



Evaluation of Environmental Impact of Dolerite Mining in Nigeria (Suspended Particulate Matter and Heavy Metal Concentrations)

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Abstract The Source Sampling of Particulate Matter (PM) of heavy metal distribution in dolerite mining site, Uturu, Abia State, was investigated using a High-Volume Sampler method. The Suspended Particulate Matter (SPM) concentrations was reported to be 2542.6, 2507.1, 2213.4, 2153.3, 3306.8, and 20.5 $\mu\text{g}/\text{m}^3$ which was mostly higher than the limits of 200 and 50 $\mu\text{g}/\text{m}^3$ set by NESREA [10] and WHO [17] respectively in most locations around the quarry site, there were regions where the values were considerably lower than these standard limits. Specifically, results obtained in the areas such as Behind Crushing Zone, Office 1, Generator House, Office 2 and Crushing Zone were markedly above the control (26.8 $\mu\text{g}/\text{m}^3$).

Keywords Particulate Matter (PM), High-Volume Sampler, Suspended Particulate Matter (SPM)

Introduction

Dolerite is an igneous rock classed as a *porphyry rock* because it has extensive crystals among its smaller crystals. It is usually situated within shallow intrusive bodies like dikes, plugs and sills, and discovered within regions where there has been substantial cooling down of magma over a long period of time. Mining of dolerite is usually associated with the emission of Suspended Particulate Matter (SPM) which has the capacity to increase heavy metal concentration in the atmosphere within the region where the mining is carried out, and even spreads beyond [8]. Although metals such as Mn, Fe, Cu, Hg, Pb, As and Zn are all classified as heavy metals, they are naturally elements of the earth's crust which are essential micronutrients to plants, but their concentration can be drastically altered by anthropogenic activities like mining have greatly contributed to the increase in concentration of SPM and heavy metals in the atmosphere [1]. Either by directly inhaling SPM from the atmosphere, by coming into physical contact with or ingesting food/plants or water with very high concentration of heavy metals, the health of living organisms could be harmed by the presence of high levels of these metals in the soil and other environments[9]. Dolerite mining activities are therefore synonymous to environmental degradation, even though there are positive economic importance to it.

Geology of the Study Area

The study area is Uturu and its environs, bounded between latitudes 5°45'N and 5° 50'N and longitude 7°25'E and 7°30'E [14], in Isuikwuato Local Government Area of Abia State, Southeastern Nigeria. This area is located within the forest belt of Nigeria, underlain by a series of geologic formations. These include, the Asu River Group, comprising of olive-brown sandy shale, fine-grained micaceous sandstones and micaceous mudstones and sometimes bluish-yellow. The Asu River Group is overlain by the unconformable Nkporo Shales, which is primarily



composed of dark shales and mudstones with subordinate sandstone and shelly limestone. Overlying the Nkporo shales is the Ajali Sandstone Formation which, although frequently overlain by a considerable thickness of red earthy sands, formed by the weathering and ferruginization of the formation, contains fresh samples of earth material which are sometimes exposed on the surface. According to [12] exposures are found in the study area about 1.5km away from Abia State University, along Afikpo - Uturu Road and also through the escarpment at Leru on Enugu-Port Harcourt expressway. Finally, there is the Mamu Formation overlying the Ajali Sandstone, consisting of white fine grained and poorly sorted sandstone usually well stratified and planer. The topology of Uturu is characterized by hills and valleys, with the hills ranging from 400m to 1000m above sea-level respectively. While the valleys are the inland extensions of the coastal plain from the Bight of Benin [13]. The geologic map of the study area is as presented in Figure 1.

