Nigerian Journal of Microbiology, 2009, Vol. 23(1);1821-1826

Effect of Mine-water on Agricultural Soil Quality in Ishiagu, Ebonyi State, Nigeria.

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Abstract

The effects of mine water from Pb and Zn mines on agricultural soil in Ishiagu, Ebonyi State, Nigeria was investigated using standard analytical methods. The soil was observed to be acidic with loss of SO_4 PO_4 NO_3 and total organic matter (TOM) with soil impaction. However the rate of loss of the soil nutrients was dependent on distance from the discharge points. The old discharge area had higher impact than the recently started discharge area. Pb and Zn were significantly high while Cr, Cd and Fe were non-statistically high in the polluted soil ($P=0.05$). In microbial estimation, total heterotrophic bacteria (THB) were the least adversely affected while nitrifying bacteria were the most affected. Phosphate solubilizing and cellulolytic bacteria were equally adversely affected. Results obtained therefore indicated adverse effects on agricultural soil and suggest the need for proper remediation before use to enhance fertility and reduce heavy metal levels.

Key words: Mine effluent. Soil fertility, bacteria, and parameters
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Introduction

Most mining activities are synonymous with environmental degradation. Wastes generated in the process are often discharged into the surrounding environment, especially in developing countries (Li *et al*, 2005 Nwaugo *et al*, 2007a). The careless disposal of waste has often resulted in the distortion of the usual ecological balance in any given environment (Onyedike and Nwosu, 2008, Ano *et al,* 2007)). This problem is often encountered more in open cast mining of solid minerals all over the world.

The soil is known to serve several human needs in addition to agricultural ones. It has also been described as the habitat with the greatest amount of biogeochemical transformations (Pelczar *et al*, 2003, Prescott *et al,* 2004). These transformations are mediated by soil dwelling organisms and their metabolites. The contamination of agricultural soil by waste has been known to cause pollution of the impacted soil, which in turn, destabilizes the ecological balance (Parham *et al,* 2003, Oliveira and Pampulha, 2006). The contamination of agricultural soil by mine waste water, also alters the soil quality in terms of nutrients and the agents which mediate the biogeochemical cycles (Montellin and Touraine, 2004, Li *et al,* 2005).

Ishiagu has remained a metal mining (Pb and Zn) community for over 30 years with its attendant problems unaddressed. The waste water from these mines is simply pumped into the surrounding farmland. Nwaugo *et al* (2007a) and Obiekezie *et al* (2006) have reported the effects of post operational effects and quality of domestic water in the area. In Nigeria, there is dearth of information on mine water effects on the environment. This study therefore was designed to bridge this gap.

Materials and methods

The study area, Ishiagu is located in the southern part of Ebonyi State where open cast mining of Pb and Zn is common and lies between latitude $7^0 30'$ to $7^0 37'$ E and longitude 5°52' and 6°00' N. The open cast mining leaves heaps of mine tailings and large pits in its wake. In the process of mining, the mine water is pumped into the nearby farmland to evacuate water from the active pits (Nwaugo *et al,* 2008).

The area has typical Guinea Savanah vegetation. The climate is tropical with mean annual rainfall of 2000mm and the vegetation is made up of a combination of tall grasses with baobab trees scattered all over. However, the banks of the streams and Ivo River have ever green trees growing (Fig. 1 shows the study area and the mining area).

Soil samples were collected from different sites in the study area. Sample one (S1) was collected from the point of fischarge of the mine water sample (S2) was from 10m away long its flow while sample three (S3) was from 100m away. Sample four (S4) (control) was taken from an area over 500m away in an unimpacted area devoid of the mining activities. The sampling was done in two areas old effluent discharge area (a) (S1-S3) and (b) new discharge area (NS1-NS3).

