HEAVY METAL CONCENTRATION IN ENUGU COALMINES, SOUTHEASTERN NIGERIA

Kaizer, A. N.
Department of Geology, Delta State University, Abraka, Nigeria
E-mail: abelkaizer@yahoo.com

ABSTRACT

Two coal mines in the Enugu coal field, southeastern Nigeria were selected to study heavy metal concentration in typical mining sites within the Enugu area. They are the Onyeama and Ogbete coal mines. Mining system within the field is essentially underground. The study area includes mined and unreclaimed, and unmined agricultural land use types. Absence of existing water boreholes in the mine areas could not allow for assessment of metal concentration in the groundwater. However, a comparison of heavy metal concentration in surface water of the mined and unreclaimed areas with those of the unmined agricultural areas indicates that concentrations are significantly higher around the mines than in the unmined areas. Similarly, concentrations of heavy metals within the mines were high compared to the WHO standards for drinking water. Adequate waste disposal, improved geophysical techniques and methods of exploiting coal, and standard water treatment procedures are recommended to minimize hazards arising from coal mining activities.

Key words: *Heavy metal, coalmine, Enugu. Nigeria.*

INTRODUCTION

Pure coal consists essentially of carbon. Mining of coal deposits may concentrate or release toxic materials to the environment. Heavy metals are of considerable concern based on their mode of accumulation and toxicity (Chow *et al.,* 1973). Their presence in coal deposits is inevitable since they are taken up easily and accumulate in ecological materials (Numberg, 1984; Bruland, 1974). Occurances of heavy metal in coal depend on factors such as the nature of the environment of deposition, source of plant materials and tectonics. Such environments may contribute heavy metals to the coal as chemical precipitates while the coal is formed or after it has formed (Hawley, 1955). Thus the availability of heavy metal in coal deposits depends on the nature of sedimentation, source of water and the character of the land undergoing erosion during its formation. Although, heavy metals are essential components of a normal biological system, they may constitute dangerous environmental pollutants when present above certain limits. This study therefore, attempts to access the concentration level of heavy metals in surface water within typical coal mining sites around Enugu. It is hoped that the findings of this study would assist in providing a practical rehabilitation measure for communities living around areas of active coalmines.

STUDY AREA

The study area lies within the Enugu City, Southeastern Nigeria and located between longitude $7^0 24^1$E - $7^0 30^1$E and latitude $6^0 29^1$N - $6^0 31^1$N (Fig. 1). Rocks consist of Cretaceous bedrock of Maastrichtian age and essentially of the coal bearing Mamu Formation and a cap of Ajali formation (Bain, 1924; Reijers, 1996; NCC, 1982). According to Simpson (1954), the coal at Enugu is formed as a result of insitu peat transformation. Within the study area, the climate reflects a humid tropical type within two distinct seasons (Ezeigbo and Obiefuwa, 1995). Major surface water bodies include the Ogbete and Ekulu rivers with minor tributaries, which empty their contents into the larger Ogbete and Ekulu Rivers. The mines considered for this study are the Ogbete and Onyeama coalmines, which are drained mainly by the Ogbete and Ekulu Rivers respectively.

METHODOLOGY

Two mines (Onyeama and Ogbete) in the Enugu coal field were selected for the study. The study area included active coal mines and unmined agricultural areas with major river networks and tributaries draining them. Qualitative determination of the heavy metal concentration in the coalmines was afforded by comparison of the hydrogeochemical analysis of the surface water in the mined and unreclaimed area with that of the unmined agricultural areas and the WHO standards for drinking water. Water samples were taken from the Ekulu and Ogbete rivers along with their tributaries to represent the Onyeama and Ogbete coalmines drainages respectively. Upstream Ogbete River (before the mine) was chosen as control to represent unmined area. Samples were collected based on the one dimensional segmenting method of the steams in one litre chemically clean, colourless plastic bottles and subsequently treated by adding few drops of 1ml concentrated trioxonitrate (V) acid (HNO_3). The samples were then preserved in the field at a temperature of about 4^0C in ice packed coolers before transferring to the laboratory for Atomic Absorption Spectrometric analysis. On the other hand, Fresh chips of the unwashed coal and fireclay samples were collected at random from both mines for analysis of the heavy metal contents. Samples were washed with distilled water, air-dried, crushed and pulverized into fine powder of less than 0.125mm with the aid of a set of sieve. I gramme of each sample was then introduced into a 50ml Pyrex flask pretreated with de-ionized water and subsequently digested by adding 5ml conc. HNO_3 to each flask at temperature of about 200^0C on a sand bath. The set up was left to stand for 2hrs after which they were allowed to cool. After cooling the samples were diluted to the 50ml mark by adding water and filtered. The filtrates were then subjected to analysis using the Perkin Elmer 2380 Atomic Absorption Spectrometer with deuterium as background corrector and appropriate lamps for the analysis of the various metals. A stock solution of the various metals was prepared by dissolving one gramme of the pure metal in 20ml of HCl and diluted to 1 litre mark of a volumetric flask with de-ionized water to give 100mg/l of the metal stock solution. This process was repeated for all metals analyzed. Several solutions of concentrations 4.00mg/l, 6.00mg/l and 8.00mg/l were prepared from the stock solution by several dilutions as described by Allen et al. (1974). Analyses of the samples were carried out according to standard methods such as APHA (1995).

