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Geospatial modeling and analysis of environmental quality indicators in Sub-Saharan African mining community of Evbonogbon, Nigeria

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Abstract

This paper examines the environmental quality impacts of rock mining (quarry) in a typical rural community in Sub-Saharan Africa. Using Evbonogbon community in Edo State, Nigeria as the study area, the environmental implications of mining and the geographic distribution of soil, ambient air and water qualities were examined and modelled using GIS Kriging method in view of sustainable growth and development. Using in-situ digital air and water quality measurement equipment, air quality, surface and underground water samples were collected and analysed. Combining the WHO, FMEnv and SON reference standards where appropriate, results of air quality assessment in the rural community were found to be within acceptable limits except in drilling and blasting environs. Study also reveals that underground water quality meets the SON standard for safe drinking while the surface water has some trace elements like copper, iron and lead. DO, TSS, and turbidity are also present in surface water owing to particulate matter and effluent discharge from anthropogenic factors (mostly farming) and surface water runoff collection. Noise levels are highest (91.6dB) near the mine generator area while resultant dust requires close control through continuous wetting with water. Drinking water surveillance, consistent use of ear muff, goggles and mouth mask within and near the mine site is recommended for safety of workers and equipment.

Keywords: Environmental quality, Geospatial analysis, Rock mining, Rural community

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1. Introduction

As defined by the European Environmental Agency (EEA), ‘environmental quality’ may refer to “varied characteristics that relate to the natural environment as well as the built environment, such as air and water purity or pollution, noise and the potential effects which such characteristics may have on physical and mental health of people” (EEA, 2012). Various activities embarked upon by man in his environment often lead to a number of problem whose consequences are severe on the environmental systems (Olorufemi and Jimoh, 2000). Studies on environmental quality, land use and land cover changes, and Earth’s energy balance are fundamental to sustainable growth and development practices (Ejaro and Abdullahi, 2013). The Earth’s energy balance is key to understanding climate and climate change variations that are caused by natural and anthropogenic changes in atmospheric composition (Huber and Knutti, 2011). Besides water and soil, clear air is considered to be a basic requirement of human health and well-being (WHO, 2006). However, air, water and soil pollutions pose a great risk to human health globally. For example, a 2013 assessment by WHO’s International Agency for Research on Cancer (IARC) (WHO, 2014) corroborate the claim that “outdoor air pollution is carcinogenic to humans, with the particulate matter component of air pollution most closely associated with increased cancer incidence, especially cancer of the lung and urinary tract/bladder”. In the World Health Organizations (WHO) assessment of burden of disease due to climate change and air pollution for instance, “more than two million premature deaths each year is attributed to the effects of urban outdoor air pollution and indoor air pollution caused by burning of cooking and automotive fuel” (WHO, 2002 and 2006). In addition, more than half of this disease burden is borne by the population of developing countries (like Nigeria) (WHO, 2006).

Very little data exist on the micro soil, water and ambient air qualities of Nigerian cities. The few synoptic data on air quality available “indicate ambient concentrations of Carbon monoxide (CO) and sulphur dioxide (SO_2) exceeding WHO short-term limits for those gases” (Akerodolu, 1989). In recent years, there is an increasing concern over climate change and water vapour generation caused by increasing concentration of Carbon dioxide (CO_2) and other greenhouse gases (GHG) in the atmosphere, and rock mining is a major contributor to CO_2 generation globally. The forcing radiative fluxes from Chlorofluorocarbon 11 and 12 (CFC11, 12), Carbon tetrachloride (CCl4), Nitric acid (HNO_3), Ozone (O_3), N_2O, CH_4, CO and CO_2 have been quantitatively determined over a range of seasons (Evans, 2006) while changes in spectrum from 1970 to 1996 due to trace gases have also been studied (Harries et al., 2001). Anthropogenic activities like bush burning, industrial brewing and rock mining may adversely impact the environment hence the need to examine the possible impacts of granite mining in Evbonogbon, a rural community in Nigeria.

Rock mining involves the exploration and exploitation of rock mineral above and below the earth surface and the processes contributes to pollution of the environment as a result of noise, particulate matter (PM) and discharge of other emissions associated with rock blasting and screening. Granite is an igneous rock resulting from the solidification of molten magma which is nearly always massive, hard and tough, and widely used for decoration and construction purposes (James, 2008). Granite with a melting temperature of 1215 - 1260 °C (Larsen, 1929) is possibly the most common igneous rock type mined and known to the general public and is heavily mined for road and infrastructural uses. Granite economic and industrial importance in terms of durability, beauty and abundance makes it a preferred choice of stone over most others (see FRN, 2007; MEA, 2005; Chappell and White, 2001; Essiet, 1995; Barcelo, 1993, and Udo, 1970). The two major contrasting granite types may be identified (Chappell and White, 2001) as the basic properties are well established in literature (Kumagai et al., 1978). However, activities associated with granitic rock mining are considered hazardous to the environment due to the attendant air, water and soil pollution.

Heavy metals such as Zinc, lead, copper and Iron present either in soil or water in trace concentration play a major role in the metabolism and healthy growth of plants and animals (Purushotham et al., 2013). Consequently, the impact of mining of natural resources such as granite, their conservation and ambient air quality assessment on the immediate environmental requires strict compliance to laid down guidelines (See Davis, 2006, WHO, 2011). This helps to avoid unwarranted environmental blight capable of adversely impacting the environment negatively. If mining is uncontrolled by relevant bodies on environment management such as the World Health Organization (WHO, 1976, 2001, 2005, 2006), World Bank (World Bank, 1997), Food and Agricultural Organization (FAO, 1978), Nigerian National Environmental Standard and regulation Enforcement Agency (NESREA) (FRN, 2007), the Nigerian Ministry of Mines and Steel Development (MMSD) and Standard Organization of Nigeria (SON) (SON, 2007), exposure to radon and radiation from granite counter-crops may lead to health hazard (Marble Institute of America, 2008). The fourth edition of the WHO 'Guideline for drinking-water quality' (WHO, 2011), for instance, develops concepts, approaches and information fundamental to environmental quality management. The new guidelines also include recommendations on specific health issues like drinking water safety, microbial hazards, climate change and chemical contaminants in drinking water, and key chemicals responsible for large-scale health effects through drinking-water exposure. The guidelines are regarded globally as "the most authoritative framework on drinking-water quality and often form the basis for national laws and regulations" (WHO, 2011). This should be adhered to and adopted by authorities controlling granite in Evbonogbon community of Edo State, Nigeria, hence its reference in this study.