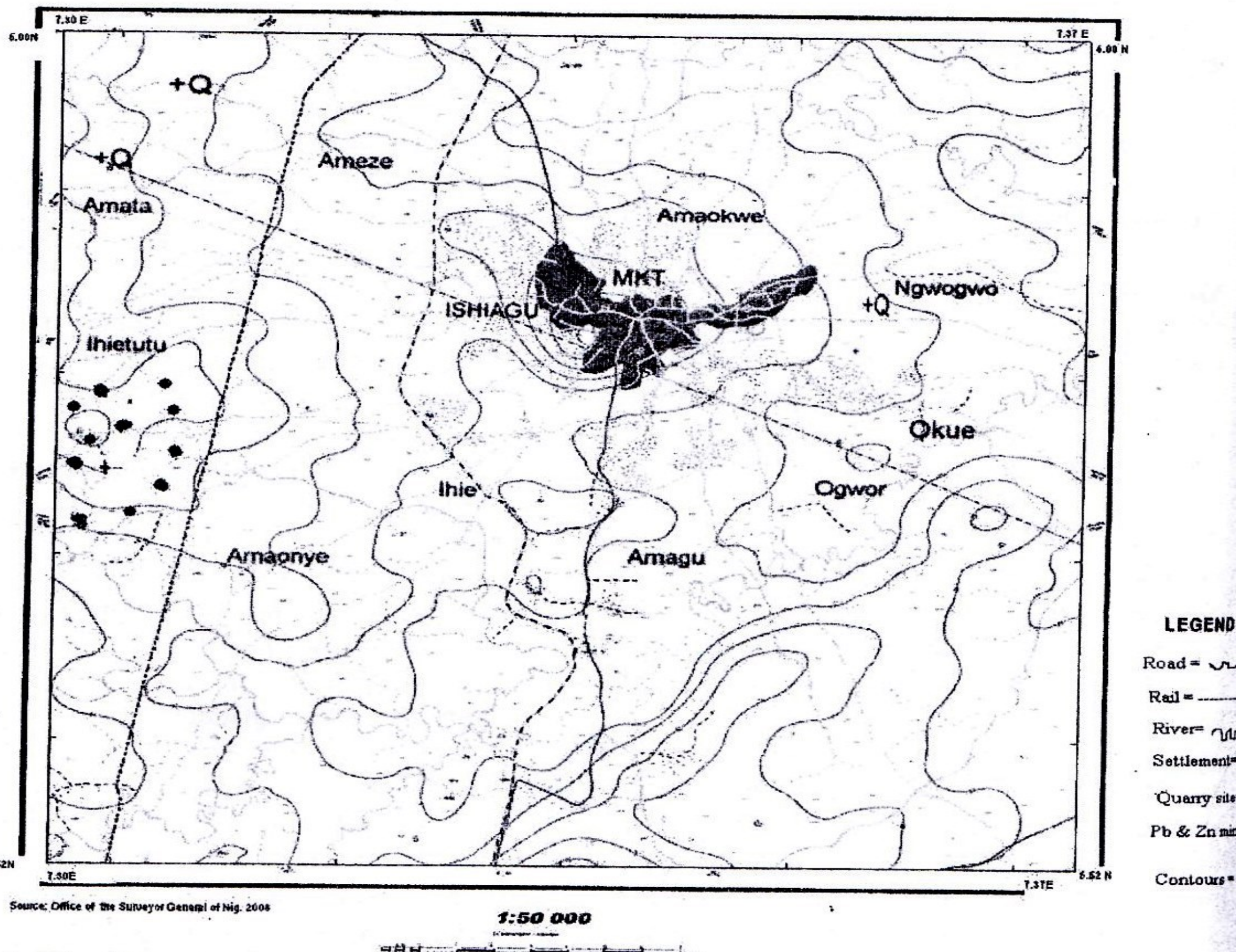

Fig. 1 Map of Ishiagu - the study area

Sampling

At each sampling spot, 3 soil samples were collected within 1-2m and pooled together to make the sample for that sampling site.

Soil properties and metal contents

The soil pH and temperature were determined at the site using multipurpose tester (Jenway, HANNA 1910 tester) organic matter content was determined using loss of ignition method as described by UNEP (2004) while soil moisture content was determined using drying to constant weight method (Pansu and Gautheyrou, 2006). Soil sulphate (SO_4), nitrate (NO_3) and Phosphate (PO_4) were using the method outlined in UNEP (2004).

Soil heavy metals, (Pb, Zn, Cr, Cd, and Fe) concentrations were determined using the Atomic Adsorption spectrophotometer (AAS) after acid digestion as described in AOAC (2005).

