea etc. The normal value for Manganese required for human growth and development is 19-20g/kg, but in all the study area, the Manganese content ranges between (0.04-0.07mg/l). Copper (Cu), Arsenate (As) and Zinc were detected in small quantity in Kantagari well and Garin Alhaji Shugaba borehole. The results of the study have revealed that in all the water sources, there are concentrations of metals which affect the water pH. This makes the water acidic and can cause different challenges on human health. The results also show high concentration of TDS, TSS and TS which signifies the presence of dissolved metals which affect the water quality with potentials of causing diseases like nervous system disease which can affects the brain and spinal cord.

Keywords: Borehole, Coal mining, Hand dug well, Heavy metals, Water pollution, Water quality

Introduction

According to a report by the World Health Organization in 2008, coal particulates pollution is estimated to shorten approximately 1,000,000 lives annually in the World (Din, Yahya, and Abdullahi, 2013). The United State Environmental Protection Agency pointed out that coal burning affect 24,000 lives every year in the United State (Jin, and Bian, 2013). Apart from the importance of coal, the mining processes, especially as shown by the artisanal and small scale miners has great disadvantages on the environment, either during the mining operations or many years after the mine has been closed down. The impact has led to most of the world's nations adopting regulations to moderate the effects of mining activities on the environment.

These environmental issues and concerns include: erosions, formation of sinkholes, and loss of biodiversity and soil contamination of underground and surface water by metals from mining activities which cause safety and health challenges to the miners and the communities around the mine (Bian, Zhang and Le, 2011).

Coal seam fires may burn underground for many years, which cause destruction of forest vegetation, houses, roads and other infrastructural facilities. In New York, winds deposit mercury from the coal-fired power plants of the mine, polluting the waters of the Catskill Mountains (Mokhter *et al*, 2014). China has the highest number of coal mining related deaths in the World. It claimed 6,027 deaths in 2004, while only 28 deaths were reported in the United States in 2004. Coal production in China is twice that of the United States (Shahbaz, 2015). According to Deswart and Casy (1993), Onyeama coal mine in Enugu started production in 1956. And the mine was active between 1916 -1996. He reported that the coal is a valuable source of wealth to Nigeria but with high environmental impacts that affects the quality of drinking water, and caused soil pollution and degradation.

Crook and Fritz (2002) pointed out that coal mining activities deteriorates the quality of the land, surface and ground water. Davies, Gore and Khan (2015) pointed out that among other mining activities; coal mining has the highest impact on environmental degradation. Those toxic pollutants contained in coal and others formed during combustions are set free into the air, water and soil. Lalor (2008) noted that some of the pollutants can cause cancer and can affect reproduction in human being. It can also affect water pH which is likely to be corrosive to metals even in our homes and may results to leaching of water container. Li and Zhang (2010) pointed out that heavy metals from coal mining activities can affect the natural constituents of river sediments. Lalor, (2008) pointed out that high arsenic in drinking water can lead to liver disease called cirrhosis.

Metals are very important pollutants in surface waters, which cause persistent environmental hazards that can seriously affect human being and ecological health (Cook and Fritz, 2002). Metals are present in surface water in various forms, which can be classified as soluble (compounds or free ions) and particulate (colloidal or adsorbed to suspended solids). Different forms of the metals exhibit different biological toxicities and environmental behaviors. The free hydrated ions of many metals can lead to chronic toxicity in aquatic organisms. Suspended solids are the dominant carriers of some metals in surface waters, and can cause 60%–97% of the total metal concentrations (Alti and Canli, 2016). The metals in drinking water which are mostly poisonous to humanbeings are cadmium, lead, copper, zinc, chromium and iron among others. They are required by the human body in small quantity, but can also be harmful if found in large quantity.

The discovery of coal in Maiganga has led to the establishment of coal mining industry in Maiganga, Akko LGA, Gombe State. The mining area has a coal reserve which is estimated to be 4.5million tons to be mined so as to provide fuel for Ashaka cement factory at Bajoga, Gombe State. This coal reserve will provide the Ashaka cement industry with fuel for the next 25years. Hence, coal mining in Maiganga is done at industrial and large scale which can cause environmental degradation, water, land and air pollution, with potential health hazards to human beings.

