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Preliminary Investigation of Trace Elements in Acid Mine Drainage from Odagbo Coal Mine, Northcentral, Nigeria

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Abstract
The objective of this study was to assess the concentration of trace elements in acid mine drainage (AMD) from Odagbo coal mine. Composite AMD samples were collected from active and abandoned mining pits and were analysed for lead, nickel, cobalt, chromium, mercury, zinc, arsenic and iron using Atomic Absorption Spectroscopy (AAS). Comparisons were made between the trace elements and environmentally acceptable quality standard (EQS) for heavy metal discharges from mines using student's *t-test*. The mean concentrations of these elements were lead (0.10 mg/l), nickel (0.49 mg/l), cobalt (0.88 mg/l), chromium (0.55 mg/l), cadmium (0.19 mg/l), arsenic (0.01 mg/l) and iron (5.80 mg/l). There were significant differences between the means of lead, mercury, cadmium, arsenic and EQS for heavy metal discharges from mines ($P < 0.05$). There were no significant differences between the means of nickel, chromium, iron and EQS for heavy metal discharges from mines ($P > 0.05$). Cobalt, iron, nickel and chromium were the dominant trace elements in the AMD. Further studies are required to determine the influence of AMD on surface water and soils around the mine.
Keywords: Acid mine drainage, trace elements, coal, mine, sulphide minerals,

INTRODUCTION

Acid mine drainage is the most significant environmental problem from mining activities. Its effects include; surface and groundwater pollution, degradation of soil quality and aquatic habitats (Davies and Mundalamo, 2010). The geochemical features of these runoffs are very complex. They contain several trace elements, poly alkaline halides and radionuclides (Kaseke et al. 2011). Acid mine drainage from coal mines are highly acidic and some could maintain their acidity even after thirty years of post-mining (Udeyabhanu and Prasad, 2010). The acidity of AMD is very critical on its own, but it equally dissolves metals such as aluminium, calcium and sodium, which then forms part of the runoff. This by-product of the coal industry is handled in several ways by coal producing firms; it could be recycled into groundwater regime, disposed to evaporating ponds or subjected to treatment for use in industry, agriculture or for potable water supply in the community (Keating, 2001).

Research had shown that AMD is Pennsylvania's single greatest source of water pollution, responsible for over 2,400 miles of polluted streams (Cooper and Wagner, 1973). Similar examples of mine drainage are associated with coal mines in Donbas (Russia), Ruhr coalfields (West Germany), in Australia, India and Canada with predominant Short-wall mining. In India the coal mines are facing serious problems due to acid mine drainage, particularly in the lower Gondwana coal of the Barakar Formation, and the Tertiary coal of Assam (Jamal et al., 1991).

South Africa has a long history of mining and limited natural water resources, leading to situation where it has a number of significant mine-water related challenges. With over 10,000 km^2 of hydraulically interlinked coal mines and over 300 of interlinked gold mines; associated mine-water challenges are not limited to local mine level but can be regional level too (Motsi, 2010).

A study by Naicker et al. (2003) revealed that the groundwater in the mining district of Johannesburg, South Africa was heavily contaminated and acidified as a result of oxidation of pyrite contained in the mine tailings dumps and elevated concentrations of heavy metals. Where the groundwater table is close to the surface, the upper 20 cm of soil profiles were severely contaminated by heavy metals due to capillary rise and evaporation of the groundwater.

Water contaminated by AMD, often contains elevated concentrations of metals which could be toxic to aquatic organisms, leaving streams devoid of most living creatures (Kimmel, 1983). In a study of the distribution of fish in Pennsylvania streams affected by acid mine drainage, Cooper and Wagner, (1973) reported that impacted streams are dominated by fewer species organisms.

