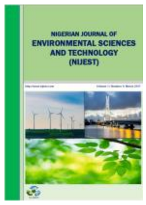
Nigerian Journal of Environmental Sciences and Technology (NIJEST)

www.nijest.com

ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501

Vol 4, No. 1 March 2020, pp 182 - 196



Assessment of particulate matter ($PM_{2.5}$, PM_{10}) in air, elemental composition of granite and weather parameters at a quarry site in Ngwogwo, Ebonyi State, Nigeria

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https://doi.org/10.36263/nijest.2020.01.0199

ABSTRACT

The World Health Organization opined that suspended particulate matter (e.g. $PM_{2.5}$, PM_{10}) are affecting more people worldwide than any other pollutant. This study aimed to determine the status of particulate matter, elemental composition of granite and weather parameters via sampling and analysis of samples from different locations at quarry site in Ebonyi State, Nigeria. The highest concentrations of Pb (2.00±0.05 mg/kg), Zn (6.85±0.06 mg/kg), Mn (94.21±0.13 mg/kg), Fe (3,461.65±3.61 mg/kg), Ca (5.41±0.01 %) and K (0.24±0.02 %) in different sizes of granites were recorded in dust particles. The order of abundance of the elemental composition in granites is: Fe > Mn > Zn > Ca > Mg > Pb > Co > As > Na > K. The highest temperature (45.88±0.53 °C) and relative humidity (49.05±0.21 %) was recorded close to the conveyor belt and walk way to pit, respectively. The concentration of $PM_{2.5}$ (69.00±1.41 µg/m^3) and PM_{10} (2,829.50±12.02 µg/m^3) were highest at the chippings deposition cum collection point. The concentration of $PM_{2.5}$ is higher than the permissible limit set by United States Environmental Protection Agency (USEPA) and World Health Organization (WHO). The concentration of PM_{10} is substantially above the permissible limit set by WHO. This suggest that quarry workers, and the wider community are subjected to prevailing environmental health threat. This emphasizes the need for rigorous implementation of existing environmental legislations established to protect the environment and public health.

Keywords: Quarrying, Granite, Particulate matter, Elemental composition, Weather, Ngwogwo

1.0. Introduction

Quarrying as a land-use practice is the extraction of non-fuel and non-metal minerals from rock deposited in the earth's crust (Okere *et al*., 2001; Ogbonna *et al*., 2011). Quarrying activities involve diverse surface methods like sand and soil excavation, solution mining, rock blasting and alluvial dredging that generate aggregate used for building and other civil construction like highways or concrete and in bitumen plants and rail track construction (Keeperman, 2000; Nwachukwu *et al*., 2018). The mining of precious metals and other types of solid minerals forms an important part of many countries' economy (Ogbonna *et al*., 2011). Notwithstanding this, rock and mineral resources cannot be extracted from the earth without some environmental impacts (Nwachukwu *et al*., 2018) and high exploitation of solid minerals may lead to generation of environmental pollutants that are left behind in tailings scattered in open and partially covered pits, while some are transported by wind and flood, resulting in various environmental problems (Ogbonna *et al*., 2011). The atmosphere is one of the major pathways for transport of dust contaminated with heavy metals and the major external input of bio-available metals in the environment, which are potential threats to the health and survival of people (Ogbonna *et al*., 2018) living in proximity to quarry sites. This may be because quarry atmosphere is submitted to large inputs of heavy metals arising from stationary source such as blasting of rock and large volume of tailing dust at quarry site.