Ristovic (2011), James (2005) and Cook (2005), have outline the problems of coal mining to includes loss of biodiversity, soil contamination, pollution of underground and surface waters from mining activities. Again, Shahbaz, Farhani and Ozturk, (2015) have also pointed out that mining activities can lead to significant environmental degradation. It is against this background, that the study addressed the following research questions: What are the concentrations of physical properties of water in the study area? What are the concentrations of chemical properties of water in the study area? What are the concentrations of heavy metals in the water supply sources in the study area? Is the water suitable for domestic uses?

The aim of the study is to assess the impact of coal mining on water quality in Maiganga, Gombe State. This aim would be achieved through the following specific objectives: To determine the physical properties of water source in the study area. To examine the chemical composition of water supply in the study area. To determine the concentration of heavy metals in the water quality in the study area. To evaluate the suitability of the water sources for domestic uses in the study area.

Description of the Study Area

The study area is Maiganga, Akko Local Government Area of Gombe State. It is located between longitude 09^0 59^1 N to longitude 11^o 09^1. Maiganga covers a land area of about $48.16km^2$(Fig. 1). It is bounded to the South by Billiri and to the West by Kumo town, the local government headquarters of Akko Local Government Area. The LGA is located between longitude 9^0 59^I N and 9 59^IN and latitude of 11^0 8^IE and 11^0 9^I E.

Maiganga lies within the tropical continental type of climate. It has both wet and dry seasons. Rainfall ranges from 850mm to 1000mm. Temperature in the study area is relatively high for most part of the year (Oruonye, Iliya and Ahmed, 2016). The mean maximum monthly temperature is 37^oC from March to October, but reduces to 21^oC in December to February.

Maiganga community is majorly dominated by Tangale, Fulani, and Jukun with few other minor tribes. The population of Maiganga is 3520 people based on 2006 National Population Commission census, and projected using 3% growth rate to 39,881.6 people in 2017. The main economic activities of the people are small scale farming; cultivation of crops like millet, maize, guinea corn, rice, soya beans, ground nut, sorghum, beans among others. They also practice open grazing in a small scale because mining activities has affected the vegetation cover in the study area.