In the context of discussing sources of air pollution according to WHO (2005), it is important to consider the geographical location and indicators of air pollution, and the distribution of sources as illustrated in Figure 1. However, up to now, the most frequently used indicator for suspended particles in the air has been PM10; that is particles with an aerodynamic diameter <10μm (WHO, 2005).Thus, the ultrafine particle fractions are important for health-impact studies and thus measured within the atmosphere. Besides GHG, the overall quality of the environment can be assessed, in part, based on factors such as ambient air quality, water and soil qualities.

In the opinion of Johnson et al. (1997), the dichotomy between and among terms relating to environmental quality assessment has different connotations to different field of studies. In an attempt to correct the problems associated with standardize usage of environmental quality terms, Johnson et al. (1997) redefined ten of the most common environmental terms. These terms includes the natural environment and environmental change, defined on the basis of what is meant by natural as reflected by common usage and dictionary entries.

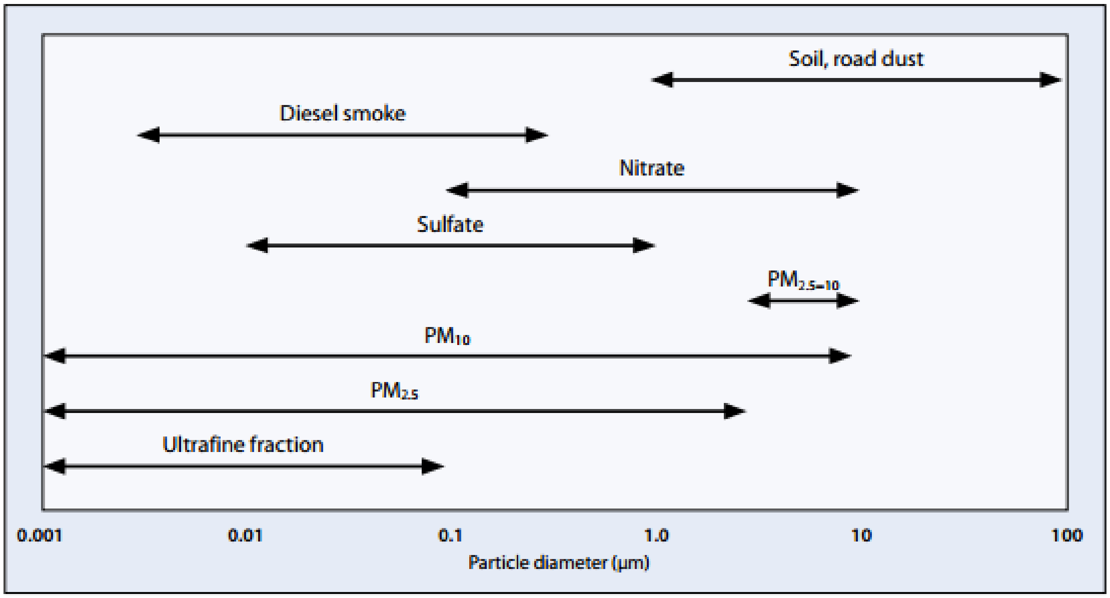

Figure 1. Size range of airborne particles, showing the health-related ultrafine, PM25 and PM10 fractions and the typical size range of some major components (Source: WHO, 2005)

The three degradation terms according to Johnson et al. (1997) are environmental degradation, land degradation, and soil degradation, which is defined as any change or disturbance to the environment, land, or soil, perceived to be deleterious or undesirable. A sixth term - soil regeneration, is defined as the reformation of degraded soil through biological, chemical, and/or physical agencies. The remaining four terms, 'environmental quality, air quality, soil quality, and water quality', are defined as measures of the condition or state of each relative to the requirements of one or more biotic species and/or to any human need or purpose."

One of the main sources of environmental pollution is rock mining and Evbonogbon community (the study area) play host to two rock mining companies which include RCC and Georgio Construction Companies. These companies require granite for their road construction activities.

The main natural resources available to the community include the tropical rainforest, granitic rock outcrops and Ofosu stream. Granite mining in Evbonogbon, Edo State, Nigeria is the main industrial activities conspicuously noticeable in the rural community and has remained the main identification or landmark of the people. Besides rainfall, the stream provides water for domestic and semi-industrial uses, and how safe the water sources are for dinking is yet to be examined. Surveillance of drinking water quality is 'the continuous and vigilant public health assessment and review of the safety and acceptability of drinking water supplies' (WHO, 1976). Thus, surveillance of impacts of pollutants resulting from mining or other sources on water, soil and air is a sure way to effectively monitor the ecosystem and the general environment forms the basis for this study.

The study aims at examining the environmental quality condition of mining impact(s) on the overall well-being of the people of Evbonogbon community.

The specific objectives include to:

- examine the existing rock mining activities in Evbonogbon in relation to health hazard;
- evaluate the geographical pattern of environmental indicators capable of constituting hazard to man; and
- ascertain the level of concentration of pollutants in air, water and soil in order to provide a basis for informed mitigative measures.

2. The study area

Evbonogbon community is located in Ohosu in Ovia South West Local Government Area of Edo State, Nigeria. The study area straddles across latitudes 6⁰44’15.7’’N and 6⁰45’30.08’’N and longitudes 5⁰ 09’27.8’’E and 5⁰10’59.6’’E.Evbonogbon is situated in a rural community bordering Ondo State to the Western part of Nigeria. It is a predominantly agrarian community with subsistence farming of cassava, palm oil, plantain, maize, yam, potatoes and melon. The community dwellers are mostly Benin speaking people with a mixture of Yoruba, Ibo and Akwa Ibom languages.

