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ENVIRONMENTAL POLLUTION FROM COAL MINING ACTIVITIES IN THE ENUGU AREA ANAMBKA STATE NIGERIA

by

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ABSTRACT

Hydrogeological studies of the Enugu coal mining area were carried out which included hydrogeochemical analyses of water samples. These analyses revealed high sulphate and iron content in the acid mine drainage water as well as high total dissolved solids' (TDS) and low pH (acidity) values. The water issues from the Ajali Sandstone formation and the underlying carbonaceous Mamu Formation and is classified as hard water. As a consequence of under-mining this aquifer, huge volumes of (polluted) water has flooded the mines are channelled into some streams or rivers which in turn get chemically polluted. Remedial measures have been indicated which include the following:

(1) the treatment of acid mine water before pumping into streams or rivers;
(2) the disposal of mine spoil wastes in carefully prepared and designed disposal sites;
(3) planned and detailed mapping of the fractures in the Mamu Formation for more effective dewatering scheme and increased exploitation of the overlying Ajali Sandstone aquifer to reduce or limit the amount of water flooding the mines in the underlying Mamu Formation.

INTRODUCTION

Enugu with an estimated (1990) population of over 400,000 owes its urban status primarily to the existence of very large deposits of coal (mainly of sub-bituminous grade), estimated at 1.5 million tons, that have been mined since 1916(1). Enugu later became the administrative capital of the then Eastern region of Nigeria and at present remains the capital of Nigeria's Anambra State. Its present large population has arisen both due to the existence of large number of industries and a large Government

Secretariat that have attracted large number of workers and their dependents to the city. Densely populated suburbs have therefore grown around the Enugu urban.

A major problem encountered in the supply of potable water to Enugu is the acid mine drainage pollution caused by coal mining activities in the area. The acid mine drainage water has elevated values of sulphate and iron ions and the pH is very low. Thus, the mine water is acidic which corrodes mining and plumbing equipment. The water is also moderately hard and has high total dissolved solids (TDS) concentration. Figure 1. Physiographic and geological map of the area.