RESULTS AND DISCUSSION

The result of analyses on 48 water samples and 16 coal/fireclay representative samples taken from the Onyeama and Ogbete coalmine revealed varied concentration level of parameters within the coalmines (tables 1-3). Control water samples were taken outside the mines to serve as background for all water samples within the mines. The results showed various concentrations of parameters within the mines. A measure of the threshold for qualitative determination was in part gained by the comparison of the results with those obtained in background samples taken outside the mine areas (upstream Ogbete River). A further comparison was done from the results obtained for the coal samples from both mines and WHO drinking water standards. The result showed that the Enugu coal was rich in iron (Fe) ranging between mean concentrations of 8.03 – 11.5mg/l in both mines. This high value was corroborated by the iron content of 3.05 – 4.25mg/l recorded in the water samples with a background of 1.03mg/l thus the characteristic reddish brown coloration of the rivers. High iron content in the water may be attributed to ground water and surface water flowing through "iron rich" lateritic soils, bogs and coal deposits, enrichment through processes of leaching, mine drainage and flooding. The Enugu coal is reported as having a "difficult" to "formidable" washing properties, with ash content between 10.3%w and 13.8%w in the Enugu and Onyeama coal respectively (NCC 1982). The mean concentration of metals in the raw coal range between Cu 0.38 – 0.44mg/l, Zn 0.19 – 0.25mg/l. Cr 0.05 – 0.06mg/l, Pb 0.018 – 0.02mg/l, Cd 0.06 – 0.08mg/l and Ni 0.10 – 0.22mg/l (tables 1-2). In the water samples, values range from Cu 0.10 – 0.27mg/l with a background of 0.09mgl, Zn 0.09 – 0.20mg/l (background 0.11mg/l) Cr 0.03 – 0.05mg/l (background 0.02mg/l), Pb 0.14 – 0.17mg/l (background 0.04mg/l), Ni 0.02 – 0.06mg/l (background 0.04mg/l). Mean values were relatively high compared with the WHO 2006 standards for drinking water. The results reported herein suggest that in terms of international standards, Ekulu River at Onyeama mine and Ogbete River at Ogbete mine are significantly enriched in metals with generally low pH. Also the high iron content which was up to 1.0mg/l impacts tastes and toxicity to aquatic lives. It caused brown to red coloration (typical of the river waters) and stains (Ezeigbo, 1988). Major contributors of metals to the rivers include leaching of waste dumps, wash outs from waste tips and flooding of the mines.

Table 1: Metal Concentration in Coal and Fire Clay Sample from Ogbete and Onyeama Coal Mines in mg/kg

PARAMETERS	CONCENTRATION (Ogbete Coal/fireclay) N = 8		CONCENTRATION (Onyeama Coal) N = 8	
	Range	Mean	Range	Mean
1ron (Fe)	7.60 – 10.15	8.03	11.40 – 11.60	11.50
Copper (Cu)	0.42 – 0.48	0.44	0.36 – 0.39	0.38
Zinc (Zn)	0.18 – 0.21	0.19	0.12 – 0.27	0.125
Chromium (Cr)	0.03 – 0.06	0.05	0.04 – 0.08	0.06
Lead (Pd)	0.22 – 2.20	0.20	0.15 – 0.19	0.18
Cadmium (Cd)	0.05 – 0.07	0.06	0.06 – 0.09	0.08
Nickel (Ni)	0.20 – 0.26	0.22	0.01 – 0.02	0.10