The production of quarry rocks ranks third in terms of volume and fourth in terms of value of all non-fuel mineral commodities over the world (Gunn and Gajen, 1987; Gunn *et al*., 1997)). Suspended particulate matter is quite outstanding among all pollutants emanating from quarrying operations (USEPA, 2008). Solid materials in the form of smoke, dust and also vapour generated during quarrying operations are usually suspended over a long period in the air (Oguntoke *et al*., 2009). Fine particulate matter ($PM_{2.5}$) causes reduction in visibility, has an adverse influence on human health, and is known to be related to global climate change (Zhu *et al*., 2016; Wang *et al*., 2020). Long-term exposure to air pollution particulate matter increases the risk of lung cancer, respiratory diseases and arteriosclerosis, and short-term exposure can exacerbate several forms of respiratory diseases, including bronchitis and asthma, as well as cause changes in heart rate variability (Liu *et al*., 2005; Garcon *et al*., 2006; Lu *et al*., 2007; Pope III *et al*., 2009; Peacock *et al*., 2011; Raaschou-Nielsen *et al*., 2011). The 2015 Global Burden of Disease (GBD) study established that 4.2 million deaths were caused by $PM_{2.5}$ pollution, accounting for 7.6% of total deaths and making $PM_{2.5}$ pollution the fifth most common cause of death for people of all ages worldwide (Xie *et al*., 2018). Similarly, a report by the Environmental Working Group in California showed that respiratory illnesses caused by particulate matter are responsible for more than 10,000 deaths and 16,000 hospital admissions. The health care cost of these illnesses was put at $132 million, in addition to millions of missed work days and school absences each year (Deborah, 1996; Douglas, 1996; USEPA, 1996; www.angelfire.com).

In Nigeria, Ebonyi State is one of the States endowed with abundant solid minerals such as granites. Hence, a lot of quarry industries exploring, mining and processing granites for various purposes are located in various parts of Ebonyi State. Quarrying as a land use has provided employment opportunities to both the youth and adults from the local community and it has also serve as a source of income to the rural women and children that sell cooked food, fruits, snacks, minerals etc. at the China quarry site in Ngwogwo in Ishiagu, Ebonyi State, Nigeria. Notwithstanding this, quarrying activities may be releasing air pollutants such as $PM_{2.5}$ and PM_{10} and contaminants like heavy metals into the surroundings with its concomitant effects on the people.

Literature search showed that very little research has been carried out on the concentration of particulate matter in air at quarry site over the world. These studies are effects of quarry activities on some selected communities in the lower ManyaKrobo District of the Eastern Region of Ghana (Nartey *et al*., 2012), environmental impact of aggregate mining by crush rock industries in Akamkpa local government area of Cross River State, Nigeria (Ukpong, 2012), air quality assessment in the vicinity of quarry site in Ogun State, Nigeria (Bada *et al*., 2013), estimation of air quality status due to quarrying activities and its impacts on the environment and health of the people in Umuoghara in Abakiliki, Ebonyi State, Nigeria (Onwe, 2015), geospatial and geostatistical analyses of particulate matter concentrations in Imo State, Nigeria (Opara *et al*., 2016), environmental impact assessment of quarries and stone cutting industries in Jammain, Palestine (Sayara, 2016), stone quarrying impact on air, soil, water in Akpoha and Ishiagu, Ebonyi State, Nigeria (Peter *et al*., 2018) and environmental impact of stone quarrying activities in Akpoha and Ishiagu in Ebonyi State, Nigeria (Kalu, 2018), but none of these studies determined the ambient temperature and elemental composition of granites in their study sites. In addition, the authors but for Bada *et al*. (2013) did not consider $PM_{2.5}$ (which is more hazardous than PM_{10} because of its smaller size). This study, therefore, is aimed to determine the level of particulate matter ($PM_{2.5}$, PM_{10}) in air, the elemental composition of granite and some weather parameters at a quarry site in Ngwogwo in Ebonyi State, Nigeria. The results of this study will provide Ebonyi State Government information to improve enforcement of health and safety legislation to protect quarry workers, the wider community and the future generation against the hazards posed by mining activities in the State.