Hence, mine water impacts negatively on the environment by increasing the levels of suspended solids, leading to mobilization of elements such as iron, aluminium, cadmium, cobalt, manganese and zinc and also decreasing pH of the receiving water (Emmanuel 2015). The overall effect of mine water is the deterioration in water quality in many surface water bodies that may negatively impact on the domestic, industrial and agricultural uses (Emmanuel 2015). Odagbo coal deposit is of medium quality (sub-bituminous) with a moisture content of 10.30% and sulphur content of 0.65% (MMSD, 2001). The coal mine is a surface mine with a proven reserve of 100 million tonnes with an average thickness of 2.30 m coal seam (Ameh, 2013). The objective of this study was to determine the concentration of trace elements in Odagbo AMD with a view to ascertain there severity on the environmental component, most especially surface water bodies within the precincts of the coal mine.

MATERIALS AND METHODS

Study area

Odagbo is a rural settlement situated towards the northeastern part of Ankpa in North-central Nigeria, at an altitude of about 275 m above m.s.l. (Omali and Egboka, 2011). It lies between latitudes 7º 28´ 30´´ N and 7º 29´ 00´´ and longitudes 7º 43´ 30´´ E and 7º 44´ 0´´ E covering an area of about 4 km^2 (Fig. 1).

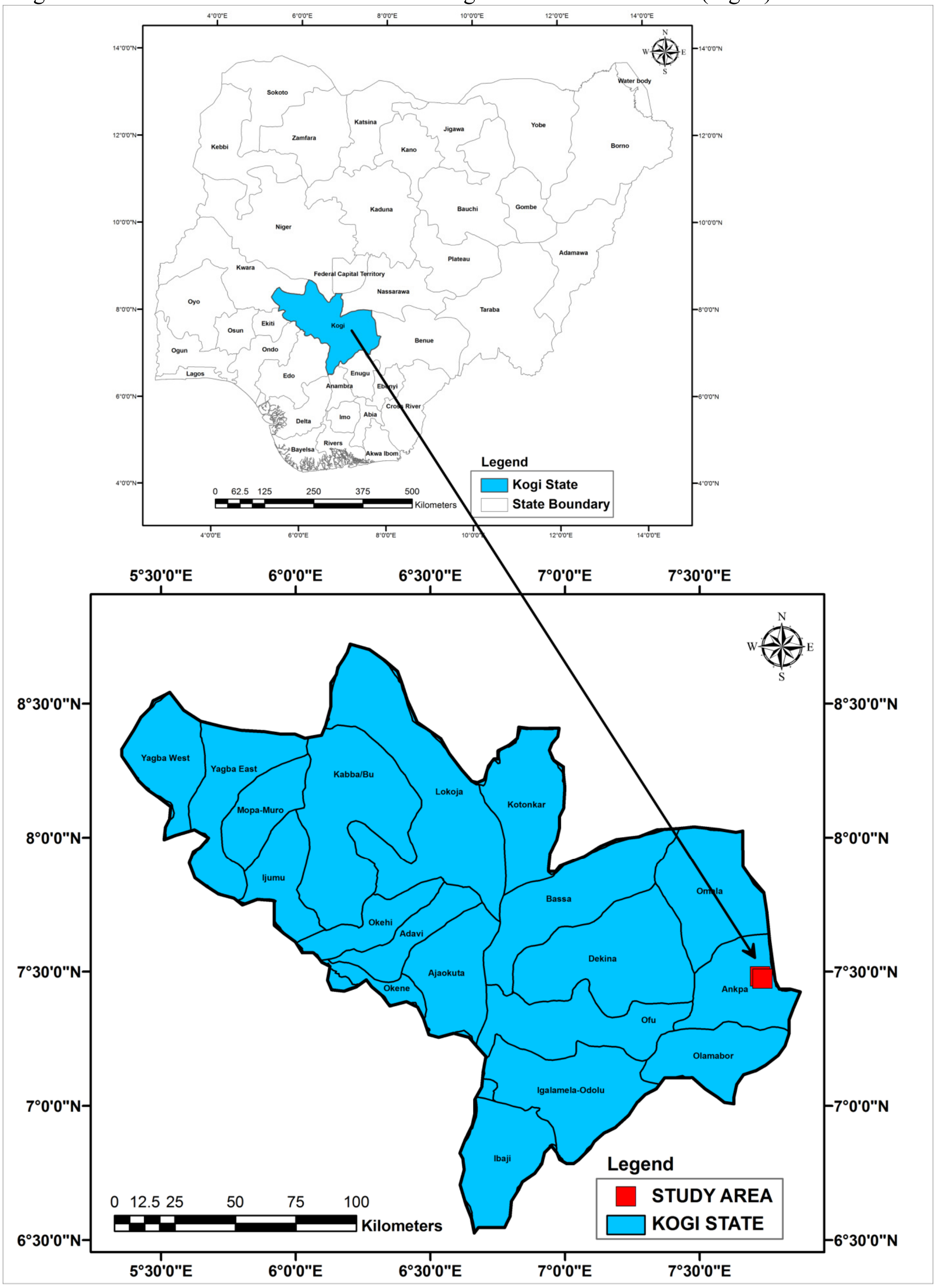

Fig 1: Map of the study area

There are two mining sites within Odagbo coal mine. Each mining site has several open pits measuring about 40 by 30 m filled with AMD (Fig. 2).