Table 2: Metal Concentration In River Water Samples From Ogbete And Ekulu Rivers In Mg/l

PARAMETERS	OGBETE MINE (Ogbete River) N = 20		ONYEAMA MINE (Onyeama River) N = 18		BACKGROUND (Ogbete River Upstream) N = 10		WHO 2006
	Range	Mean	Range	Mean	Range	Mean	Mean
1ron (Fe)	0.90 – 8.22	4.25	0.29 – 6.31	3.25	0.12 – 1.03	1.03	0.03
Copper (Cu)	0.06 – 0.11	0.10	0.22 – 0.29	0.27	0.03 – 0.014	0.09	0.05
Zinc (Zn)	0.04 – 0.25	0.09	0.18 – 0.23	0.20	0.07 – 0.20	0.11	5.0
Chromium (Cr)	0.02 – 0.06	0.05	0.01 – 0.04	0.03	0.02 – 0.03	0.02	0.01
Lead (Pd)	0.18 – 0.27	0.17	0.05 – 0.20	0.14	0.02 – 0.03	0.04	0.01
Cadmium (Cd)	0.05 – 0.11	0.05	0.01 – 0.05	0.02	0.02 – 0.07	0.04	0.01
Nickel (Ni)	0.04 – 0.72	0.06	0.01 – 0.25	0.02	0.02 – 0.50	0.04	0.01

The results reported herein suggest that in terms of the international standards of FEPA and WHO based on the tentative limits for toxic substances in drinking water, the Enugu mine area is significantly impacted. The very low pH of the water is probably associated with the high sulphate content of the formation. Oxidation of common pyrite produces sulphuric acid that further helps in dissolving out mineral constituents. Furthermore, the relatively low proportions of the basic components such as CaO, MgO may account for part acidity of the water in the mines. According to Ezeigbo (1988), sulphate content greater than 250mg/l is objectionable in water while, water containing about 500mg/l tastes bitter. High iron content above the limit for drinking water characterizes the mines because iron forms a major constituent of the lateritic soils that underlies the area. Iron is also derived as ferrous iron (Iron II Oxide) - a common constituent of bogs and swamp, lignites and coal deposits. Groundwater in contact with such strata frequently contains between 1 to 10mg/l of ferrous iron (Mandel and Shiftman, 1981). The total amount of dissolved ion in an aqueous solution is a function of its redox potential (eh) and pH. Oxygenation of such water oxidizes ferrous iron (iron II oxide) to ferric iron (Iron III oxide) which precipitates. Concentrations of iron exceeding the WHO (2006) standard, limit of 0.3mg/l can stain surface (clothing, cooking utensils and plumbing fixtures). Up to 1.8mg/l of iron in drinking water impacts a metallic taste while it is toxic to some aquatic species at concentrations of between 0.32 and 1.0mg/l. High concentrations of iron in water impacts a brown colouration to the water due to oxidation of insoluble ferric oxide on exposure to air which is typical of the surface waters around the mines. The results of heavy metal analysis showed generally high concentrations of certain metals above WHO recommended concentration limits. Pollution therefore can be attributed to abundance of chromium (Cr), cadmium (Cd), nickel (Ni) and to a lesser extent lead (Pb) within the mines. The deviation in pattern displayed in the water chemistry around Ogbete mine from others may be related to the process of washing and processing of the coal at Ogbete mine which releases more of these elements into the environment. Further more, other processes of combustion or conversion of the coal, weathering and disposal may add up to the total amount. However, the ground water samples could not be analyzed due to absence of boreholes and hand dug wells in the mines.

CONCLUSION

In minimizing health and environmental hazards due to heavy metals in coal-mines environments, adequate mining and scientific waste disposal practices and water treatment processes should be encouraged. Actions toward updating the Nigerian coal reserves should consider the implications on the environment and possible ways of reducing such problems. All aspects of environmental hazards should be considered in developing a mine plan. Modern reclamation methods should involve sealing of abandoned mines, seeding and mulching to produce vegetative cover and to check erosional activities, which may introduce toxic substances into nearby surface water systems.

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