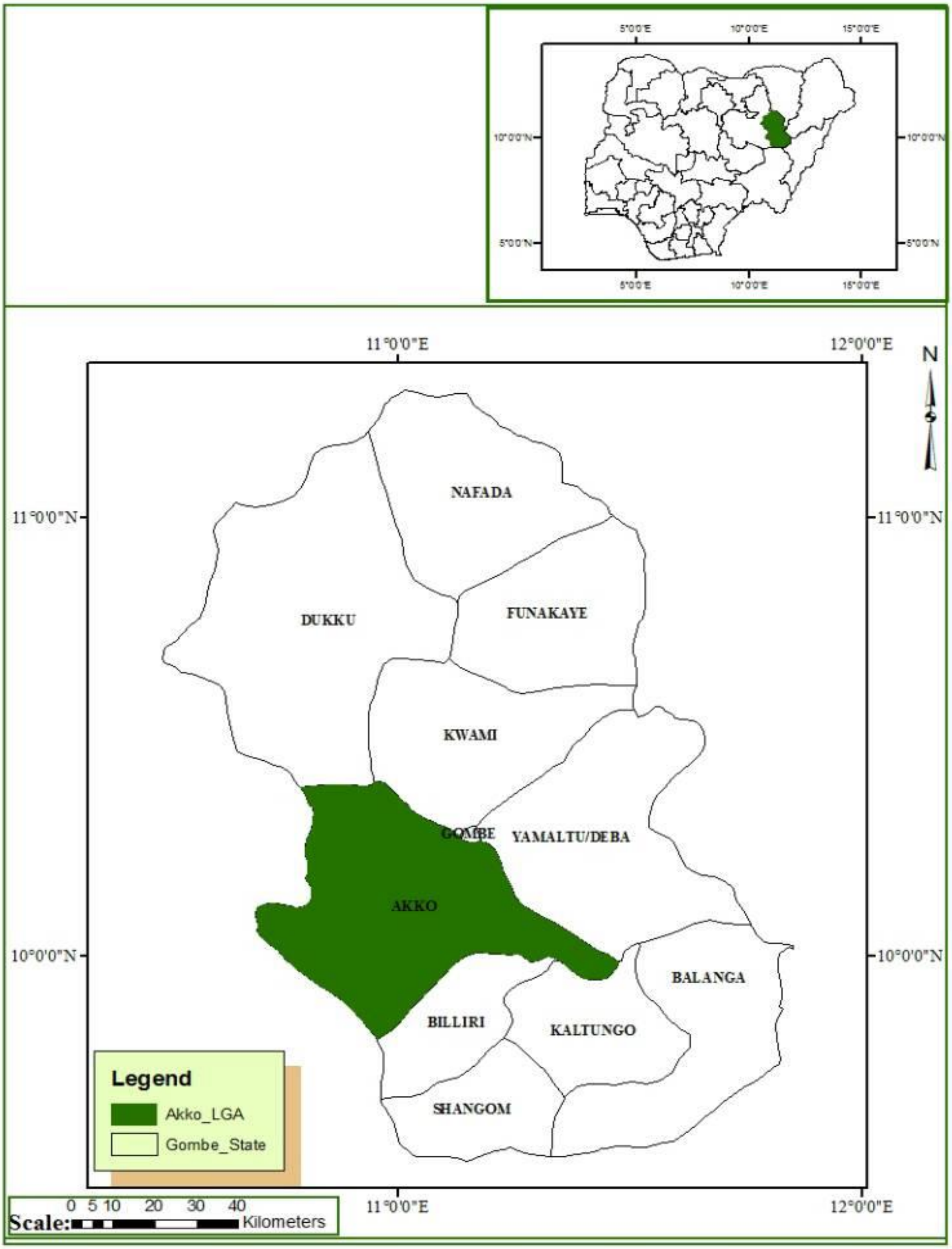

Fig.1 Map of Gombe State

Source: Google earth/Arcgis Analysis 2018

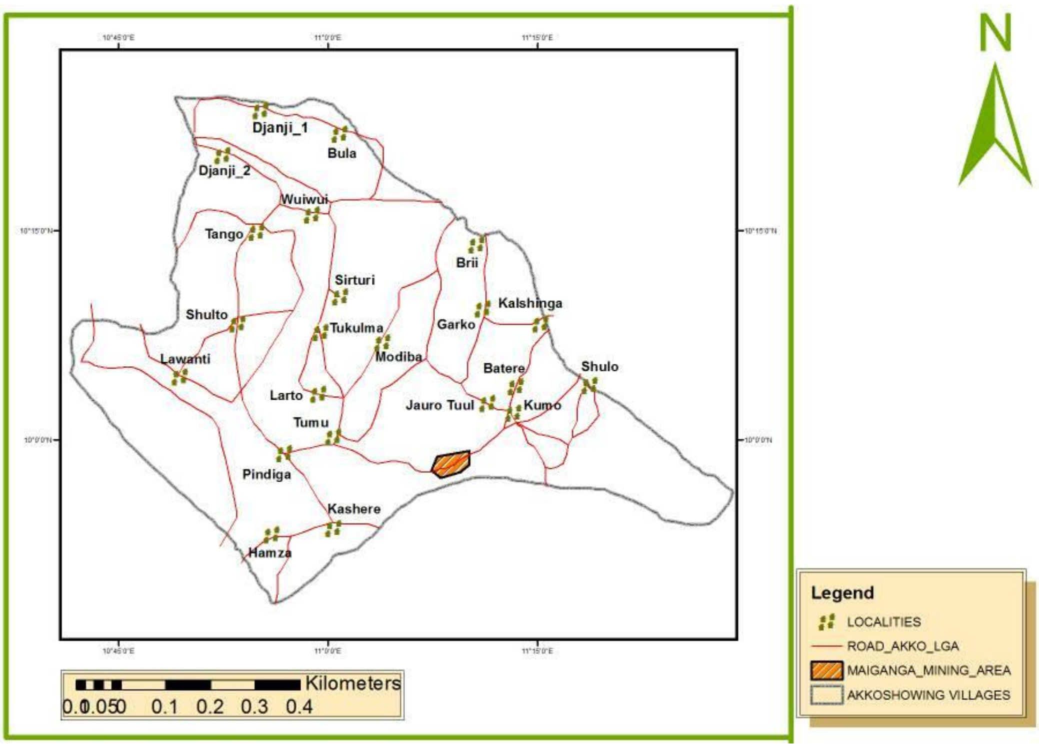

Fig.2 Map of Akko Local Government Area

Source: Google earth/Arcgis Analysis 2018

Materials and Methods

Data collection

The water samples were obtained from boreholes and hand dug wells during fieldwork in the five communities affected by Maiganga coal mining activities in the study area. These communities are Maiganga, Kayel Baga, Kantagari, Tudun Kuka and Garin Alhaji Shugaba.