2.0. Methodology

2.1. Study area

The study was carried out at China quarry in Ngwogwo in Ishiagu, Ebonyi State, Nigeria. Ishiagu is made up of seventeen villages and it is one of the largest communities in Ivo Local Government Area of Ebonyi State. It is located on the plains of the south-eastern savannah belt and lies within latitudes 5°51' and 5°59'N and longitudes 7°24' and 7°40'E. The dry season start from December and end in March while the wet season commence from April and end in November with annual precipitation of about 1,925 mm and average temperature of 27°C (Ofomata, 2002). The highest elevation is about 110 m above sea level and formed by erosion-resistant igneous intrusive while the lower areas are underlain by soft rocks (Edeani, 2015). Ishiagu is drained by a number of rivers such as Ikwo River, Ivo River, Odu River and Ihetutu streams. The main river Ivo takes its source from the Udi-Okigwe cuesta and then splits into smaller streams such as Ikwo, Ngado, Ihetutu and Eku rivers that create dendritic drainage pattern (Edeani, 2015). The major occupation of the individuals in the community is stone crush work, lead mining, trading and farming. The crops commonly grown are rice, yam, cassava, and vegetables such as *Telfaria occidentales* (fluted pumpkin), *Vernonia amydalina* (bitter leaf) etc.

2.2. Sample collection and analysis

Reconnaissance survey was carried out prior to sample collection to identify or determine wind direction, the different sizes of chippings and the different points of major activities in the study area, among others. Air samples were collected using an absolute instrument system, AIS (model Aerocet 5315) to measure the total concentration of particulate in the air. The air samples were randomly collected from nine (9) different sampling points (quarry entrance, first dust heap, before change room, $^3/_7$ chipping heap, close to conveyor belt, chipping deposition and collection point, walk away to pit, Truck Park, and pit). The control was taken 4 km from the quarry site where there was no visible sign of contamination since some quantities of particulate matter are known to be suspended in air several kilometres from its source of generation before deposition on soil, plants, and water bodies or inhaled by man. The instrument was held 2 m above the ground and at stability, readings for particulate matter (respirable and inhalable particulates $PM_{2.5}$ and PM_{10}), air temperature and relative humidity were taken. The air monitor was calibrated according to the manufacturer's directions before being deployed for the air quality sampling. Sampling was carried out for one hour (1 hour) each day for a period of three (3) days during the afternoon in each of the nine (9) air monitoring points. The 3 days serves as replicates and the average of the means for the three days were determined as concentrations for $PM_{2.5}$ and PM_{10}, temperature and relative humidity. Other parameters measured include air temperature with Digital thermometer (model Omron MC-246) and relative humidity with hygrometer (Cigar Oasis Caliber 4R Gold Digital/Analog).

2.3. Collection of granite chippings and analysis

Different sizes of chippings such as 0.50 unmixed, 0.50 mixed, 3/8 inch, 1/2 inch, 1 inch, hard-core, and dust were collected from China quarry site. Dust samples were collected by placing five (5) white cardboard papers at five (5) different positions at the quarry site and the dust deposited on the cardboard sheets for three different days were emptied into a polythene bag. About one (1) kilogram samples of 0.50 unmixed, 0.50 mixed, $^3/_7$ inch, $^1/_2$ inch, 1 inch, and hard-core were randomly collected from China quarry site, placed separately in plastic buckets with cover, labelled well, placed in wooden box and transported to the laboratory. Each of the chippings were further crushed into smaller sizes, sieved, and measured into conical flask prior to digestion. Exactly 0.5 g of each sample was measured into Teflon crucible and 20 ml of aqua–regia (HCl: HNO_3 solution in the ratio of 3:1) was added, then a 10 ml of hydrofluoric acid was added. The preparations were covered and heated in the oven at about 100 ^oC in a fume cardboard until the solution became clear. The preparations after heating were cooled in a desiccators and transferred to 250 ml volumetric flask (Hambidge and Krebs, 2007), and thereafter, determination of the amount of each heavy metal and macronutrient were carried out using Atomic Absorption Spectrophotometer (AAS). The elements that were determined were nickel (Ni), cadmium (Cd), arsenic (As), lead (Pb), zinc (Zn) and iron (Fe), manganese (Mn), cobalt (Co), sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg).