Microbiological analysis:

Prevalence of specific groups of bacteria was determined by using the viable count technique. This was done using specific culture media and spread plate technique after ten-fold serial dilution. The groups of bacteria determined were total heterotrophic bacteria (THB), cellulolytic bacteria (CB), nitrifying bacteria (NB) and phosphate solubilizing bacteria (PSB). The THB was determined using tryptone soy agar, CB with Cellulose Agar and NB with modified mineral salt Agar. The prevalence of the PSB was determined using the PSB medium (US Patent, 2003). Each group was expressed as cfu/g.

Results

Table 1 shows the Physico-chemical parameters of the various soil sample analyzed. The pH values of the discharge points of both old and new effluent discharge areas (S1 and NS1) (4.5-6.2) were acidic. The acidity of the soil decreased as the distance increased away from the discharge points till it becomes alkaline in the control (S4)-7.8. Variations in temperature values were not statistically significant (P=0.05) though higher values were observed in S1 and NS1 than in S3, NS3 and control (S4). TOM, SO_4, PO_4 and NO_3 were equally lowest at the point of discharge of the mine water. Their values increased with distance away from the discharge points (S2, S3, NS2, and NS3). The parameters had their highest values in the control soil (S4).

Values of heavy metal concentrations are shown in Table 2. Pb and Zn had values which were statistically higher in the impacted soil than the control (P=0.05). Higher impaction resulted in increased concentrations of these metals in the impacted soil. Again values obtained in the new mine water discharge area (NS1-NS3) were lower than their counter parts from the old discharge area. Concentrations of Pb ranged from 266.91-102.35 mg/g for S1-S3 (old discharge area) and 167.30-41.35mg/g for NS1-NS3 (new discharge area). The concentrations of Cd (0.13-0.07mg/g) and Cr (014-0.06 mg/g)were not statistically different (P=0.05) from the control soil values (0.3 for Cr mg/g) accept at S1 and N1. Fe showed non significant increase too.

Table 3 shows the effects of the mine water on soil microbial groups. Bioload of THB ranged from 2.4×10^4-3.7×10^7 cfu/g (S1-S4) and 3.7×10^4 - 1.7×10^7 ctu/g (NS1-NS3) while NB had 1.2×10^1 -3.7×10^3 cfu/g and 1.0-1.6×10^2 cfu/g in the various soil samples (Table 3). CB had higher bioloads than PSB in both old and new mine water discharge areas. Correlation analysis with bioloads and distance as variables showed positive correlation as effects of the impact decreased with distance away from discharge points.

Table 1: Physicochemical parameters of the impacted and unimpacted soil

Parameter.	S1	S2	S3	S4	NS1	NS2	NS3
PH	5.4	5.7	6.2	7.8	5.9	6.2	6.4
Temp^{0}C	29.7	28.8	28.4	28.2	28.9	28.3	28.2
TO	5.42	5.82	6.2	7.5	5.62	5.97	6.5
SO_4	9.21	11.42	16.79	21.14	12.7	15.24	18.26
NO3%	0.37	0.48	0.92	1.04	0.48	0.85	0.95
PO_4	2.04	2.55	3.89	4.94	2.57	3.96	4.10

Values are means of 3 times sampling result.
S1-Old discharge point; S2-10m away from the old discharge area and S3 =100m from the discharge point. S4= control (500m away from the discharge area).
NS1 – NS3 – similar distances but in the new discharge area.

Table 2: heavy metal concentration in the impacted and unimpacted soil

Metal	S1	S2	S3	S4	NS1	NS2	NS3
Pb mg/g	266.41 ±1.29	214.36 ±1.20^a	102.35 ±0.91^b	22.71 ±0.32^c	167.30 0.89^b	102.61 ±0.54^b	31.36 ±0.34^c
Zn	187.31 V1.29^a	141.21 V2.91^a	93.11 V1.2^b	31.10 V0.41^c	127.36 V2.06^a	67.34 V1.04^d	39.41 V0.47^c
Cr	0.10 ±0.41^a	0.08 ±0.40^b	0.07 ±0.32^a	0.03 ±0.11^b	0.08 ±0.14^b	0.05 ±0.14^b	0.03 ±0.10^b
Cd	0.13 ±0.41^a	0.07 ±0.11^b	0.07 ±0.11^b	0.05 ±0.09^c	0.09 ±0.10^b	0.06 ±0.81^c	0.06 ±0.06^c
Fe	38.9 ±3.11^a	32.6 ±3.10^a	28.2 ±2.91^a	20.4 ±1.84^b	22.4 ±.183^b	22.0 ±1.83^b	23.2 ±1.92^b