The procedure for water samples collection

The study took 2 water samples in the rainy season in each of the five settlements (1 sample from a well water and another 1 sample from borehole). This gave 10 water samples for rainy season only. The water sample collected, were fed into 2 litres plastic container and labelled so as to have enough water samples for laboratory analysis. The plastic containers which were used for the collection of the water samples were thoroughly washed and distilled to avoid contamination. In collecting the borehole water sample, the boreholes were pumped severally to allow the collection of fresh water from the aquifer. In collecting water samples from the well, a plastic distilled fetcher (using plastic container tied with long plastic/rubber robe) was deepen into the well which collected the water sample and put into the distilled plastic container severally before collecting the water in the container. After that, the water samples were then finally fed into the 2 litres distilled plastic container, then 3 mills nitric acid were added into each collected water sample to avoid biochemical reaction that may likely occurred before laboratory analysis. Each water sample was labelled for laboratory analysis. At the points of water sampling, the coordinates of the wells and the boreholes from which the samples were collected, were recorded using a hand help Geographical Positioning System (GPS).

Water analysis.

The following standard analytical procedures for physical, chemical and heavy metals of water properties were used to analysed the collected samples and compared with World Health Organization (WHO).

a. Thermometer was used to measure temperature (Jackson, 1958); Turbidity by the use of Turbidity Meter; Electrical Conductivity (EC) and Total Dissolved Solid (TDS) were determine by the use of Conductivity Meter (Wilcox, 1950). Total Suspended Solid (TSS) was determined by Gravimetric method (Black, 1965).

b. Water pH was determined by pH Meter; Total Solid (TS) by Gravimeter; Biological Oxygen Demand (BOD) was determined by BOD Track method; and lastly the Chemical Oxygen Demand (COD) was determined by Photometric method (Jackson, 1958).

c. Also heavy metals like Iron (Fe), Manganese (Mn) and Chromium (Cr) were determined by Photometry method (Jackson, 1958). Copper (Cu), Total Arsenate (TAs), Cadmium (Cd) and Zinc (Zn) were determined using Metalyser method (AOAC, 1950).
However, a field sheet was used to record all information such as sampling points, coordinates, Geographical Positioning System (GPS), and so on.
The data were analysed using statistics presented in mean, tables and figures

Results of the Findings

Physical Parameters of Water Samples

Temperature (°C)

The highest temperature is found in water sample from Tudun Kuka borehole (34.6°C), followed by Kayel Baga well (34°C). The least temperature is recorded in Kantagari borehole (30.5°C), followed by the well water at Garin Alhaji Shugaba (30.5°C).

Turbidity (NTU)

The result of the findings reveals high turbidity in Maiganga borehole (274 us/cm), followed by the borehole water at Tudun Kuka Borehole (191 us/cm). While the least turbidity is recorded in Kayel Baga well (5 us/cm) followed by Tudun Kuka well (9 us/cm) which make water moderately suitable for drinking since it is not too far from the WHO Standard (5 us/cm). This shows that in all the water sources, there is evidence of concentration of some dissolved metals that are harmful to human health.

Conductivity (us/cm)

The highest conductivity was recorded in Kayel Baga borehole (746 us/cm) followed by Tudun Kuka borehole (669 us/cm). The least conductivity was recorded at Kantagari well (166 us/cm) and Garin Alhaji Shugaba (189us/cm). All the sources of water are not too polluted since they are all below the WHO standard (1000 us/cm) for drinking. All these are within the permissible limit for human consumption. The highest World Health Organization (WHO) permissible limit is 1000us/cm. Any value beyond this limit is dangerous to human health as observed.

Total Dissolvrd Solids (mg/l)

The highest Total Dissolved Solid (TDS) is recorded in Kayel Baga (575mg/l) followed by Tudun Kuka borehole (335mg/l) and the least is recorded in Maiganga borehole (81mg/l) and Kantagari well (81mg/l). All the results are below the World Health Organization (WHO) Standard (500mg/l), hence the water is suitable for drinking. All these did not exceed the World Health Organization permissible safety limit which is 500mg/l, hence, the TDS available in all the sources of water in the study area did not portray much health hazard for human consumption since it does not exceed the WHO Safety limit.