For quality assurance and control (QA/QC) measures, high purity reagents of analytical grades were obtained from British Drug Houses (BDH) Chemicals Ltd., UK. All glassware was thoroughly washed and oven-dried and cooled in a desiccator. Reagent blanks and a series of standard solutions of 0.5, 1.0, 2.0, 5.0, 10.0 and 100 mg/l were prepared from the stock standard solution of each test metal by diluting known volumes of the stock solution in 100 ml volumetric flasks using distilled water. The blanks and standard solutions were aspirated directly into the atomic absorption spectrometer.

2.4. Experimental design and statistical analysis

A simple factorial experiment was conducted in a randomized complete block design with three replications in dust particles. Data generated from the experiment were subjected to one way analysis of variance (ANOVA) using statistical package for the social sciences (SPSS) v. 20 and means were separated (Steel and Torrie, 1980) at $P < 0.05$ using Duncan's Multiple Range Test (DMRT) while Correlation analysis was used to determine the relationship between the means of the parameters analysed in soil and cassava plant.

3.0. Results and Discussion

3.1. Elemental composition of granite chippings

The result of heavy metal concentration in various sizes of chipping extracted from the china quarry at Ngwogwo in Ivo Local Government Area of Ebonyi State, Nigeria is presented in Table 1. The result shows different level of significance among the various sizes of chipping ranging from dust particles size to hard-core (granite) size at the study site. The result indicates that the highest concentration of Pb (2.00±0.05 mg/kg), Zn (6.85±0.06 mg/kg), Mn (94.21±0.13 mg/kg) and Fe (3461.65±3.61mg/kg) were obtained in the dust particle size collected from the china quarry site at Ngwogwo and the values are significantly (P < 0.05) higher than their corresponding values in the 0.50 unmixed size (0.73±0.04, 3.97±0.01, 90.68±0.00 and 2.415.60±36.20 mg/kg), the 0.50 mixed size (1.73±0.23, 5.71±0.39, 93.20±0.27 and 3154.71±28.72mg/kg), the $^{3}/_{7}$ inch size (0.72±0.01, 3.72±0.04, 90.43±0.11 and 2332.20±60.95 mg/kg), the ¾ inch size (0.70±0.00, 3.63±0.12, 91.55±0.35 and 2,517.25±5.73 mg/kg), the ½ inch size (0.61±0.05, 6.15± 0.06, 92.23±0.32 and 2592.63±12.13 mg/kg), the 1 inch size (0.69±0.00, 5.76±0.06, 92.17±0.33 and 2389. 65±2.05 mg/kg) and the hard-core (0.47±0.01, 4.27±0.02, 84.80±0.42 and 2427.55±1.06 mg/kg), respectively for Pb, Zn, Mn and Fe. The high concentration of Pb (2.00±0.05 mg/kg), Zn (6.85±0.06 mg/kg), Mn (94.21±0.13 mg/kg) and Fe (3461.65±3.61 mg/kg) in the dust particle size is 2.74, 1.16, 2.78, 2.86, 3.28, 2.90, and 4.26 times for (Pb); 1.73, 1.20, 1.84, 1.89, 1.11, 1.19 and 1.60 times for (Zn); 1.04, 1.01, 1.04, 1.03, 1.02, 1.02 and 1.11 times for (Mn) and 1.43, 1.10, 1.48, 1.38, 1.34, 1.45 and 1.43 times for (Fe) higher than their corresponding values in the 0.50 unmixed size, the 0.50 mixed size, the $^{3}/_{7}$ inch size, the ¾ inch size, the ½ inch size, the 1 inch size and the hard-core size, respectively for Pb, Zn, Mn, and Fe.