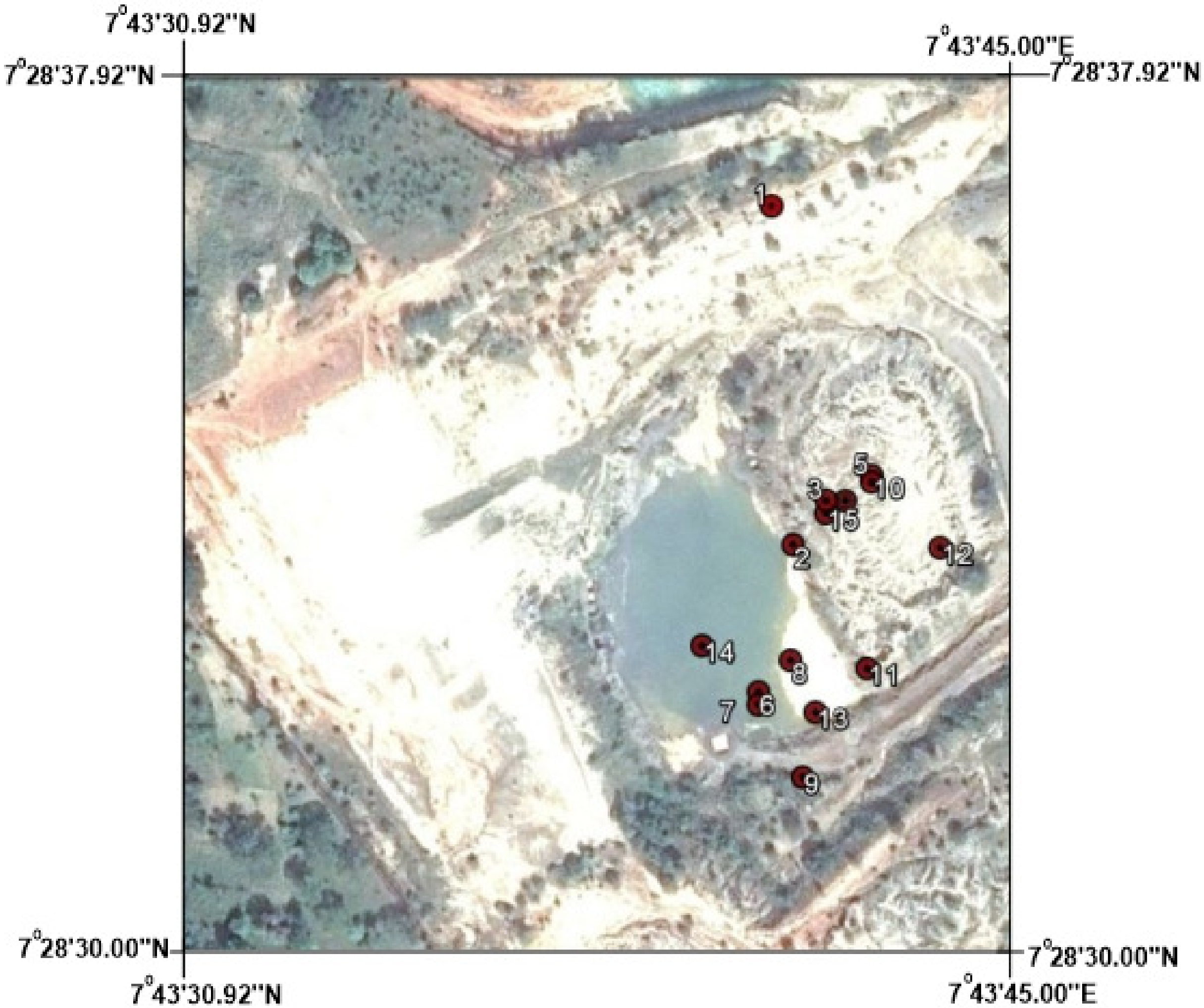

Fig 2: Location of sampling points in the study area

These mining sites were owned by Nigerian Coal Corporation and Nordic Industries Limited. In 2001, Nigerian Coal Corporation had a production sharing agreement with Nordic Industries Limited to jointly produce coal from Odagbo coal mine. A total of 2,712 tonnes of coal were produced from the mine (MMSD, 2001). Presently, artisanal miners are mining coal from the Nigerian Coal Corporation site (Fig. 3). Odagbo is underlain by two geological formations, the Mamu Formation and Ajali Formation. The coal seam is found within the Mamu Formation (Umeji, 2005).

Fig. 3: Coal Mining face at Odagbo

Beneath the Mamu Formation is the Nkporo Shales. The Mamu Formation (Lower coal measures) consists of siltstones, mudstones, grey carbonaceous shales, sandstones and coal seams at several horizons (Ameh, 2013). The shales and mudstones are alternated with thin bands of siltstones. The Ajali Formation is made up of friable coarse grained sandstones and gravelly sands. Overlying the Ajali Formation is the red earthy sand; this was due to the effect of weathering and lateritization (Umeji, 2005).

Sample collection and analyses

Fifteen (15) AMD samples were collected from coal mining pits within the mine in 250 ml polyethylene bottles. Each sample was filtered through 0.45 µm thick mixed cellulose ester membrane. The bottles were washed with distilled water, soaked in 10% nitric acid for 24 hours and finally rinsed with distilled water, prior to sample collection. All the AMD samples were acidified with two drops of HNO_3 to prevent any self-culturing by organisms and were kept at 4ºC before the analysis (APHA, 1989). The trace elements in AMD were determined by atomic absorption spectroscopy at the Geochemical Laboratory of Nigerian Geological Survey Agency (NGSA) Kaduna. A standard solution for each of the element was used for the calibration of the equipment to ensure analytical precision. The detection limit of the analytical tool was 0.01ppm.

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 17.00. Student's t-test was used to examine statistically significant differences in the mean concentration of trace elements. The results of the analyses were expressed as mean standard deviations. The level of statistical significance was set at $P < 0.05$.

Results

Results of trace elements analyses are presented in Table 1.

Table 1: Results of trace elements analyses of AMD from Odagbo coal mine (mg/L) and descriptive statistical data