Total Suspended Solids (mg/l)

The highest Total Suspended Solids (TSS) is recorded (263mg/l) at Maiganga borehole, followed by Tudun Kuka borehole (243mg/l). The least are in Kantagari well (1mg/l) and Tudun Kuka well (5mg/l), while WHO Standard is 10mg/l. On the average, all the water sources indicate high Total Suspended Solid (TSS) showing the water is polluted. All the boreholes have higher concentration above the World Health Organization (WHO) safety limit of 10mg/l. This indicates that the water obtained from all the boreholes are not safe for human consumption as observed by (Alex, 2008). He stated that such concentration in drinking water can cause multiple sclerosis (i.e. a nervous system disease which affects brain and spinal cord). However, water from the dug well (DW) are also above the said WHO safety limit especially in Maiganga with a concentration of 66m and in Kantagari with 25mg/l.

Total Solid (mg/l)

The highest Total Solid (TS) was recorded at Tudun Kuka borehole with 580mg/l, followed by Kayel Baga borehole with 390mg/l. The least was recorded in Garin Alhaji Shugaba with 100mg/l then Kantagari well with 160mg/l. Drinking water is obtained from different sources like wells, boreholes, rivers, lakes, reservoirs, ponds etc. All the different sources of water in the area poses great risk to human health due to contamination of these sources by water pollutants which mainly consists of some metals, microorganisms, fertilizers and thousands of toxic organic compounds. Metals in water occur only in trace levels but are more harmful to the human body as could be seen in all the sources of water in the settlements, as observed by Hedryx (2015).

Chemical Analysis Results

pH

From the findings of study, Kayel Baga borehole has more acidic water with 5.66m followed by the water at Kantagari well measuring 5.96 pH. The water at Kantagari well is relatively suitable (7.3pH) for drinking followewd by the well water at Garin Alhaji Shugaba with 6.89pH. However, all the water sources are not too bad for drinking. If the pH were to be too low and very acidic, it would have great impact on human health as observed by Hendryx (2015).

Biological Oxygen Demand

Findings of the study reveals that the Biological Oxygen Demand (BOD) simply means the amount of Dissolved Oxygen needed (or demanded) by aerobic Biological Organism to break organic materials in water sample at a given Temperature. The highest concentration is recorded in Tudun Kuka borehole with 10mg/l, followed by Maiganga well (9.24mg/l). And the least is recorded in Tudun Kuka well with 3.71mg/l and Garin Alhaji Shugaba well with 3.77mg/l. Unpolluted water has a BOD of 2mg/l. This in line with the finding of the study conducted by Ristovic (2011) which reported that all the sources of water are polluted in the area.

Chemical Oxygen Demand (mg/l)

The result of the study reveals higher Chemical Oxygen Demanded (COD), the higher the level of pollution which cannot be oxidized biologically (Black, 1965). The highest concentration of COD is recorded in Tudun Kuka borehole (23mg/l) followed by Maiganga well (22mg/l). And the least is recorded in Tudun Kuka well (8mg/l) and Kayel Baga borehole (11mg/l). This shows that all the water sources are polluted but some are more polluted than others when compared with the World Health Organization safety limit of 10-20mg/l.

Heavy Metals Analysis Results

Fe (mg/l)

The result of the study shows that the highest concentration of iron (Fe) was recorded in Kantagari well (0.67mg/l), followed by Garin Alhaji Shugaba well (0.603mg/l), and the least was recorded in Tudun Kuka well (0.1mg/l) and Maiganga well (0.3mg/l) when compared to the World Health Organization safety limit of 0.30mg/l. This corroborated the finding of Boyd (1992) that toxic metals like iron, copper, lead are commonly found in municipal, industrial and urban runoff, which can be dangerous to man and other biotic organism.

Manganese (mg/l)

The result of the study shows that the highest concentration of Manganese (Mn) was recorded in Tudun Kuka borehole (0.14mg/l), followed by Tantagari well (0.05mg/l). The least was recorded in Kayel Baga well and borehole (0.00mg/l). The World Health Organization safety limit is 0.10mg/l. This indicates the absence of excess Manganese in the water which make the water less harmful for consumption.