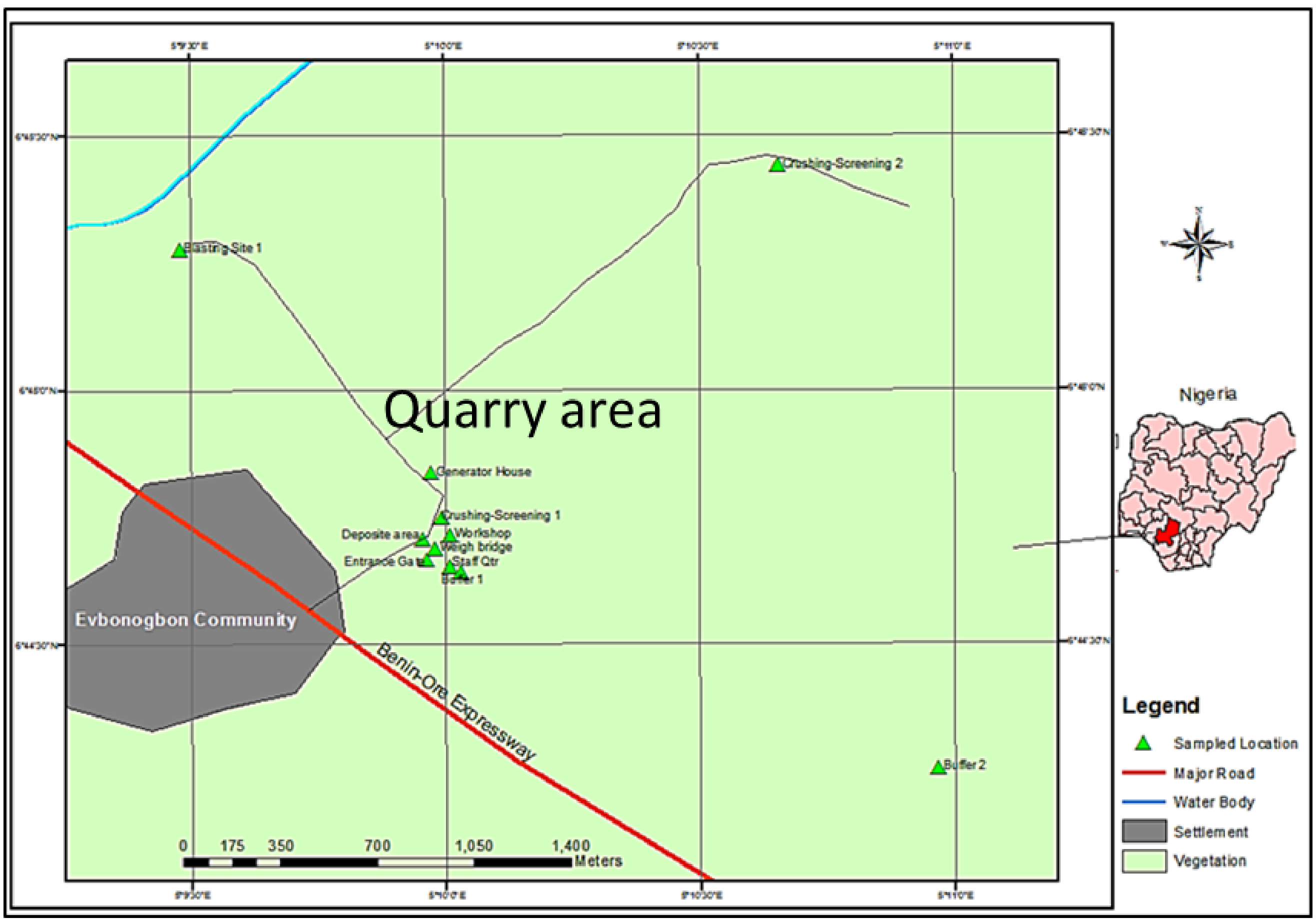

Figure 2. Map of the study area

Geologically, the study area is underlain with abundance of igneous rocks of Precambrian age. The availability of this mineral has led to the mining of granite for civil and construction engineering works by Georgio Rocks limited and RCC Nigeria Limited who both operates quarries in the rural community. The impact of rock blasting, screening and haulage are considered a source of environmental pollution within the study area hence this study. Figure 2 shows the map of the study area generated from SPOT satellite image.

3. Materials and method

Sampling and analysis of air (particulate and aerosol), water (ground and surface water), soil and other pollutants that encompass various sampling techniques are the essential features of environmental analysis and quality control of contaminants and pollutants (Narayanan, 2007). Data used for this study were, therefore, generated using a combination of field studies; analysis of maps, satellite imagery; review of related literature, social surveys on soci-economic activities, and internet searches. Similarly, a handheld GPS 72 plus was used to geo-locate the sampled points for air, water and soil quality. For the study area, SPOT imagery (5m resolution) was used to generate the image map of the study area. For air quality assessment, a handheld in-situ digital CEM DT-8820:4-in-1 Multifunction Environment Meter instrument was used to measure parameters of interest in sampled locations. The instrument measures sound/noise Levels, Humidity (RH in %) and Temperature. CO, SO_2, HN_3 and Suspended particulate matter (SPM) were also measured. From the point values obtained for air quality assessment, a Geographic Information Systems (K-GIS) Kriging interpolation analysis in ArcGIS 10.1 was carried out to geovisualized the geographic pattern of pollutant concentration within the mine area. The Ordinary Kriging method with the Exponential Semivariogram model and an output cell size of 1 search radius was adopted. The visualization symbolization was executed with the 'stretched' red to green cartographic model. Red implying higher concentration while green (or blue in the case of temperature) implying lower concentration.

For water quality, an in-situ digital water measurement instrument was also utilized to record the level of concentration of different parameters such as Dissolved Oxygen (DO), Turbidity, pH value(level of alkalinity or acidity), Temperature (^{0}C), Total Dissolved Solids (TDS) and Conductivity. Water samples were collected using well labelled calibrated water containers which were sent to the laboratory for analysis. Other water parameters such as Total Suspended Solids (TSS), Alkalinity, Total Hardness, Ammonia, Chloride, Sulphate, Nitrate (NO3), Biological oxygen Demand (BOD), phosphate, Chemical Oxygen Demand (COD), Lead (Pb), Copper (Cu), Iron (Fe), Nitrite (NO_2), Total Coliform, Faecal Coliform and Total Hydrocarbon (THC) levels were also analysed in the lab. For soil quality assessment, soil auger was used to collect soil samples which were further examined at the laboratory for various parameters as presented in the results and discussion section of this paper. There are environmental quality reference materials (primary and secondary) established to validate analytical methods in order to ensure that the results obtained are consistent with acceptable standards.

The results of measured parameters were compared with at least one acceptable standard of the Federal Ministry of Environment Nigeria (FMEnv), Standard Organization of Nigeria (SON) and that of World Health Organisation (WHO) where applicable.

4. Results and discussion

We present below the results of the parameters or indicators investigated in the evaluation of the environmental quality assessment of the study area.

4.1. Air quality assessment

In theory, air pollutants are classified as primary pollutants (e.g. NOx, SOx, NHx, and H_2S) and secondary pollutants (e.g. photo-oxydants such as PAN, aldehydes, and free radicals) (Narayana, 2007). Table 1 shows a total of eleven (11) sampled locations for the measured parameters. Nine of the sampled locations were mainly within the quarry sites while the remaining two (2) control buffers were measured outside the main quarry. As indicated in Table 2 and Figures 2, 3a, b and c, the study shows that on the average, none of the measured parameters were beyond the standard maximum limit set by FMEnv. A cursory analysis of the specific environmental indicators shows that Carbon monoxide (CO), though an odourless, colourless and tasteless gas that is slightly less dense than air and toxic to humans and animals when encountered in higher concentrations is specifically less in concentration in the study area with mean values of 1.55ppm less than the FMEnv standard of 11.4ppm.