Sample ID	Pb	Ni	Hg	Co	Cr	Cd	Fe	As
SS 1	0.15	0.21	0.02	0.25	1.19	0.35	3.15	0.01
SS 2	0.48	0.05	0.01	0.42	0.13	0.27	4.25	0.01
SS 3	0.03	0.33	0.01	0.45	0.35	0.25	5.56	0.01
SS 4	0.06	2.01	0.01	3.4	1.01	0.06	6.54	0.01
SS 5	0.13	0.15	0.01	0.92	0.44	0.24	7.72	0.01
SS 6	0.04	0.72	0.01	1.52	1.01	0.23	3.75	0.02
SS 7	0.06	0.34	0.01	0.13	0.31	0.02	4.54	0.01
SS 8	0.05	0.09	0.01	0.17	0.08	0.21	5.64	0.03
SS 9	0.02	1.21	0.01	1.55	0.62	0.07	6.54	0.02
SS 10	0.03	0.07	0.01	0.12	0.09	0.32	3.45	0.01
SS 11	0.11	0.05	0.01	2.05	1.11	0.09	6.53	0.02
SS 12	0.05	0.31	0.01	0.24	0.23	0.31	8.01	0.03
SS 13	0.04	0.65	0.02	0.71	1.01	0.05	7.11	0.02
SS 14	0.08	0.55	0.02	0.12	0.45	0.24	6.87	0.01
SS 15	0.17	0.63	0.01	1.24	0.29	0.22	7.46	0.01
Min	0.02	0.05	0.01	0.12	0.08	0.02	3.15	0.01
Max	0.48	2.01	0.02	3.40	1.19	0.35	8.01	0.03
Mean	0.10	2.01	0.02	0.89	1.19	0.35	8.01	0.03
T – test	0.01	0.07	0.01	0.05	0.06	0.00	0.30	0.01

Min = Minimum
Max = Maximum

Lead ranges from 0.02 – 0.48 mg/l. Nickel content ranges from 0.05 – 2.01 mg/l. The values of mercury ranges from 0.01 – 0.02 mg/l, cobalt ranges from 0.12 – 3.40mg/l. Chromium ranges from 0.08 – 1.19 mg/l. Sample one had the highest concentration of chromium. Distribution of cadmium in the AMD ranged from 0.02 – 0.35 mg/l with an average value of 0.19 mg/l while iron ranges from 3.15 – 8.01 mg/l with an average value of 5.80 mg/l. Arsenic value in the AMD ranges from 0.01 – 0.03 mg/l with a mean value of 0.01 mg/l. Mean values of arsenic, mercury and lead in the AMD were within the Environmentally acceptable quality standards (EQS) for trace element discharges from coal mine (Table 2).

Table 2: Mean values of trace elements compared with published data

Elements (mg/L)	Studied samples	1	2	3	EQS
Pb	0.10	0.001	0.04	1.14	1.0
Ni	2.01	0.24	13.00	<0.001	n.d
Hg	0.02	n.d	n.d	n.d	0.05
Co	0.89	0.18	5.07	< 0.001	n.d
Cr	1.19	0.006	3.69	<0.001	n.d
Cd	0.35	0.0017	0.33	n.d	0.005
Fe	8.01	8.20	2,150	0.437	1.00
As	0.03	n.d	n.d	n.d	0.05

n.d = not determined
EQS = Environmentally Quality Standards (Motsi, 2010)

1. Cravotta (2008)
2. Ball and Nordstrom (1989)
3. Azzie (2012)

The students *t -tests* conducted on the mean values of lead, mercury, cadmium, and arsenic yielded a value of t = 0.01 (Table 1). This observation was considered as significantly different from the environmentally acceptable quality standards for heavy metal discharges from mines. Student's *t-test* conducted on the mean values of nickel, chromium, and iron ranged from 0.06 - 0.30. These variations were considered as not significantly different from the EQS values for heavy metal discharges from mines.

Discussion

Acid mine drainage flowing out from coal mines in South Africa were characterized by high levels of toxic heavy metals such as cadmium, cobalt, copper and molybedenum (Davies and Mundalamo 2010). Also, acid mine drainage from the Endako mine in British Columbia, Canada contained up to 30 mg/l dissolved molybdenum (Nordstrom 2011). The present finding showed that the acid mine drainage from Odagbo coal mine, Nigeria was characterized by high levels of nickel, chromium and iron; whereas molybdenum was absent.