Chromium (mg/l)

The result of the study shows that Chromiun (Cr) was only recorded in Tudun Kuka borehole (0.01mg/l) and well (0.004mg/l). The World Health Organization limit is 0.05. All the other four settlements have no Chromuin in their water sources. The metals in drinking water which are mostly poisonous to humans are cadmium, lead, copper, zinc, chromium, iron etc as observed by Hendryx (2015).

Copper (mg/l)

The consumption of high copper can cause nausea, vomoting, diarrhoea, gastric (stomach) complain and headaches. If taken for too long, can cause Liver damage and death (Hendryx, 2015). The concentration of Copper (Cu) is only detected in Kantagari Well (0.016mg/l) and Garin Alhaji Shugaba borehole (0.021mg/l) whereas the World Health Organization limit is 2.0mg/l. It has not been detected in the other four settlements. This means that the water sources has no Copper effect. Even in Kantagari well and Garin Alhaji Shugaba, the concentration is not too high, hence it has less effect.

Total Arsenic (mg/l)

Total Arsenic, it is not out of place to have Total Arsenic (As) in drinking water. The permissible limit is not more than 0.010mg/l (Jin, 2013). The highest concentration of Total Arsenic (As) is recorded in Tantagari borehole (0.099mg/l) followed by Garin Alhaji Shugaba Borehole (0.079mg/l), whereas the World Health Organization limit is 0.10mg/l. The least was recorded in Garin Alhaji Shugaba well (0.002mg/l). All of the sources are within the permissible WHO limit and has no effect on human health.

Cadmium (mg/l)

The concentration of Cadmiun (Cd) was only detected in Maiganga well (0.089mg/l), the World Health Organization limit is 0.003mg/l, but it has not been detected in the remaining four settlements. Cadmium is completely dangerous to man even in low concentrations, and will bio-accumulate in organisms and ecosystems. Long term exposures to Cadmium can cause renal damage as observed by Hendryx, (2015).

Zinc (mg/l)

Small quantity of zinc (less than 5mg/l) is believed to be essential for body growth and development, or else it can cause stomach cramps, nausea and vomiting (Din, 2013). The highest concentration of zinc (Zn) was recorded in Kayel Baga borehole (0.148mg/l), followed by Maiganga well (0.052mg/l) and the least was recorded in Kayel Baga well (0.007mg/l). Hence, the zinc intake is of usefulness to the body since they are all below the WHO safety limit of 5mg/l.

Summary of Water Quality Results in the Study Area

From the Table 1, the water pH in all the settlements are not too acidic for consumption since it falls within the World Health Organization (WHO) safety limit (6.5-8.5). The temperature in all the settlements are below the mean maximum monthly temperature ($37^{O}C$) for Akko LGA. According to WHO, temperature is variable. The turbidity for all the water sources is far above the WHO safety limit of 5 ntu. This indicates that all the water sources are highly polluted with contaminants and are not too pure for human consumption and are likely to cause some ailments. Conductivity for all the settlements is below the WHO safety limit (1000us/cm), hence it has less effect on humans. The Total Solid (TS) in all the settlements indicates high presence of pollutants in the water because they are all having values above the WHO safety limit of 10mg/l. The Dissolved Oxygen (DO) in all the sources of water indicates that the water has high pollution and hence it affects the water quality for consumption. The study findings shop that all the sources of water in the study area contain high pollutants which affect the oxygen content of all the water sources. This make it lower than the required standard for WHO of 4.0-6.0mg/l. The Biological Oxygen Demand (BOD) for WHO is less than 6mg/l. Most of the settlements has little above this limit while some are below the limit. Chemical Oxygen Demand (COD) in all the settlements are within the range of WHO safety limit (10-20mg/l). Only Maiganga well which has 22mg/l and Tudun Kuka borehole which has 23mg/l. Iron (Fe) content is high in all the settlements except in Maiganga well and Tudun Kuka borehole which is within the WHO safety limit (0.3mg/l). Manganese (Mn) is rarely found in some of the settlements and it was not detected at all in the other settlements. This implies that all the sources of water are free from the health effect of Manganese in drinking water. Chronium (Cr) was hardly detected in Tudun Kuka borehole (0.01mg/l) and well (0.004mg/l) which was far below the WHO safety limit (0.05mg/l), hence the water it is free from the effect of Chronium. Copper (Cu) was only detected in Kantagari well (0.016mg/l) and in Garin Alhaji Shugaba borehole (0.21mg/l). This implies that all the water sources are free from the effect of Copper since the WHO safety limit is 2mg/l. Total arsenite (As) has high concentration in all the water sources in the study area. Cadmiun (Cd) was only detected in Maganga well (0.089mg/l) and it is above the WHO safety limit of 0.003mg/l, so only the people of Maiganga settlement are likely to be affected by Cadmiun. Zinc (Zn) is found in all the settlements but are all below the WHO safety limit(5mg/l).