The concentration of Pb increased from 0.47±0.01 (hard-core) to 2.00±0.05 mg/kg (dust particle size) and the values is well below 14.30 to 23.99 mg/kg reported in branded gneiss, granite and quartzite at Okemesi-Ijero area South Western Nigeria (Ayodele *et al*., 2018), 21.3 to 184.0 mg/kg in biotite granite and 6.0 to 39.5 mg/kg in mica granite in the Variscan Erzgebirge, Germany (Forster *et al*.,1998), 2.0 to 24.0 mg/kg in volcanic rocks (Husin *et al*., 2015) but relatively lower than 3.0 mg/kg in igneous rock (Alloway, 1995). The differences in the concentration of the heavy metals may be attributed to locational and or environmental differences vis-à-vis differences in heat and pressure brought about by weathering processes, erosion and by compression during rock formation. The highest concentration of As (0.47±0.00 mg/kg) is obtained in the ½ inch size of chippings and the value is significantly ($P < 0.05$) higher than its corresponding values in the dust particle size (0.33±0.01 mg/kg), the 0.50 unmixed size (0.42±0.00 mg/kg), the 0.50 mixed size (0.40±0.01mg/kg), the 1inch size (0.32±0.01 mg/kg) and the hard-core (0.39±0.00 mg/kg). The concentration of As in the ½ inch size of chippings is 1.43, 1.12, 1.18, 1.12, 1.15, 1.47 and 1.21 times higher than values obtained from dust particle size, the 0.50 unmixed size, the 0.50 mixed size, the $^{3}/_{7}$ inch size, the ¾ inch size, the 1 inch size and the hard-core, respectively. The concentration of As increased from 0.32±0.01 (1 inch size) to 0.47± 0.00 mg/kg (the ½ inch size) which is relatively lower than 0.23 to 0.90 mg/kg in branded gneiss, granite and quartzite (Ayodele *et al*., 2018) and 1.5 mg/kg in igneous rock (Alloway, 1995) but well below 5 to 10 mg/kg in volcanic rocks in Tawau, Sabah in Malaysia (Husin *et al*., 2015).

The highest concentration of Co (1.92±0.02 %) was obtained in the 0.50 mixed size and the value is significantly ($P < 0.05$) higher than its corresponding values for dust particle size (1.40±0.04 %), the 0.50 unmixed size (1.72±0.01 %), the $^{3}/_{7}$ inch size (1.54±0.08 %), the ¾ inch size (1.36±0.01 %), the ½ inch size (1.40±0.01 %), the 1 inch size (1.62±0.01 %) and the hard-core granite (1.53±0.01 %) (Table 2). The values of Co increased from 1.36±0.01 % (¾ inch) to 1.92±0.02 % (0.50 mixed size). The highest value of Ca (5.41±0.01 %) is observed in the dust particle size but the value is statistically ($P < 0.05$) not different from values recorded for the 0.50 unmixed size (5.32±0.01 %) and the 0.50 mixed size (5.36±0.06 %) but significantly ($P < 0.05$) higher than values observed in the $^{3}/_{7}$ inch size

(5.28±0.08%), the ¾ inch size (5.20±0.01 %), the ½ inch size (5.00±0.00 %), the 1 inch size (5.11±0.09 %) and the hard-core (4.42±0.00 %) (Table 2).

Table 1: Heavy metals concentration (mg/kg) in chippings

Samples	Pb	As	Zn	Fe	Cd	Ni
Dust	2.00±0.05[a]	0.33±0.01[e]	6.85±0.06[a]	3,461.65±3.61[a]	0.03±0.01[b]	0.62±0.01[b]
0.50 (unmixed)	0.73±0.04[c]	0.42±0.00[b]	3.97±0.01[de]	2,415.60±36.20[e]	0.02±0.00[b]	0.48±0.00[bc]
0.50 (mixed)	1.73±0.23[b]	0.40±0.01[c]	5.71±0.39[c]	3,154.71±28.72[b]	0.09±0.02[a]	1.44±0.03[a]
3/8 inch	0.72±0.01[c]	0.42±0.00[b]	3.72±0.04[e]	2,332.20±60.95[f]	0.01±0.00[b]	0.57±0.01[b]
3/4 inch	0.70±0.00[c]	0.41±0.00[bc]	3.63±0.12[e]	2,517.25±5.73[d]	0.02±0.00[b]	0.42±0.00[bc]
½ inch	0.61±0.05[cd]	0.47±0.00[a]	6.15±0.06[b]	2,592.63±12.13[c]	0.03±0.01[b]	0.60±0.01[b]
1 inch	0.69±0.00[c]	0.32±0.01[e]	5.76±0.06[c]	2,389.65±2.05[ef]	0.03±0.01[b]	0.44±0.01[bc]
Hardcore	0.47±0.01[d]	0.39±0.00[d]	4.27±0.02[d]	2,427.55±1.06[e]	0.01±0.00[b]	0.39±0.00[bc]