Acid mine drainage from a coal mine in Southern Brazil showed higher concentrations of arsenic, iron, manganese, and zinc (Campanar et al. 2014). Dlamini et al. (2013) reported that the acid mine drainage that emanated from a coal mine at Ngwenya, Swaziland was enriched in chromium, manganese, nickel, cobalt, lead and cadmium. This observation was in line with other studies (Davies and Mundalamo 2010; Lar et al. 2013). The average value of lead in this study was 0.1 mg/l, which was higher than a study by *Ball and* Nordstrom (1989) who reported average value of lead to be 0.04 mg/l from acid mine drainage in Leviathan mine, California, USA. A study by Azzie (2012) found that high lead was determined in acid mine drainages from Vryheid in South Africa. Research by Nordstrom et al. (2011) on the acid mine drainage and climate change in California, USA showed higher concentration of 11.9 mg/l of lead in coal mine drainages. Nickel concentration could be relatively high in certain regions of the world due to mining and other human activities (Gimemo-Garcia et al. 2006). In this study, the concentration of nickel in the AMD from Odagbo coal was relatively high compared to AMD from coal fields in South Africa. This could be due to the local geology and the nature of Odagbo coal deposit. Similar study carried out at Leviathan coal mine, California, USA showed very high concentration of nickel in the AMD. Mercury was relatively very low in the AMD from Odagbo coal mine; similarly, very low mercury contents have been reported in AMD that emanated from several coal fields in Swaziland and South Africa (Dlamini et al. 2013; Azzie 2012). The mean concentration of cobalt in the AMD was lower than the reported value in a study of AMD from Leviathan mine, California, USA by Ball and Nordstrom (1989). Cobalt was completely absent in the AMD that emanated from Wheal Jane coal mine in the UK (Motsi, 2010). Iron was the most abundant element in the AMD from Odagbo coal mine. This was similar to several researches on AMD (Dlamini et al., 2013; Cravotta, 2008). It could be as a result of the larger exposure of materials from the tailings which were oxidized due to the presence of pyrite (Cheng et al., 2009). Acid mine drainage could have a range of constituents but the major one is pyrite, being an iron bearing mineral as the major source of AMD due to its abundance in the environment (Motsi, 2010). The mean concentration of arsenic was found to be lower than the mean concentration of arsenic in AMD from Rio Tinto mine in Spain. Azzie (2012) reported that cadmium in AMD that emanated from Vryheid coal mine in South Africa was less than the environmentally acceptable discharges from coal mines. In this study, cadmium was relatively high compared to the environmentally acceptable quality standard value for heavy metal discharges from coal mine. Research had shown that the presence of arsenic, cadmium, cobalt, chromium, nickel, lead and zinc in acid solutions results from the leaching of sulphides, oxides and silicates that were associated with the coal layers and host rocks such as sandstones, siltstones and limestones (Campanar et al., 2014). In Odagbo mine, the coal and host rocks contain significant quantity of pyrite, sphalerite and silicates bearing rocks such as sandstones, claystones and siltstones (Ameh, 2013).

Conclusion

Concentrations of lead, arsenic and mercury were within the environmentally acceptable quality standard values for metal discharges from coal mines. Nickel, chromium and iron were above the legal concentration range. The result could be used as baseline data for AMD emanating from coal mines around Odagbo and environs in view of the effort made by the two companies that are currently mining coal from the area for coal fired power plants in the state. The acid mine drainage from Odagbo coal mine is a potential source of trace element that could impair the quality of water bodies in this locality. Stringent measures must be taken by the artisanal coal miners to prevent the flow of AMD into surface water bodies around the coal mine such as Ashokpa, Otokpa Rivers and other biodiversity's in the area.

References

Ameh, E.G. (2013). Multivariate statistical analyses and enrichment of heavy metal contamination of soils around Okaba coal mine. American-Eurasian Journal of Agronomy, 6(1): 9-13.

American Public Health Association, APHA (1989). Standard methods for the examination of water and wastewater. 17th edition. Washington.

Azzie, B.A. (2012). Coal mine waters in South Africa: Their geochemistry, quality and classification. Unpublished Ph.D thesis, University of Cape Town, South Africa.

Ball, J.W., Nordstrom, D.K. (1989). Final revised analyses of major and trace elements from acid mine waters in Leviathan mine drainage basin, California and Nevada. USGS Water Resources Investigations Report, 89-4138.