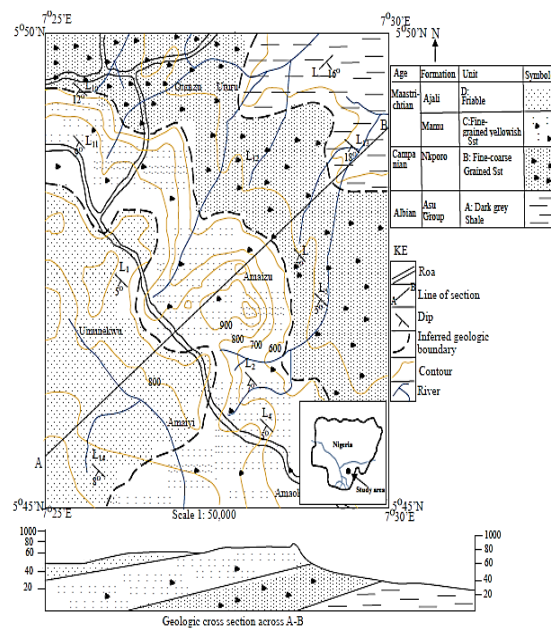


Figure 1: Geological Map of Uturu and Environs [13]

Materials and Methods

The Sierra-Anderson/GMW model 1200 High Volume Air Sampler was used for dust sampling in accordance to CEN Standard [4] for Particulate Matter (PM₁₀) measurements. Other materials include Global Positioning System (GPS), Power Generating Set, Thermometer, Time Piece, and Quartz Fibre Filter Paper (FT).

Sampling and Instrumentation for Suspended Particulate Matter (SPM)

The FT was weighed in the laboratory and labelled FT₁ to FT₈, where FT₈ is used as the Control Location. The High-Volume Air Sampler is connected to the Power Generating Set and calibrated so that ambient air is drawn through it at a constant flow rate of 1.4 m³/min. The ambient air is usually drawn through the Filter Paper, via the inlet at a constant flow rate of about 1.1 m³/min to 1.7 m³/min for about six (6) hours, or less if the SPM levels are high [6]. For this work however, a constant flow rate of 1.4 m³/min was sampled for about 4 hours. SPM of diameter between 0.1µm and 100µm were removed from the air stream by filtration on the Quartz Fibre. The method described here can be used to measure SPM concentration for as low as 1µm/m³. The volume of the air sampler for this duration is calculated as:

$$1.4 \text{ m}^3/\text{min} \times 240 \text{ min} = 336 \text{ m}^3 \text{ of air}$$



The mass of SPM (M_{SPM}) is calculated using the formula below:

$$M_{SPM} = M_{FT} - M_I$$

where,

M_{SPM} = Mass of Suspended Particulate Matter,

M_{FT} = Mass of Filter Paper after Sampling Final Mass of Filter Paper),

M_I = Mass of Filter Paper before Sampling (Initial Mass of Filter Paper)

According to [18]

$$C_{SPM} = \frac{M_{SPM} (\mu g)}{\text{Vol. of Sampled Air}}$$

$$C_{SPM} = \frac{M_{SPM} (\mu g)}{336 \text{ m}^3}$$

Table 1 gives an overview of the different locations, their GPS locations and also filter identifications.

Table 1: Geographical Location of all Sampled Points during the Dust Particle Concentration Measurement

S/N	Coordinates	Location	Filter Identities
1	N05°52'25.8 ¹¹ E007°25'16.9 ¹¹	Behind Crushing Zone	FT1
2	N05°52'18.5 ¹¹ E007°25'16.9 ¹¹	Office 1	FT2
3	N05°52'26.2 ¹¹ E007°25'15.6 ¹¹	Generator House	FT3
4	N05°52'25.6 ¹¹ E007°25'12.6 ¹¹	Foot Path	FT4
5	N05°52'18.6 ¹¹ E007°25'20.9 ¹¹	Gate	FT5
6	N05°52'26.0 ¹¹ E007°25'17.0 ¹¹	Crush Zone	FT6
7	N05°52'18.3 ¹¹ E007°25'18.5 ¹¹	Office 2	FT7
8	°49'55 ¹¹ E007°35'18.2 ¹¹	between Ishiagu and Uturu	FT8