Source: Ogbonna et al. (2020)
Values are mean ± standard deviation of 3 replicates
[a,b,c,d,e,f,g,h] Means in the same column with different superscripts are significantly different (P < 0.05)

Table 2: Macronutrient content in granite chippings

Samples	Ca (%)	Mg (%)	K (%)	Na (%)	Co (%)	Mn (mg/kg)
Dust	5.41[a] ± 0.01	3.23[ab] ± 0.01	0.24[a] ± 0.02	0.42[a] ± 0.00	1.40[e] ± 0.04	94.21[a] ± 0.13
0.50 (unmixed)	5.32[ab] ± 0.01	3.16[d] ± 0.00	0.13[d] ± 0.00	0.29c ± 0.02	1.72[b] ± 0.01	90.68[e] ± 0.00
0.50 (mixed)	5.36[ab] ± 0.06	3.20[bcd] ± 0.01	0.22[a] ± 0.01	0.41[a] ± 0.00	1.92[a] ± 0.02	93.20[b] ± 0.27
3/8 inch	5.28[bc] ± 0.08	3.11[e] ± 0.01	0.18[b] ± 0.01	0.41[a] ± 0.00	1.54[d] ± 0.08	90.43[e] ± 0.11
3/4 inch	5.20[cd] ± 0.01	3.17[cd] ± 0.00	0.15[c] ± 0.00	0.41[a] ± 0.01	1.36[e] ± 0.01	91.55[d] ± 0.35
½ inch	5.00[e] ± 0.00	3.21[bc] ± 0.02	0.14[cd] ± 0.01	0.40[a] ± 0.00	1.40[e] ± 0.01	92.23[c] ± 0.32
1 inch	5.11[de] ± 0.09	3.36[a] ± 0.04	0.14[cd] ± 0.00	0.42[a] ± 0.01	1.62[c] ± 0.01	92.17[cd] ± 0.33
Hardcore	4.42[f] ± 0.00	3.04[f] ± 0.00	0.23[a] ± 0.00	0.33[b] ± 0.01	1.53[d] ± 0.01	84.80[f] ± 0.42

Values are mean ± standard deviation of 3 replicates
[a,b,c,d,e] Means in the same column with different superscripts are significantly different (P<0.05)