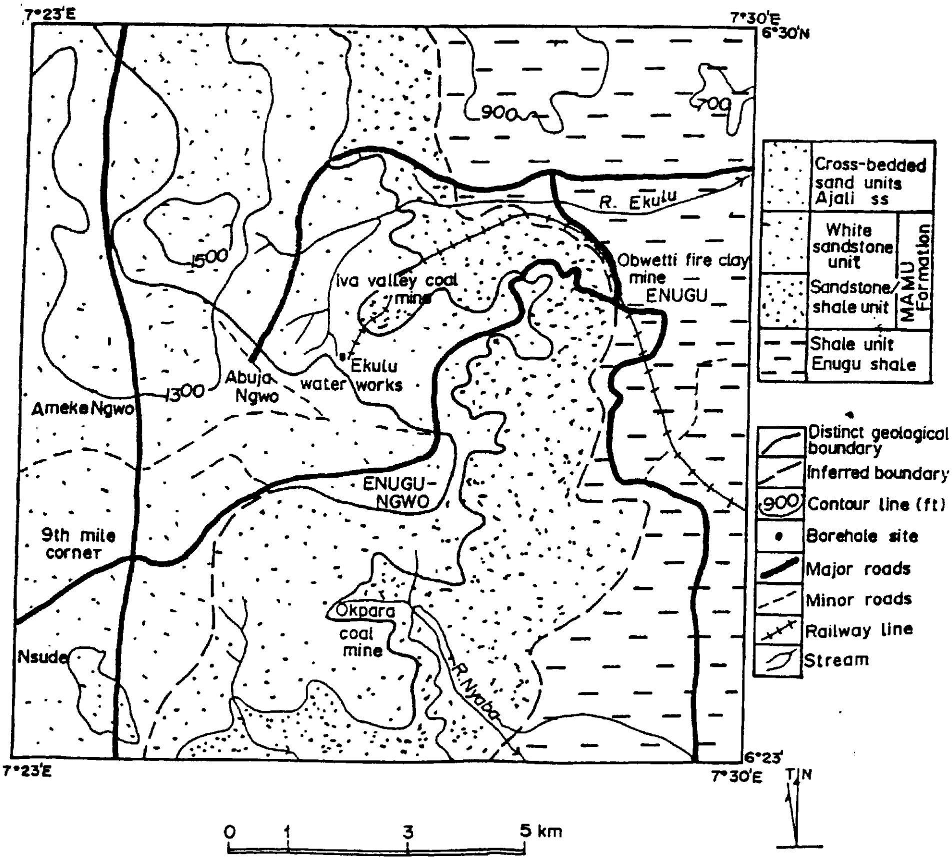

Figure 1. Physiographic and geological map of the area

Fractures create hydrologic interconnectivity between the highly permeable overlying Ajali Sandstone formation and the largely moderately permeable underlying carbonaceous Mamu Formation that is mined. Problematic flooding of the mines occur and most effective and efficient dewatering scheme is desirable to cope with the problem. At present the floodwaters are channelled into streams or rivers that get contaminated or even polluted as a result. This paper examines these problems and proffers solutions to them.

PHYSIOGRAPHIC SETTING AND GEOLOGY

Three largely conformable geologic formations, the Enugu Shale (Campanian), the Mamu Formation (Lower Maastrichtian) and the Ajali Sandstone (Upper Maastrichtian) comprise the geology of the Enugu coal mine area (Figure 1).

The Enugu shale outcrops occur in the plains east of the north-south trending escarpment. This formation consists of soft grey to dark grey shales and mudstone as well as intercalations of sandstone and sandy shale. The shales weather rapidly to red clay soil which forms lateritic capping of considerable thickness.The Mamu Formation consists of fine to medium grained sandstones, sandy shales, shales and mudstones. Five coal seams occur and the third which maintains a workable thickness in excess of 1.5m is mined. The formation is highly fractured and is about 395m thick in the area. The shales contain pyrite flakes and show sulphur stains.

The Ajali Sandstone which overlies the Mamu Formation consists of thick friable poorly sorted highly cross-bedded sandstone that is generally white in colour but sometimes is iron stained. Intercalations of mudstone and shale occur. The Ajali Sandstone which is about 406m thick in the area is overlain by lateritic/ red earth deposits.