See below a schematic of the High Voltage sampler used;

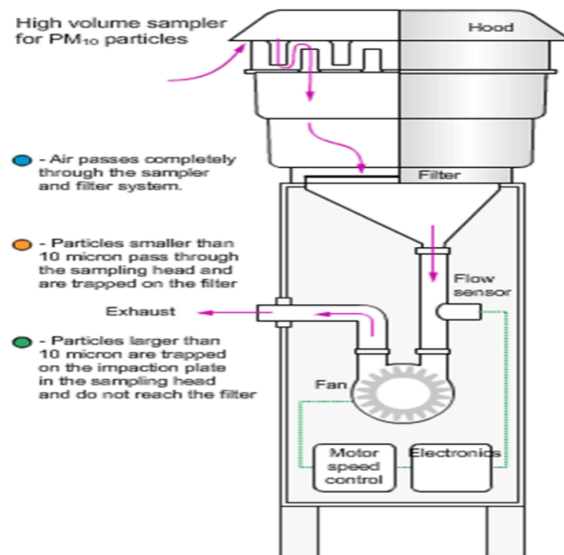


Figure 2: A Sierra-Anderson High Volume Air Sampler



Digestion of the Filters for Heavy Metal Analysis

The materials used for digestion of the filter papers are:

- Hot plate
- 500ml breaker
- Sample bottle
- Filter paper
- Weighing balance
- Distilled water
- 100ml volumetric flask
- Funnel
- Concentrated H₂SO₄
- Concentrated Perchloric acid and
- Hydrochloric acid.

The procedure is as follows; the air filter sample was inserted in 500 ml beaker. 100 ml of conc. H₂SO₄, 20 ml of aqua regia was added and heated on a hot plate for eight hours. At the end of the digestion, the solution must have formed a paste and brought down to cool. 50 ml of distilled water was added and stirred with a stirring rod and filtered into a 100 ml volumetric flask. More distilled water was added to the mark (*i.e.* 100 ml). A portion or volume was transferred into a sample bottle for metal analysis using Atomic Absorption Spectrophotometer. The Aqua Regia is prepared by mixing 3 ml of HCl with 1 ml of HNO₃, (ratio 3:1).

Sampling and Instrumentation Principles for Heavy Metal Analysis

After digesting the filters, Atomic Absorption Spectrophotometer (AAS) was used for the heavy metal analysis. AAS employs the principle of Beer-Lambert Law (which is used to determine the concentration of a particular analyte).

In the Atomic Absorption Spectrophotometer testing, a known amount of energy is passed through the atomized sample, and by measuring the quantity of light remaining after absorption, it is possible to determine the concentration of the element. A schematic diagram of Atomic Absorption Spectrophotometer is as presented in the figure below:

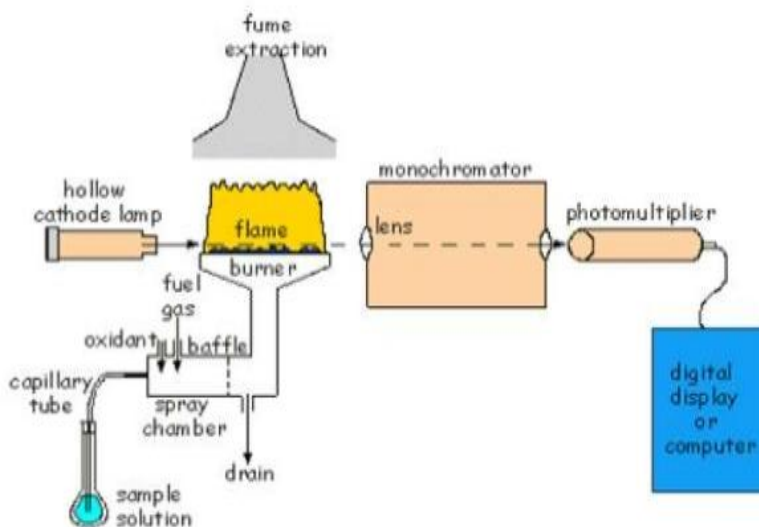


Figure 3: Schematic Diagram of Atomic Absorption Spectrophotometer



Results, Discussions, Conclusions

Results

Table 2: Results of Mass Concentration Investigated During Suspended Particulate Matter (SPM) Investigation in Setraco Quarry Site, Uturu