The values of Ca increased from 4.42±0.00 (hard-core) to 5.41±0.01 % (dust particle size) which is well below 37.6 to 43.1 % in sedimentary rocks of the Kaštela Bay coastal area, Croatia (Mikelić *et al*., 2013) but higher than 0.00438 % reported by Tossavainen (2000) and 0.2700 % in carbonate rocks (Halamic and Miko, 2009). The highest value of Mg (3.36±0.04 %) is recorded for the 1 inch size of chippings but the value is statistically (P > 0.0.5) not different from the value obtained in the dust particle size (3.23±0.01%) but significantly ($P < 0.05$) different from values observed in the 0.50 unmixed size (3.16±0.00%), the 0.50 mixed size (3.20±0.01 %), the $^{3}/_{7}$ inch size (3.11±0.01 %), the ¾ inch size (3.17±0.00 %) the ½ inch size (3.21±0.02 %), and the hard core (3.04±0.00 %). The values of Mg increased from 3.04±0.00 (hard-core) to 3.36±0.4 % (1 inch size) (Table 2) which is higher than 2.09 % (Pidwirny, 2006). The highest value of K (0.24±0.02 %) is obtained in the dust particle size but the value is statistically ($P > 0.05$) not different from values recorded for the 0.05 mixed size (0.22±0.01 %) and the hard-core (0.23±0.00 %) but it is significantly ($P < 0.05$) higher than values observed in the 0.50 unmixed size (0.13±0.00 %), the $^{3}/_{7}$ inch size (0.18±0.01 %), the ¾ inch size (0.15±0.00 %), the ½ inch size (0.14±0.01 %) and the 1 inch size (0.14±0.00 %) (Table 2). The value of K increase from 0.13±0.00 (0.50 unmixed) to 0.24±0.02 % (dust particle size) which is lower than 0.06 to 0.54 % in sedimentary rocks of the Kaštela Bay coastal area, Croatia (Mikelić *et al*., 2013) and 0.27% in carbonate rocks (Halamic and Miko, 2009). The value of Mn (94.21±0.13 mg/kg) in dust particles is significantly ($P < 0.05$) higher than its corresponding values in 0.50 mixed (93.20±0.27 mg/kg), ½ inch (92.23±0.32 mg/kg), 1 inch (92.17±0.33 mg/kg), 3/4 inch (91.55±0.35 mg/kg), 0.50 unmixed (90.68±0.00 mg/kg), 3/8 inch 90.43±0.11 mg/kg) and 84.80±0.42 mg/kg). The value of Mn increased from 84.80 (hardcore) to 94.21 mg/kg (Dust) and the values are lower than 130 to 210 mg/kg reported in sedimentary rocks of the Kaštela Bay coastal area, Croatia (Mikelić *et al*., 2013) and 0.07% in carbonate rocks (Halamic and Miko, 2009). The highest value of Na (0.42±0.00 %) is jointly recorded for the dust particle size and the 1 inch size but the value is statistically ($P > 0.05$) not different from values obtained in the 0.05 mixed size (0.41±0.00 %), the $^{3}/_{7}$ inch size (0.41±0.00 %), the ¾ inch size (0.41±0.01 %) and the ½ inch size (0.40±0.00 %) but are significantly ($P > 0.05$) higher than values obtained for hard-core (0.33±0.01%) and the 0.05 unmixed size (0.29±0.02 %) (Table 2). The values of Na increased from 0.29±0.02 % (0.50 unmixed sizes) to 0.42+0.00 % (dust particle/the 1 inch size) which is lower than 2.83 % (Pidwirny, 2006). In this study, the order of abundance in the elemental composition of the chippings is: Fe > Mn > Zn > Ca > Mg > Pb > Co > As > Na > K.

3.2 Particulate matter ($PM_{2.5}$ and PM_{10}) in air, temperature and relative humidity

Table 3 summarized the concentration of particulate matter in air, temperature and relative humidity at the quarry and control sites. The concentration of $PM_{2.5}$ and PM_{10} in µg/m^3 respectively were 15.00±1.41 and 56.50±6.36 for quarry entrance, 21.50±2.12 and 133.00±2.83 for first dust heaps, 13.00±2.83 and 67.00±2.83 before change room, 14.50±2.12 and 88.50±2.12 for $^3/_7$ chippings heaps, 17.50±2.12 and 197.00±4.24 for truck park, 15.50±2.12 and 232.00±4.24 for close to conveyor belt, 69.00±1.41 and 2,829.50±12.02 for walk way to the pit, 17.50±3.54 and 86.00±5.66 for the pit, as well as 12.00±1.41 and 60.00±2.83 for the control site. The concentration of $PM_{2.5}$ and PM_{10} were highest detected at the chippings deposition cum collection point with the values (69.00±1.41 and 2,829.50±12.02 µg/m^3), respectively. At the China quarry site, the highest and lowest concentration of $PM_{2.5}$ occurred at chippings deposition cum collection point and before change room while the highest and lowest concentration of PM_{10} were observed at the chippings deposition cum collection point and quarry entrance, respectively. The concentration of $PM_{2.5}$ increased from 13.00±2.83 (before change room) to 69.00±1.41 µg/m^3 (chippings deposition cum collection point) and the values is higher than the permissible limit of 35 µg/m^3 and 25 µg/m^3 ($PM_{2.5}$) set by United States Environmental Protection Agency (USEPA, 1996) and World Health Organization (WHO, 2005).