Campanar, V. P., Luiz-Silva, W., Machado, W. (2014). Geochemistry of acid mine drainage from a coal mining area and processes controlling metal attenuation in stream waters, southern Brazil. Annals of the Brazilian Academy of Sciences, 86(2): 539-554.

Cheng, H., Hu, Y., Xu, B., Zhao, J. (2009). Geochemical processes controlling fate and transport of arsenic in acid mine drainage (AMD) and natural systems. Journal of Hazardous materials, 165: 13-26.

Cooper, E.L., Wagner, C.C. (1973). The effects of acid mine drainage on fish populations. United States

Environmental protection Report, 73-032: 114.

Cravotta, C.A. (2008). Dissolved metals and associated constituents in abandoned coal mine discharges, Pennsylvania, USA. Applied Geochemistry, 23: 166-202.

Davies, T.C., Mundalamo, H.R. (2010). Environmental health impacts of dispersed mineralization in South Africa. Journal of African Earth Sciences, 58: 652-666.

Dlamini, C., Fadiran, A., Thwala, J. (2013). A study of environmental assessment of acid mine drainage in Ngwenya, Swaziland. Journal of Environmental Protection. 4(11): 20-26.

Emmanuel, P.R. (2015). Geochemical assessment of acid mine drainage from Odagbo coal mine, Nigeria. Unpublished BSc thesis. University of Jos, Nigeria. PP. 3-40.

Gimeno-Garcia, E., Andreu, V., Boluda, R. (1996). Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. Environmental Pollution, 92: 19-25.

Jamal, A., Dhar, B.B., Ratan, S. (1991). Acid mine drainage control in an open cast coal mine. Journal of Mine Water and Environment. 10: 1-16.

Kaseke, C., Gitari, W.M., Nkuzani, B.B. (2011). Passive remediation of acid mine drainage using bentonite clay: A laboratory Batch Experimental study. Book of Programme and Abstracts. 1st International Conference on Clays and Clay Minerals in Africa and 2nd International Conference on Geophagia in Southern Africa; Bloemfontein, South Africa, 19th -21st October, 2011, pg. 59.

Keating, M., (2001). Cradle to Grave. The Environmental Impacts from Coal. Clean Air Task Force Report, Spectrum Printing and Graphics, PP. 201-213.

Kimmel, W.G. (1983). The impact of acid mine drainage on the stream ecosystem. Pennsylvania coal. Publication of Academic Science. PP. 424-437.

Lar, U.A., Ngozi-Chika, C.S., Ashano, E.C. (2013). Human exposure to lead and other potentially harmful elements associated with galena mining at New Zurak, central Nigeria. Journal of African Earth Sciences, 84: 13-19.

Ministry of Mines and Steel Development, MMSD (2014). Coal: Exploration and Power generating opportunities in Nigeria. A publication of MMSD. P. 5

Motsi, T. (2010). Remediation of acid mine drainage using natural zeolite. Unpublished Ph.D thesis, University of Birmingham, United Kingdom. PP. 254-315.

Naicker, K., Cukrowska, E., Mcarthy, T.S. (2003). Acid mine drainage from gold mining activities in Johannesburg, South Africa. Environmental Pollution, 122: 29-40.

Nordstrom, D.K. (2011). Mine waters. Acidic to circumneutral. Elements, 7: 393-398.

Umeji, P.O. (2005). Palynological study of the Okaba coal mine section in the Anambra Basin, Southeastern Nigeria. Journal of Mining and Geology, 4(2): 193-203.

Omali, A.O., Egboka, BC.E. (2014). Physico-chemical assessment of water around Okaba coal mine, Kogi State, Northcentral Nigeria. Journal of Natural and Applied Sciences, 12(2): 140-203.

Udeyabhanu, S.G., Prasad, B. (2010). Studies on Environmental Impact of acid mine drainage generation and its treatment. An appraisal. Indian Journal of Environmental Protection, 30(11): 953-967.