Filter No.	Initial Mass of filter (g)	Final Mass of filter (g)	Mass of SPM (g)	Mass Concentration ($\mu\text{g}/\text{m}^3$)
FT1	2.8421	2.9452	0.1031	306.8
FT2	2.8235	3.6778	0.8543	2542.6
FT3	2.839	3.5674	0.7235	2153.3
FT4	2.8343	2.8452	0.0109	32.4
FT5	2.8420	2.8489	0.0069	20.5
FT6	2.8241	3.5678	0.7437	2213.4
FT7	2.8332	3.6756	0.8424	2507.1
FT8	2.8520	2.8610	0.009	26.8
		Mean		1188.2
		NESREA Limit		200
		WHO Limit		50

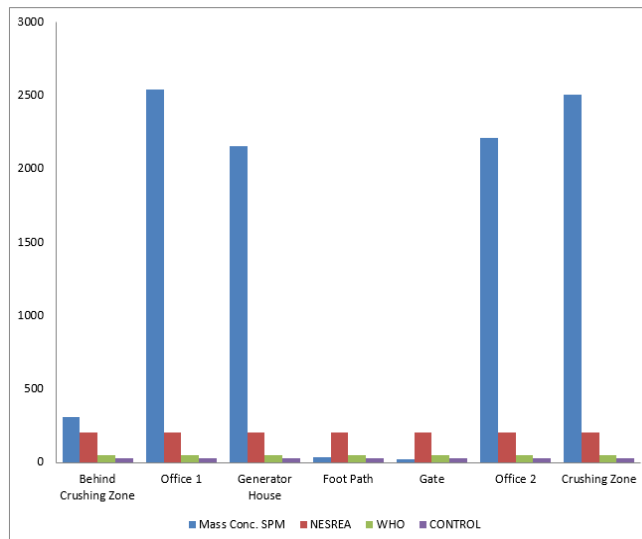


Figure 4: A Bar Chart Comparing Mass Concentration of SPM at different Locations with NESREA [10] and WHO [17] Control Location

Table 3: The Results of Mean Concentration of some selected Heavy Metals Distributed in Suspended Particulate Matter in Setraco Quarry Site Uturu in PPM

Heavy Metals	FT ₁	FT ₂	FT ₃	FT ₄	FT ₅	FT ₆	FT ₇	FT ₈	MEAN (ppm)
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Pb	0.08	ND	0.02	0.03	0.02	ND	0.08	0.01	0.03
Zn	7.3	11.1	3.2	2.6	1.8	6.8	10.7	1.00	6.25
Mn	0.00	ND	0.01	0.02	0.01	0.00	0.01	0.02	0.01
Cr	0.08	ND	ND	0.10	0.13	ND	0.08	0.06	0.20
Cd	0.00	0.01	ND	0.00	0.00	ND	0.01	0.01	ND

Table 4: The Results Comparing Mean Concentration of Some Selected Suspended Particulate Matter with Selected Standard and Control

Heavy Metals	Mean Concentration (ppm)	Control FT8 (ppm)	UNEP (NESREA 2009) (ppm)
Pb	0.03	0.01	0.050
Zn	3.03	1.00	1.000
Mn	0.00	0.01	0.01
Cr	0.20	0.01	0.001
Cd	ND	0.01	0.002