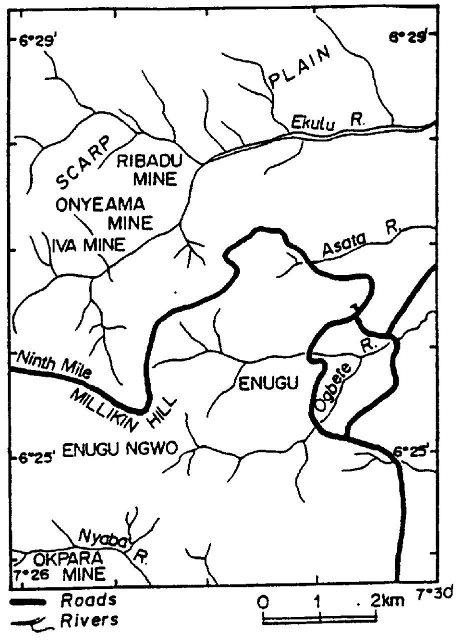

Figure 2 Drainage of the area

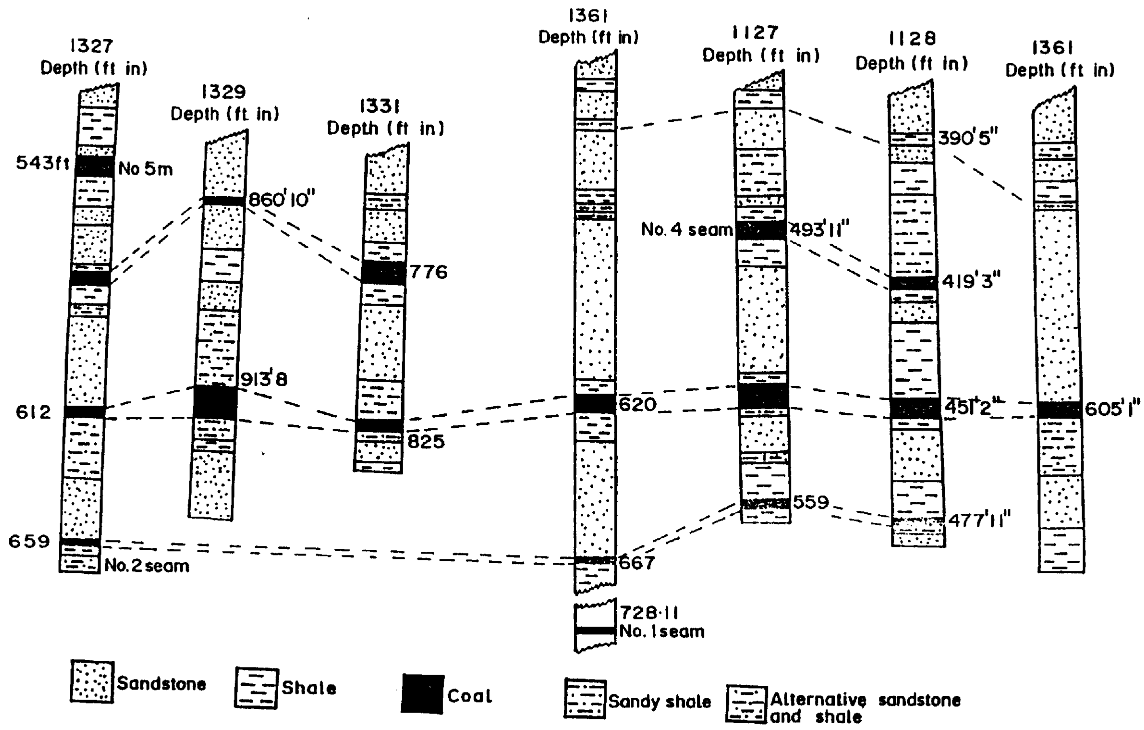

Figure 3. Lithologic logs of some of the boreholes drilled for coal corporation in the study area (De Swardt and Casey, 1963)

The formations in the Enugu coal mine area are highly fractured (as both jointing and faulting occur). Major faults exist was well as criss crossing minor faults, slips and grabbers. The disturbed nature of the fault zones, the uncertainty of the direction and throw of major faults, and huge groundwater flows into the mines render coal mining hazardous (2, 3, 4).

HYDROGEOLOGY

The study area is tropical and experiences two seasons both of which are warm. Mean annual rainfall is about 1600m (5). The rainy season generally lasts from April to October while the dry season lasts from November to March. The natural vegetation is tropical rain forest type which has largely changed to guinea savannah due to human activities such as farming.

Surface Water Hydrology

The area is well drained. Major streams/rivers include the Ekulu, Asata, Ogbete and Nyaba (Figure 2). Most of the smaller streams rise from about 300m a.m.s.l. in the form of springs and flow through deep V-shapped valleys incised in the soil materials and the Ajali Sandstone. These, however, are often not perennial and get dry during the late part of the dry season. More perennial streams rise from the middle levels of the escarpment near the base of the Ajali Sandstone. The streams or rivers, some of which appear fracture-controlled in their flow paths give rise to dendritic drainage pattern (Egboka, 1985).

The acid mine drainage waters from the various mines are continuously pumped into the nearby streams thereby polluting them. The Ekulu River water employed (usually after treatment) to augment water supply to the Enugu metropolis is also affected.

Groundwater Hydrology

Two main aquifer systems, one unconfined and the other confined exist in the area as can be deciphered from the borehole lithologic logs (Figure 3).

Table 1. Aquifer parameters of the Ajali Sandstone and Mamu Formation, after Egboka, 1983.