Table 1. Air Quality

Point	Description of Sampled Locations	GPS Reading Latitude	Longitude
1	Weigh Bridge	*6^{0}44’43.5’’*	*5^{0}09’58.5’’*
2	Crushing-Screening Unit	*6^{0}44’47.2’’*	*5^{0}09’59.3’’*
3	Buffer 2	*6^{0}44’17.5’’*	*5^{0}10’57.8’’*
4	Granite deposit area.	*6^{0}44’44.6’’*	*5^{0}09’57.1’’*
5	Generator House	*6^{0}44’52.4’’*	*5^{0}09’58.1’’*
6	Workshop	*6^{0}44’45.1’’*	*5^{0}10’ 00.3’’*
7	Staff Quarters	*6^{0}44’41.4’’*	*5^{0}10’00.2’’*
8	Entrance Gate	*6^{0}44’42.1’’*	*5^{0}09’57.5’’*
9	Buffer 1	*6^{0}44’40.7’’*	*5^{0}10’01.5’’*
10	Crushing-Screening 2	*6^{0}45’28.6’’*	*5^{0}10’39.1’’*
11	Blasting Site 1	*6^{0}45’18.8”*	*5^{0}09’28.5”*

Source: 2014 Fieldwork

Similarly, Sulphur dioxide (SO_2) though being one of a group of highly reactive gasses known as "oxides of sulphur" is a toxic gas with a pungent, irritating and rotten smell emitted mainly from fossil fuel combustion at power plants and industrial facilities, and the burning of high sulphur containing fuels by locomotives such as haulage lorries within the mine site. SO_2 has severe health impact on respiratory system if it exceeds the allowable standard maximum limits.

The study reveals that an average of 0.06ppm of SO_2 was observed and this is far less than the maximum limit of 26.0 set by the FMEnv and 0.5ppm by WHO (see Figures 3a and b).

Table 2. Summary of ambient air quality assessment

Point	GPS Reading		CO (ppm)	HN3 (ppm)	SO_2 (ppm)	Noise (dB)	Temp (^0C)	RH (%)	SPM
	Latitude	Longitude							
1	$6^0$44'43.5''	$5^0$09'58.5''	3	0.1	0.0	52.7	29.3	66.4	67
2	$6^0$44'47.2''	$5^0$09'59.3''	1	0.3	0.0	72.5	31.6	64.9	75
3	$6^0$44'17.5''	$5^0$10'57.8''	1	0.1	0.0	58.9	30.3	67.9	73
4	$6^0$44'44.6''	$5^0$09'57.1''	2	0.2	0.0	67.4	30.6	65.4	68
5	$6^0$44'52.4''	$5^0$09'58.1''	3	0.3	0.2	91.6	31.6	65.7	65
6	$6^0$44'45.1''	$5^0$10' 00.3''	1	0.3	0.4	63.4	31.3	64.0	68
7	$6^0$44'41.4''	$5^0$10'00.2''	2	0.1	0.0	56.7	30.0	64.6	68
8	$6^0$44'42.1''	$5^0$09'57.5''	1	0.1	0.1	63.4	30.7	66.2	66
9	$6^0$44'40.7''	$5^0$10'01.5''	2	0.2	0.0	49.8	30.7	64.3	64
10	$6^0$45'28.6''	$5^0$10'39.1''	1	0.2	0.0	79.7	31.8	66.4	70
11	$6^0$45'18.8"	$5^0$09'28.5"	0	0.1	0.0	47.8	34.2	55.5	69
Mean record			**1.55**	**0.18**	**0.06**	**63.99**	**31.1**	**64.66**	**68.46**
FMEnv's Standard			***11.4***	***2.0***	***26.0***	***90.0***	***<40***	***90-100***	***<250***
WHO Standard			-	-	***0.5***	-	-	-	***20-50***

Source: 2014 Fieldwork

As shown in Figure 3b, the relative humidity (RH in %) and environmental temperature in degree Celsius (^0C) were also measured to provide the baseline information for examining the conducive nature of the mining location. From Table 2, we can also deduce that the temperature of the study area averages to 31.1^0C less than the 40^0C maximum standard limit set by FMEnv while the relative humidity (RH) averages 64.66% which is below the maximum limits of 90-100%.

In addition, hydrazoic acid (HN_3), a colourless volatile poisonous explosive liquid that has a foul odour and yields explosive salts of heavy metals was also found to be of minimal concentration around the generator and administration area within the mine site. HN_3 records a mean value of 0.18ppm which is less than the 2.0ppm maximum limit set by FMEnv standard. The measurement of this element became significant because the explosive used during mining causes noise and chemical contamination that adversely affects human organs.