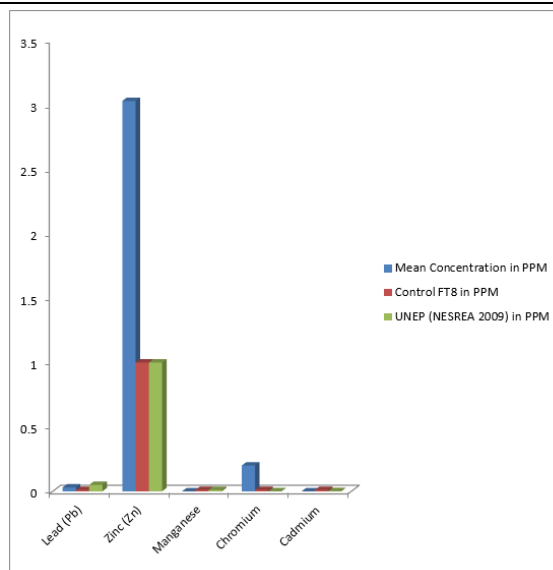


Figure 5: A Bar Chart Comparing Heavy Metal Concentration with NESREA [10] and Control.

Discussion

Table 2 and Figure 4 are results from the measured concentration of suspended particulate matter (SPM) in the surveyed area with values between $20.5 \mu\text{g}/\text{m}^3$ and $2542.6 \mu\text{g}/\text{m}^3$, most of which are significantly above the NESREA [10] and WHO [17] limits ($26.8 \mu\text{g}/\text{m}^3$, $200 \mu\text{g}/\text{m}^3$ and $50 \mu\text{g}/\text{m}^3$) used as control measures. This is an indication of the significant volume of dust particles suspended in the air which is possibly due to mining and crushing activities being carried out in the surveyed area.

Table 2, Table 3, and Figure 3 display the results of the analysis of selected heavy metal concentrations in SPM within the site investigated, with the mean concentration of Lead being 0.03ppm as opposed to the 0.01 ppm control limit but below the 0.05 ppm standard set by NESREA [10]. The high concentration of Lead (Pb) could be ascribed to the presence of lead in the fuel used by heavy duty vehicles and machineries in quarry-related activities. Duruibe, Ogwuegbu [5] attributed long-time exposure to lead as the result of kidney damage.

The concentration of Cadmium (Cd) is not indicated as it was not recorded by the instrument used.

Results of the Atomic Absorption Spectrophotometer (AAS) used to analytically determine some selected metals in the air around the quarry site revealed that the mean concentrations of Zn, Cr, Pb, Mn and Cd were 6.35 ppm, 0.2 ppm, 0.03 ppm, 0.01 ppm and 0.00 ppm respectively (See Figure 5). The concentrations of Zn, Cr and Pb were mostly higher than the limits and standards set by NESREA [10], especially that of Zn and Pb (see Table 4). Such concentrations could be detrimental to the health of man and other living organisms especially within the vicinity of the quarry site. Breathing in large amounts of Zinc dust which happens to be a necessary component of dolerite mining could cause metal fume fever [2].



Conclusion

The measured mean concentration of suspended particulate matter within the surveyed area is $1188.2 \mu\text{g}/\text{m}^3$, a value way beyond the NESREA [10] and WHO [17] permissible limits of $200 \mu\text{g}/\text{m}^3$ and $506 \mu\text{g}/\text{m}^3$ respectively. Such remarkable values of SPM could be the reason behind some prevalent health effects of residents and quarry workers [16].

According to WHO [18], long-term exposure to current ambient Particulate Matter Concentration when it is very high may lead to a marked reduction in life expectancy due to increased cardiopulmonary and lung cancer mortality. Short-term and long-term exposure to Particulate Matter are associated with diseases such as stress on the heart, bronchial constriction, impairment of lung elasticity and gaseous exchange efficiency, silicosis (a form of pneumoconiosis caused by inhalation of dust particles), respiratory tract disease, systematic toxicity, and altered immune defense [11, 19].

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