Aquifer	Ajali Sands	Nkpologwu Sands	Mamu Sands (1)	Mamu Sands(2)
Formation	Ajali Ss	Ajali Ss	Mamu Fm	Mamu Fm
Hydraulic conductivity K, (cm/s)	9.2×10^{-3}	2.1×10^{0}	9.2×10^{-3}	2.6×10^{-2}
Specific discharge, V (m^3/yr)	17.5	3,936.0	14.5	40.4
Groundwater velocity, V' (m/yr)	49.9	1,900 000	48.4	134.6
Total discharge, Qt (m^3/yr)	109.7	29,223.7	12.4	23.1
Transmissivity, T (m^3/yr)	3.2×10^{5}	8.5×10^{7}	4.4×10^{4}	8.1×10^{4}

The Aiali Sandstone and an upper white sandstone members of the Mamu Formation are largely unconfined, while two confined units exist below within the Mamu Formation. Table 1 shows the aquifer parameters of the Ajali Sandstone and the Mamu Formation.The values indicate highly permeable to moderately permeable aquifers. Fractures create connectivity between the Upper Ajali largely water table aquifer and the lower Mamu Formation aquifer (water table to pressure conditions) and large-scale flooding of the mines result.

HYDROGEOCHEMISTRY AND WATER POLLUTION

Surface water and groundwater samples from the area were analysed between 1987 and 1988. Table 2 shows the hydrogeochemical data of the Onyeama, Okpara as well as those of the abandoned Iva Valley coal mine and active Obwetti fireclay mine. Stiff diagram and Piper diagram analyses show magnesium as the predominating caution and sulphate as the predominating anion. The prevalent water type is thus the magnesium - sulphate type. The highest concentration of the sulphate ions occurs in the Okpara coal mine waters. At the abandoned Iva Valley coal mine (see Figure 1) bicarbonate ions are significant (up to 25%) even though sulphate ions remain the highest. In the Onyeama and Okpara mines strong acids are predominating over the weaker acids and hydrogen ions combine with sulphate ions to form acid. In the Iva Valley coal mine area, the composition is such that weak acids are predominating over the strong ones. A significant ion exchange and limited mixing is probably the cause of this trend.

Table 2. Hydrogeochemical data of Enugu coal mine groundwater

Geochemical Parameters	Onyeama Mine	Okpara Mine	Iva Valley Mine	Obwetti Fireclay
pH	2.8	2.3	6.1	6.3
Colour (Platinum/Cobalt True Colour)	5.0	10	20	25
Electrical Conductivity Uhoms	700.0	1550	110	800
Total hardness mg l^{-1}	100.0	100	80	-
Silica as SiO_2 "	30.0	30	7.5	12.5
Nitrate "	1.20	1.11	0.13	1.02
Total iron "	8.4	25.76	1.7	6.4
Sulphide "	1.4	-	1.8	-
Sulphate "	310.0	420	58.0	174.0
Magnesium "	158.08	85.12	12.16	111.87
Sodium "	6.95	1033	4.40	-
Potassium "	9.46	2.19	2.35	-
Calcium "	4.0	6.41	4.01	3.21
Chloride "	10.42	1.99	-	8.93
Phenolp Acidity	124.0	320	10	10
Total Alkalinity	20.0	16	80	90
Total dissolved solids"	330	785	65	515
Free Carbondioxide	230	38	8	68
Bicarbonate "	16	9.6	65.0	80.5

Water Quality

Coal mining in the Enugu area has caused significant degradation in groundwater quality. Coal mining and milling expose the overburden and mine spoils to oxidation. Enugu coal deposits as most others are associated with pyrite (and marcasite FeS_2).

This is stable for conditions below water table but is oxidized if the water table is lowered. Oxidation of this pyrite produces sulphuric acid which renders the waters corrosive. pH values are low: 208 at the Onyeama mines 2.3 at the Okpara mine and 6.1 at the abandoned (for over 20 years) Iva Valley coal mine and 6.3 at the active Obwetti fireclay mine. The low pH or corrosive water produced has increased leaching action. As a result, elevated total dissolved solids (TDS) levels obtain. The water also corrodes mining equipment.