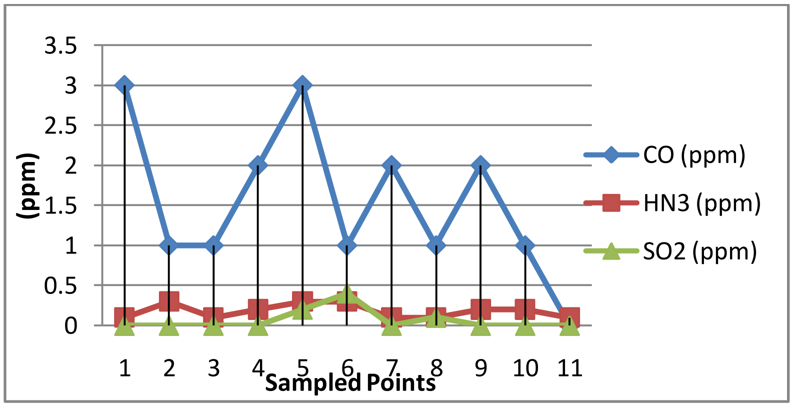

Figure 3a. Comparative analysis of CO, HN_3 and SO_2

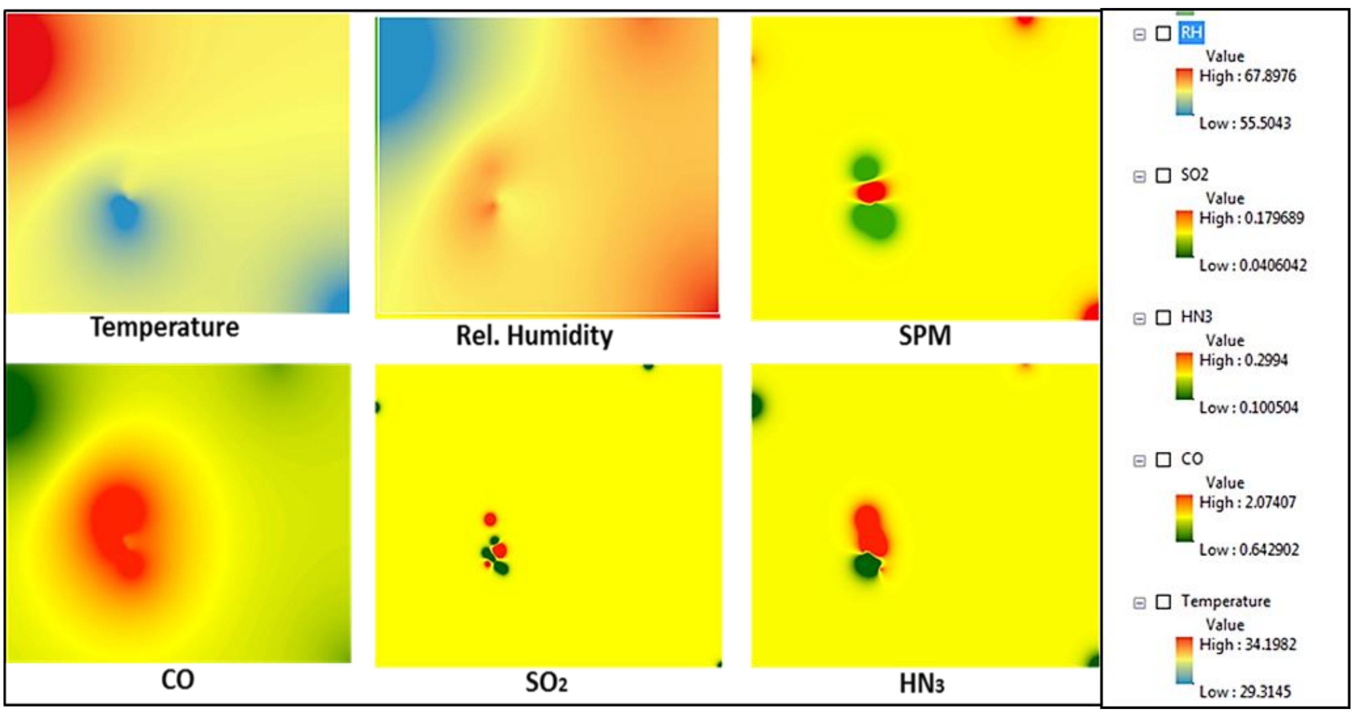

Figure 3b. Kriging result of Geospatial pattern of air quality during working hours

The implication of the above results (Figures 3a and b) is that CO, SO_2, $HN_3$and temperature, did not exceed the acceptable limits for human health. The concentration of CO is attributed to environmental and anthropogenic factors like gaseous exchange resulting from generators and heavy machines used at the quarry and, clearing and burning of vegetal cover for agricultural and domestic purposes in the rural community. The health implications of high concentrations of CO include asphyxiation, headache, vertigo coma and consequently death. Areas of gaseous exchange like generator require good ventilation and catalytic oxidation. Figure 3c shows that the average noise pollution level measured within the study area was found to be at a tolerable level of 63.99dB which is less than the maximum limit of 90dB. This is in exception of the generator house with a noise level of 91.6dB. The operator-in-charge of the generator is directly affected by the noise pollution originating from the generator hence will require ear protection while working with the generator.

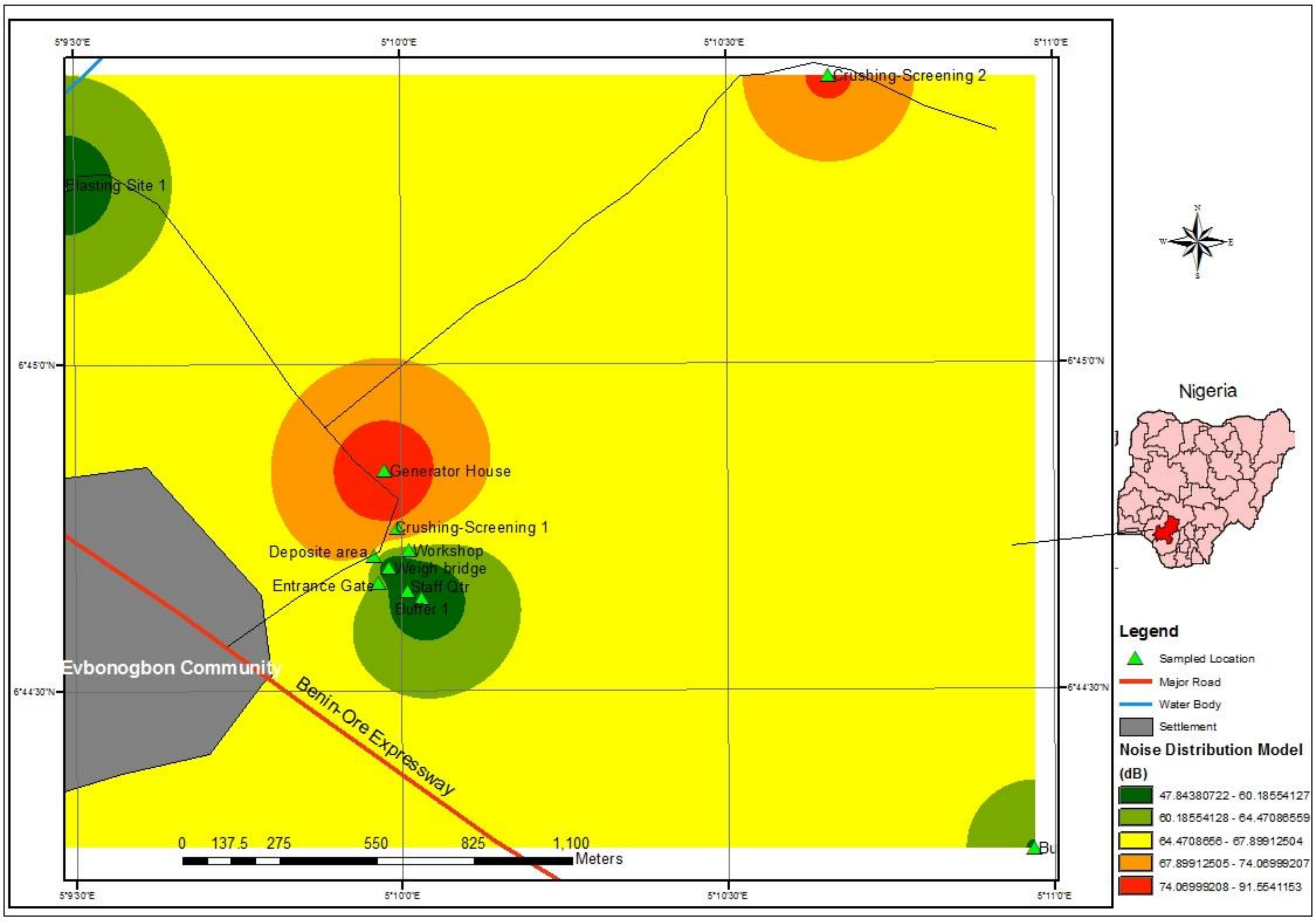

Figure 3c. GIS Kriging Modeling result of Noise level during working hours at the mine site

Furthermore, result of the measured suspended particulate matter (SPM) in this study averages 68.46µm. This value though less than the maximum limit of 250µm set by FMEnv is rather higher than WHO standard of 10µm(for annual mean) and 50µm (for 24 hour mean). This result can be attributed to rock mining activities that emit dust particles into the atmosphere especially within the crushing/screening area and along the earth road during granite haulage (see Figure 3b). The implications of this finding is that, with the concentration of SPM in the atmosphere, there is reduction in visibility in the quarry. The result for SPM is also particularly worrisome in view of the health impact associated with short term exposure. Health impact attributed to long-term exposure to SPM may include mortality due to chronic changes in physiologic functions, lung cancer, and intrauterine growth restriction: low birth weight and intrauterine growth retardation (WHO, 2005).