Table 1. Result of Water Quality Analysis in the Study Area

	Mai Ganga		Tudun Kuka		Kayel Baga		Kanganri		Garin Allah Shugaba		WHO
	BH	WL	BH	WL	BH	WL	BH	WL	BH	WL	
pH-meter	6.49	6.67	6.21	6.52	5.66	6.7	7.3	5.96	6.01	6.98	6.5-8.5
Temperature (0C)	33	31.5	34.6	31.7	32.4	34	30.5	31.6	32.4	30.5	Ambient
Turbidity (NTU)	274	74	191	9	26	5	33	78	24	26	5
Conductivity us/cm	162	471	669	428	746	594	310	166	189	452	1000
TDS (mg/l)	81	233	335	215	375	298	155	81	95	226	500
TSS (mg/l)	263	66	243	5	21	1	25	70	18	22	10
TS (mg/l)	340	281	580	248	390	296	186	160	100	251	
DO (mg/l)	1.6	2.9	4.4	1	1.2	1	2.7	2.3	1.4	1.3	6.0 - 4.0
BOD (mg/l)	6.1	9.24	10	3.71	4.52	7.11	6.53	7.21	5.92	3.77	<6.00
COD (mg/l)	12	22	23	8	11	13	18	19	16	14	10.0 - 20.0
Fe (II) (mg/l)	0.57	0.3	0.1	0.507	0.502	0.515	0.5	0.67	0.603	0.6	0.3
Mn (II) (mg/l)	0.07	0.04	0.14	0	0	0	0.03	0.05	0	0	0.1
Cr (VI) (mg/l)	0	0	0.01	0.004	0	0	0	0	0	0	0.05
Cu (II) (mg/l)			ND	ND	ND	ND	ND	0.016	0.021	ND	2
Total As (mg/l)	0.06	0.063	0.078	0.057	0.051	0	0.099	0.078	0.079	0.002	0.01
Cd (mg/l)		0.089	ND	ND	ND	ND	ND	ND	ND	ND	0.003
Zn (mg/l)	0.05	0.052	0.032	0.008	0.148	0.007	0.021	0.017	0.006	0.012	5
Ni (mg/l)			ND	ND	ND	ND	ND	ND	ND	ND	0.07
Pb (mg/l)			ND	ND	ND	ND	ND	ND	ND	ND	0.01

NOTE: BH, means borehole. All read colour stands for borehole
WL, means well. All blue colour stands for well
ND, means not detected
WHO, means World Health Organization

Conclusion

The findings of the study have shown that coal mining activities at Maiganga has affected the quality of water sources in the study area. The result indicates that the water sources have lower pH below the WHO Standard, indicative of acidic water. The results show high Total Solids, Total Suspended Solid, Total Dissolved Solids which indicates the presence of high concentration of heavy metals like Zinc, Copper and Lead among others which can affect human health. The Biological Oxygen Demand and Chemical Oxygen Demand are higher than the World Health Organization limit (2mg/l), which indicates higher contamination by metals and can cause different diseases in man like nervous system disease which can affect human brain and spinal cord.

Recommendations

Since the water sources (borehole and well) indicates high concentration of Total Solids, Total Suspended Solids, Total Dissolved Solids and concentration of heavy metals, the study recommend as follows:

i. There is need to connect the settlements with treated water supply from the State Water Cooperation through the combine efforts of the coal mine company, Akko Local Government Council and State government.

ii. Non-Governmental Organizations (NGOs) and Civil Society Organization can assist the local communities with water tankers which will supply them with clean water through various overhead reservoirs around the coal mine.

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