Sulphate ions are in high concentration in the (acid mine drainage) waters. Values of 310 mg/l , 420 mg/l , 58 mg/l and 174 mg/l were obtained for the Onyeama, Okpara, Iva Valley and Obwetti (fireclay) mines respectively. Sulphate ions in excess of 250 mg/l may have laxative effect while (the presence of) hydrogen sulphide (whose characteristic odour was perceived) may be toxic (8 and 9). Its high solubility favours its increased presence in the water.

High iron concentration also characterize the water. Total iron concentrations ranged from 1.7 to 25.76 mg/l in the mines. Iron in the coal mine area is probably largely due to the large presence of pyrites. Above 0.3 mg/l water containing it stains plumbing fixtures~ has metallic taste and may be toxic to some aquatic species (10, 11, 12).

Acid mine drainage waters flooding the mines are pumped into some nearby streams and rivers thereby polluting them. In the streams/rivers affected by mining activities which include the Ekulu River whose waters part supply the Enugu urban, the pH is quite low (3.3 - 5.6), the total iron content is (1.7 - 16.4 mg/l) (high) and there are elevated levels of sulphate ions (14.8 - 348 mg/l). In the streams and rivers not affected by mining activities, the pH values are higher (6.2 - 6.8) while the iron content and that of sulphate are less ranging 0.19 - 1.40 mg/l and 0.o - 28.86 mg/l respectively.

All the surface streams analysed showed high level of bacteriological pollution and should be treated employing chlorination before household use.

Other Environmental Problems

Other environmental problems arising from coal mining activities include devegatation, fault reactivation and the presence of noxious gases. The high acidity of the mine waste limits the amount of nutrients in the water that would encourage the flourishing of vegetation. The highly fractured nature of the formations of the Enugu coal mine area with the presence of major faults as well as criss-crossing minor faults, slips and grabbers make fault reactivation a potential hazard. Noxious gases such as hydrogen sulphide (H_2S), carbon monoxide (CO), methane (CH_4) as well as oxides of sulphur and nitrogen are produced mainly through the burning of mine spoils. Miners remain exposed to the harmful effects of these gases and other negative effects of coal mining in this area.

DISCUSSION AND CONCLUSION

Acid mine drainage pollution is a major pollution in the Enugu coal mine area affecting the chemical quality of both the groundwater and surface water into which the waters flooding the mines are emptied. Waters from the coal mine area may, with some treatment mainly involving pH and iron, be employed in augmenting the present inadequate supplies that come from the Ninth mile borehole network and the Ekulu River reservoir. This apart from mitigating the potential risks of well interference and land subsidence that could arise from over-utilization of over-concentrated borehole network in the area, could also lessen the mine flooding problem. At present over 18 million litres of mine water are discharged daily into nearby streams (Ezeigbo, 1988). Larger diameter pipes may need to be laid for better utilization of this enormous volume of mine water. Planned and detailed mapping of the fractures in the Mamu Formation would be necessary before effective and efficient dewatering scheme is effected.

Acid mine drainage pollution is increased by the indiscriminate dumping of mine spoils whose leachates also pollute the surface streams. OKAGBUE and ONUOHA (Okagbue and Onuoha, 1986) have suggested calcining in a chamber that will allow the trapping and retention of gases as an effective way of controlling the environmental pollution but noted that the method may have high original and maintenance costs. They may be disposed of in properly designed sites where they may be compacted and covered with clayey soil to mitigate oxidation reactions.

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LIST OF SYMBOLS

a.m.s.l.	above mean sea level
cm /s	centimetres per second
K	Hydraulic conductivity
M	meter(s)
mg/l	milligrams per litre
m/yr	meters per year
T	transmissivity
Qt	total discharge
V	groundwater velocity
V	specific discharge