4.2. Water quality assessment

The presence of some inorganic, organic, biological, radiological or physical foreign substance in the water tends to degrade its quality hence making it polluted (Narayanan, 2007). Although drinking water is essential to life, it can, however, still be a source of exposure to chemical, physical and radiological contaminants. For waterborne pathogens, including bacteria, viruses and protozoa, drinking water is a major contributor to human exposure to disease (Boyd, 2006). Table 3 shows the geographic coordinates of sampled locations for surface (stream) and underground (borehole) water. In this study, physical (turbidity, conductivity) and chemical (pH, dissolved oxygen (DO), total dissolved solids (TDS). Parameters measured and analysed from collected samples within the study area are shown in Table 4.

Table 3. Water quality sampling locations with GPS

Sampled Points	GPS Reading	
	Latitude	Longitude
1. Borehole	*6^0 44'40.6''*	*5^0 10'01.3''*
2. Stream	*6^0 44'44.3''*	*5^0 09'58.1''*

Source: Author's Fieldwork, 2014

Table 4 shows the result of both surface and underground water analyses for the study area. The pH values for both water samples analyzed were found to be alkaline (pH 7.58 and 7.62) in nature with underground water lesser in content (see Table 4, parameter 2).

The result also reveals that temperatures for both samples are below 40 ^{0}C (underground 24.5^{0}C and surface water 24.8^{0}C respectively). Similarly, going by the standard set by Standard Organization of Nigeria (SON, 2007) as indicated in Table 4, all the parameters analyzed for borehole are within the acceptable limit hence the borehole water is safe for drinking. The study however reveals that the surface water is polluted. Result of surface water (Ofosu stream) analyses shows that DO has 4.16mg/L and Turbidity has 37.96NTU concentrations implying both exceeds the set maximum limit of 4mg/L and 5NTU respectively and as such not suitable for consumption. The transportation characteristic of the river is also adduced for the harmful content of both DO and Turbidity in the available sources of water to the community. Result of water analysis further reveals that Total Suspended Solids (TSS) is insignificant (3.0mg/l) in underground water but exceeds the maximum limit of 30mg/l in surface water with mean values of 82.5mg/l. The TSS concentration is caused by suspended solids resulting in low penetration of light at river beds (Benthic zone) which destroys the photosynthetic plants and bacteria at river bed, and in turn can destroy the entire ecosystem.

Result of trace elements like Copper (Cu) was found to be 0.01mg/l in underground water which is below the standard maximum limit of 2mg/l (WHO, 2005) and 1mg/l (SON, 2007) respectively. However, the concentrations of copper in surface water far exceed the standard maximum limit with a total of 3.45mg/l. Consequently, the microbiological results of the analysis reveals that stream water is Amberish hence turbid, having high level of suspended solids while the borehole has the lowest THC and zero Faecal coliform. The parameters for the coliforms has normal microbial load but the surface water had more.

Table 4. Results for physical, chemical and bacteriological analysis of water quality

	PARAMETER	**METHODOLOGY**	**Under Ground Water (Bore-hole)**	**Surface Water (Ofosu Stream)**	***Standard Max. limit***	
					WHO	***SON***
1.	Colour	In-Situ	Colourless	Amber	-	-
2.	pH	Electrometric	7.58	7.62	***6-9***	***6.5-8.5***
3.	Temperature (^oC)	Electrometric	24.5	24.8	-	-
4.	E. Conductivity (uS/cm)	Electrometric	100	94	***250***	***250***
5.	Turbidity (NTU)	Nephenometric	2.52	37.96	-	***5***
6.	Alkalinity (mg/l)	Titrimetric	25.6	21.9	-	-
7.	Total Suspended Solid (mg/l)	Gravimetric	3.0	82.5	***30***	-
8.	Total Dissolved Solid (mg/l)	Gravimetric	44	42	-	***500***
9.	Total Hardness (mg/l)	Colorimetric	70.0	60.0	-	***150***
10.	Ammonia (mg/l)	Colorimetric	0.50	1.50	-	-
11.	Chloride (mg/l)	Titrimetric EDTA	16.0	5.6	***250***	***250***
12.	Sulphate (mg/l)	Respirometric	55	60	***250***	***100***
13.	Nitrate (mg/l)	Colorimetric	0.26	0.20	***50***	***50***
14.	BOD_5^{20}(mg/l)	Electrometric	02	70	-	-
15.	Phosphate (mg/l)	Colorimetric	0.84	1.40	-	-
16.	Dissolved Oxygen mg/l	Closed reflux	3.23	4.16	-	***4***
17.	NO^{2-} mg/l	Colorimetric	0.06	0.04	***3***	***0.2***
18.	COD mg/l	Colorimetric	06	150	-	-
19.	Copper (mg/l)	Colorimetric	0.01	3.45	***2***	***1***
20.	Lead (mg/l)	Colorimetric	0.05	1.08	***0.01***	***0.01***
21.	Iron (mg/l)	Colorimetric	0.35	0.80	***0.3***	***0.01***
22.	Total Hydrocarbon: THC – (mg/l)	Colorimetric	78.00	689.22	-	-
23.	Total Coliform (MPN/100ML)	Multiple tube Fermentation	<1	350	-	***400***
24.	Faecal coliform (Cfu/100ML)	Pour plate/membrane filter	Nill	150	-	- -

Source: Lab result, 2014

4.3. Soil quality assessment

Generally, a typical soil is composed of sand, silt and clay particles, organic matter (humus), water and airspace that support agricultural activities (Narayanan, 2007). As shown in Table 6, the analytical result indicated that point 1, 2 and 5 have high level of Zinc all averaging 13.55mg/kgDW while point 4 and 5 contain much of the Iron averaging 131.17mg/kgDW which exceeds the maximum standard limit of 3.00. Point 1 also has high level of Exchangeable cations (EC) while Point 3, 4 and 5 had no faecal coliform. The implication of this result is that in the study area, agriculture is the mainstay of the people hence, the need to re-examine the soil quality within and around the mine.