Values followed by different alphabets are significantly different values followed by the some alphabets are not significant different.
Key
S1-Old discharge Point
S2-10m away from discharge point
S3-100m away from old discharge point
S4-control.
NS1-New discharge point
NS2-10m away from new discharge point
NS3- 100m away from new discharge point

Table 3: Estimation of the load of various bacterial group in the impacted and unimpacted soil

Metal Bacterial group	S1	S2	S3	S4	NS1	NS2	NS3
NB	$1.2x10^1$	$1.7x10^2$	$1.1x10^3$	$3.7x10^3$	$1.8x10^2$	$2.1x10^2$	$1.6x10^3$
THB	$2.4x10^4$	$3.9x10^4$	$3.2x10^6$	$3.7x10^7$	$3.6x10^4$	$1.4x10^5$	$5.7x10^6$
CB	$2.1x10^3$	$5.1x10^3$	$2.4x10^4$	$5.7x10^4$	$5.4x10^3$	$1.7x10^4$	$4.3x10^4$
PSB	$1.4x10^3$	$2.3x10^3$	$2.1x10^4$	$2.9x10^4$	$1.9x10^3$	$1.6x10^4$	$2.4x10^4$

Values are means of three times samples results.

Discussion;

The effects of the mine water on the agricultural soil in Ishiagu showed extensive adverse effects. Results obtained in the physicochemical parameters analysis showed that the soil became acidic with considerable loss of soil nutrients (NO_3, SO_4, PO_4 and TOM). The acidic nature of the mine water with its high leaching effects caused the loss of soil nutrients. Some other researchers had earlier reported similar observations. Nwaugo *et al,* (2007a) working on post-operational effects of mining in Ishiagu observe this too. Similar observations were reported by Ano *et al*, (2007), Weillinga *et al,* (1999) and Brener *et al,* (1995). Lee *et al,* (2002) and Aroh *et al* (2008) too reported that high soil acidity is in consonance with low soil nutrients. This study therefore agrees with these researchers that mine water is acidic and affects soil nutrients adversely.

The heavy metal analysis results showed that Pb and Zn were significantly high in impacted soil. Obiekezie *et al,* (2006) and Nwaugo *et al*, (2007bc) had reported that Pb and Zn which are the metals mined in the area, were very high in the soil. Results obtained in this study show the same situation. Though the other metal analyzed - Cr, and Fe- were equally high in the impacted soil, the concentrations of Pb, Zn and Cd were quite significant. The high concentrations of the other metals could be as a result of impurities in the mined Pb and Zn ores. Observations showed that the impaction of the soil showed decrease away from the points of discharge, based on metal concentration. This agrees with Chinyere (2001) that the concentration of pollutants decreases with distance away from the source of the pollutant.

Observations in the microbial groups estimated agree with Nwaugo *et al* (2007b, 2006), Li *et al* ,(2005) and Oliveira and Pampulha (2002). The most prevalent organisms were the THB while the most adversely affected were NB. Prescott *et al.* (2003) had stated that THB is a complex group which may include other microbial groups in the soil, while the other groups were specific. The low NB prevalence could be attributed to the high sensitivity of the NB to environmental contamination and the effects of the heavy metals on them. In addition, the mine water saturated the soil pores making it anaerobic which affected the highly aerobic NB extensively. The other groups of bacteria analyzed, PSB, and CB were equally low towards the mine water discharge points.

The above observations in the microbial analysis showed that soil nearest the discharge points will be low in biogeochemical transformations, hence low in mineral recycling. The low NB, PSB and cellulolytic bacterial courts indicates low fertility.

Results equally indicated that time frame was significant in the level of soil impaction. The old mine water discharge area had significantly high (S1-S3) adverse environmental impacts than the new discharge area (NS1-3). This portrayed the old discharge area as more impacted and not safe for agriculture than the new site. Li *et al*, (2005) and Fortin *et al,* (1995) had earlier reported such situation and this study is in consonance with their results.

This study therefore suggests that extensive remediation should be carried out if the impacted soil will be used for agricultural purposes. This became more pronounced as most food crops in the area (especially tubers) have been reported to have high Pb and Zn contents (Onyedike and Nwosu (2007).

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