Table 5. GPS reading of soil sample collections locations

Sampled Points	Latitude (N)	Longitude (E)
1	*6^{0}44'40.8''*	*5^{0}10'01.1''*
2	*6^{0}44'44.5''*	*5^{0}09'58.2''*
3	*6^{0}44'53.5''*	*5^{0}09'58.6''*
4	*6^{0}44'42.4''*	*5^{0}09'57.0''*
5	*6^{0}44'35.5''*	*5^{0}10'23.7*

Source: Fieldwork, 2014

Table 6. Physical, Chemical and Bacteriological result of soil analysis

PARAMETER	METHODOLOGY	Point 1	Point 2	Point 3	Point 4	Point 5	Mean Value	Standard Max limit (FMEnv)
1. pH	Electrometric	5.91	6.56	6.05	5.99	5.12	**5.93**	**6.0-9.0**
2. Temperature^{o}C	Electrometric	27.0	27.0	27.1	26.90	26.80	**26.96**	**35**
3. Conductivity (mS/cm)	Electrometric	107.30	89.90	63.20	18.90	26.80	**61.22**	**150**
4. TDS (mg/kgDW)	Electrometric	69.75	58.44	41.08	12.29	9.04	**38.12**	**500-3500**
5. Moisture content (%)	Gravimetric	7	14	4	6	5	**7.2**	**30**
6. Vinyl mg/kg (Vi)	Colorimetric	5.01	3.99	4.4	5.1	3.71	**4.44**	**nill**
7. Total Hydro Carbon (mg/kgDW)	EDTA Titrimetric	80.00	66.01	50.08	64.06	130.16	**78.06**	**nill**
8. SO_4^{2-}(mg/kgDW)	Colorimetric	50.00	70.68	30.30	66.01	46.60	**52.72**	**500**
9. $N0_3^{-}$(mg/kgDW)	Colorimetric	20.10	10.13	40.10	13.00	20.93	**20.85**	**nill**
10. Nickel (mg/kgDW) (Ni)	Colorimetric	2.05	6.80	4.46	3.96	7.00	**4.85**	**nill**
11. Fe^{2+}(mg/kgDW)	Colorimetric	66.56	76.13	60.61	164.57	288.00	**131.17**	**3.00 ***
12. Pb^{2+}(mg/kgDW)	Colorimetric	12.00	7.00	5.00	15.00	8.00	**9.4**	**0.05 ***
13. Zn^{2+}(mg/kgDW)	Colorimetric	12.21	26.07	8.00	6.03	15.45	**13.55**	**nill**
14. Cu^{2+} (mg/kgDW)	Colorimetric	2.93	0.60	0.49	1.00	0.70	**1.14**	**1 ***
MICROBIAL LOAD		**MICROBIOLOGICAL RESULTS**						
15. THB (Cfu/g)	Spread Plate	6.42x10^{3}	5.22x10^{3}	8.26x10^{3}	7.20x10^{3}	3.56x10^{3}	**6.13x10^{3}**	-
16. Faecal coliform (Cfu/g)	Pour Plate / Memmbrane Filter	1.0	2.0	nil	nil	nil	**1.5**	-
17. Yeast/Mould (Cfu/g)	Spread Plate	nil	3	7	3	nil	**4.33**	-

Source: laboratory result of collected soil samples from the author's fieldwork, 2014g
*Note: * = parameters that exceed the standard maximum limits*

Results of the soil analysis, therefore, reveal that the soil is distinctively acidic with an average pH value of 5.93, temperature of 26.96^{0}C and conductivity of 61.22mS/cm. Consequently, out of the seventeen (17) parameters examined for soil quality, three (3) elements (Iron –Fe, Lead – Pb, and Copper – Cu) were found to have exceeded the maximum limit set by the FMEnv on soil quality. While lead averages 9.4mg/kgDW which exceeds the standard maximum limit of 0.05mg/kgDW, copper on the other hand averages 1.14mg/kgDW, also more than the1mg/kgDW maximum standard limit set by FMEnv in Nigeria.

The summation of the above result is that the soil within the mining area of Evbonogbon community has high concentration of Iron which is good for agriculture and lead which is poisonous to plants and animals. Despite the fact that mine operator has provided borehole water and low skill jobs for some of the locals in the area, appropriate mitigative measures that include remediation plans after mine site decommissioning is advocated.

5. Conclusion and recommendation

In this study, we examined the environmental quality of a traditional African rural mining community of Evbonogbon in Edo State, Nigeria. Air, water and soil samples were collected and analyzed to reveal the concentrations of pollutants. The results were measured against established global and national standard such as WHO, Federal Ministry of Environment (FMEnv) and Standard Organization of Nigeria (SON). The study shows that particulate matter is a major contributing factor to pollution in the study area as a result of rock mining. The study also shows that noise levels are highest near the generator, rock blasting and mining area and the particulate matter mainly results from blasting and crushing of rock by the rock mining companies within Evbonogbon community. The result of the water analysis showed that the underground borehole water is safe for drinking with lowest total hydrocarbon (THC) and zero Faecal coliform. The parameters for the coliforms has normal microbial load but the surface water had more. However, the surface river water is not safe for drinking because of its turbidity, having high level of suspended solids, dissolved oxygen and copper. This corroborates with Olofin (1991) research that surface water pollution is a menace to the quality of life in Nigeria.

The study has shown that dust particles and other particulates matter resulting from mining activities require close control through continuous wetting of mining area with water. In addition, consistent use of ear muff for sound control and mouth mask for dust within and near the mines is also recommended. Similarly, continuous analysis and surveillance of drinking water is recommended for effective monitoring of the progression of the impact of mining in the study area. This requires a systematic programme of surveys, which may include auditing, analysis, sanitary inspection by institutions and community health personnel (WHO, 2011). Continuous rehabilitation of mine site in addition to adequate clean up measures as part of decommissioning plans is advocated.

References

Adebisi, A. (2002), "Environmental sanitation and waste management policies at the local level in Nigeria", *Geo-studies Forum*, Vol. 1 No. 1 & 2, pp. 29-37.

Akeredolu, F.A. (1989), "Atmospheric environmental problems in Nigeria - an over view", *Atmospheric Environment*, Vol. 23 No. 4, pp. 783-792.

Barcelo, D. (1993), *Environmental analysis: techniques, applications and quality assurance*, Elsevier: Amsterdam.

Boyd, D.R. (2006), "The water we drink: an international comparison of drinking water standards and guidelines." A report prepared for the David Suzuki Foundation Health Environment, Healthy Canadian Series, Vancouver, Canada. Available at: http://www.davidsuzuki.org/publications/downloads/2006/DSF-HEHC-water-web.pdf (accessed 28 April 2015).

Chappell, B.W. and White, A. J. R. (2001), "Two contrasting granite types: 25 years later", *Australian Journal of Earth Sciences,* Vol. 48, pp. 489-499.

Cowell, R. (2000), Environmental Compensation and the Mediation of Environmental Change: Making Capital out of Cardiff Bay", *Journal of Environmental Planning and Management*, Vol. 43, pp. 689–710.

Davis, C. (2006), "Natural Resources Conservation Authority Ambient Air Quality Guideline Document", Prepared for National Environment and Planning Agency, Kingston 5, Jamaica. Available at: http://www.nepa.gov.jm/regulations/air-ambient-guideline-2006.pdf (accessed 18 January 2015).

EEA (2012), "Environmental quality. Glossary.Environmental terminology and discovery service". European Environment Agency, Copenhagen, Denmark, available at: http://glossary.eea.europa.eu/EEAGlossary /E/environmental_quality (accessed 18 February 2014).

Ejaro, S.P. and Abdullahi, U. (2013), "Spatiotemporal analyses of land Use and land cover changes in Suleja Local Government Area, Niger State, Nigeria",*Journal of Environment and Earth Science.*Vol. 3 No. 9, pp. 72-83.

Essiet E.U. (1995), "Soil Quality and Agricultural Sustainability under Small Farming System in Rogo, Kano State", Paper Presented at the 3rd workshop on Land Admin and Development in Northern Nigeria, March 12-16, Kano, Nigeria.

Evans, W.F.J. (2006), "Measurements of the radiative surface forcing of climate", 18th Conference on Climate Variability and Change, pp. 1-7. Available at: ftp://ftp.orbit.nesdis.noaa.gov/pub/smcd/spb/lzhou/AMS86/ PREPRINTS/PDFS/100737.pdf (accessed 23 April 2014)

FAO (1978), "Systematic index of international water resources treaties, declarations, acts, and case by basin: Legislative Study No. 15", FAO, Rome.

FRN (2007), "National environmental standard and regulation enforcement agency. Official gazette, established Act No.92", Federal Republic of Nigeria. 94: A635-655.

Harries, J. E., Brindley, H.E.,Sagoo, P. J. and Bantges, R. J. (2001), "Increases in greenhouse forcing inferred from the outgoing longwave radiation spectra of the Earth in 1970 and 1997", *Nature.*Vol. 410 No. 6826, pp. 355-357.doi:10.1038/35066553

Huber, M. and Knutti, R. (2011), "Anthropogenic and natural warming inferred from changes in Earth's energy balance", *Nature Geoscience,* Vol.5 No. 1, pp. 31-36.

James, A.H. (2008), Decorative stones in the pre-ottoman islamic buildings of Cairo, Egypt. Available at:http://www.eeescience.utoledo.edu/Faculty/Harrell/Egypt/Mosques/CAIRO_Rocks_1.htm(accessed4 January 2013).

Johnson, D.L., Ambrose, S.H., Bassett, T.J., Bowen, M.L., Crummey, D.E., Isaacson, J.S., Johnson, D.N., Lamb, P., Saul, M. and Winter-Nelson, A.E. (1997), Meanings of environmental terms",*Journal of Environmental Quality*, Vol. 26 No. 3, pp. 581-589.

Kumagai, N., Sadao, S. and Hidebumi, I. (1978), "Long-term creep of rocks: results with large specimens obtained in about 20 years and those with small specimens in about 3 years". *Journal of the Society of Materials Science,* Vol. 27 No. 293, pp. 157–161.

Larsen, E.S. (1929), "The temperatures of magmas", *American Mineralogist*, Vol. 14, pp. 81-94.Available at: http://www.minsocam.org/msa/collectors_corner/arc/tempmagmas.htm (accessed 17 March 2014)

Marble Institute of America (2008), "Natural stone countertops and radon - Environmental Health and Engineering - Assessing Exposure to Radon and Radiation from Granite Countertops", Available at: http://www.marble-institute.com/industryresources/countertops_radon_wp.pdf and http://www. stonesofnorthamerica.com/technical/Natural_Stone_Countertops_and_Radon.pdf(accessed 14 May 2014).

MEA (2005), "Ecosystems and human well-being: biodiversity synthesis, millennium ecosystem assessment", World Resources Institute. Washington, DC. Available at: http://www.millenniumassessment.org/ documents/document.356.aspx.pdf (accessed 22 March 2014).

Narayanan, P. (2007), *Environmental Pollution: Principles, Analysis and Control,* CBS publishers and distributors, India.

Olofin, E.A. (1991), "Surface Water Pollution: A Menace to the Quality of Life in Urban Areas of Nigeria". Paper presented at the 34th Annual Conference of the Nigerian Geographical Association, Owerri.

Olorufemi, J.F. and Jimoh, H.I. (2000), Anthropogenic Activities and the Environment, in: Jimoh, H.I. and Ifabiyi, I.P. (Eds.), *Contemporary Issues in Environmental Studies,*Haytee press and Publishing Co. Ltd., Kwara State, Nigeria, pp. 7-11.

Purushotham, D., Rashid, M., Lone, M.A., Rao, A.N, Ahmed, S., Nagaiah, E. and Dar, F.A. (2013), "Environmental impact assessment of air and heavy metal concentration in groundwater of Maheshwaram Watershed, Ranga Reddy District, Andhra Pradesh", *Journal Geological Society of India*, Vol. 81, pp. 385-396.

SON (2007), "Nigerian standard for drinking water quality", Nigerian Industrial Standard (NIS) 551:2007, Abuja, Nigeria.

Udo, R.K. (1970), *Geographical regions of Nigeria,* Heinemann Education, London.

WHO (1976), "Selected methods for measuring air pollutants", WHO offset Publication No. 24. Geneva.

WHO (2001), *Guideline for Drinking Water*, World Health Organisation, Geneva, Switzerland.

WHO (2005), "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide", Global update 2005, Summary of risk assessment, Geneva, Switzerland.

WHO (2011), *Guidelines for drinking water-quality, 4th edition.* World Health organisation, Geneva.

WHO (2014), "Ambient (outdoor) air quality and health", Fact sheet N°313, WHO Media centre. Available at: http://www.who.int/mediacentre/factsheets/fs313/en/ (accessed 5 May 2014).

World Bank (1997), "Environmental performance monitoring and supervision". Update. Environmental Assessment Sourcebook. World Bank, Washington, DC.

WHO (2002), "Reducing risks, promoting healthy life", World Health Report, World Health Organization, Geneva, Switzerland.