Further, the value of $PM_{2.5}$ (13.00±2.83 to 69.00±1.41 µg/m^3) in this study is higher than the Control Standards of 35, 25, 15, 12 and 8 µg/m^3 ($PM_{2.5}$) set by the People Republic of China, European Union, Japan, United States of America and Australia, respectively (Table 4). Consequently, the concentration of the particulate matter released from China quarry site into air may trigger serious health challenges to both workers at the quarry site and inhabitants of Ngwogwo in Ishiagu of Ebonyi State, Nigeria since they are living not too far from the quarry site. Data for Nigeria's air quality status contained in the Little Green Data Book puts the population exposed to air pollution at $PM_{2.5}$ levels, and exceeding WHO guidelines, at 94% (WHO, 2015). This number is above the 72% Sub-Saharan Africa average (WHO, 2015). Thus, the discharge of airborne particulate matter (dust) in the environment poses health threats to people in mining communities and its surroundings. Air pollution is one of the anthropogenic activities where particulate matter (dust) with diameter 1 to 75 µm are generated and found in the surrounding areas of such activities (Sayara, 2016). Particles with aerodynamic diameters of less than 10 µm termed PM_{10} (inhalable particles) can be transported over long distances (Nickling and Boas, 1998), enter the human respiratory system (Ferris *et al*., 1979) and cause lung damages and related respiratory problems (Last, 1998). Chen *et al*. (2013) found that the average life expectancy in northern China was shortened by five years due to air pollution while Liu *et al*. (2016) established that in 2013 the number of adults who died of $PM_{2.5}$ pollution reached 1.37 million based on ground-level monitoring data. Some ecological studies show that particulate matter (PM) is associated with increased morbidity and mortality from respiratory (Ignotti *et al*., 2010; Silva *et al*., 2010) and cardiovascular diseases (Nunes *et al*., 2013; Rodrigues *et al*., 2015) in children and the elderly, especially during the dry season in the Brazilian Amazon and Cerrado (Rodrigues *et al*., 2017). The concentration of PM_{10} increased from 56.50±6.36 (quarry entrance) to 2,829.50±12.02 µg/m^3 (chippings deposition cum collection point) and the values are substantially well above the permissible limit 50 µg/m^3 (PM_{10}) set by World Health Organization (WHO, 2005). The results suggested that the air within and around the quarry area is subjected to high level of pollution, which can be detrimental to the health of man, animals and plants inhabiting the Ngwogwo area. Based on data from 22,905 subjects between 1982 and 2000 in Los Angeles, Jerrett *et al*. (2005) found that mortality rate increased by 1.17% for each 10 µg/m^3 increase in $PM_{2.5}$ concentration, while Jeremy and Nicholas (2014) used meta-analysis to evaluate 367,251 participants in Europe, finding that each 5 µg/m^3 increase in $PM_{2.5}$ concentration increased mortality rate by 1.07%.

Table 3: Particulate matter ($PM_{2.5}$ and PM_{10}) in air, temperature and relative humidity

Sample Location	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	Temperature (°C)	Relative humidity (%)
Quarry entrance	15.00±1.41^c	56.50±6.36^f	42.97±0.54^{ab}	41.30±0.14^c
Dust	21.50±2.12^b	133.00±2.83^d	41.32±1.43^b	40.85±1.34^c
Before change room	13.00±2.83^c	67.00±2.83^f	43.12±0.16^{ab}	39.80±0.57^d
3/8 chipping heap	14.50±2.12^c	88.50±2.12^e	42.63±1.88^{ab}	39.95±0.64^c
Truck park	17.50±2.12^{bc}	197.00±4.24^c	42.69±1.36^{ab}	38.60±0.71^{ed}
Close to the conveyor belt	15.50±2.12^c	232.00±4.24^b	45.88±0.53^a	36.90±1.27^e
Chipping deposition and collection	69.00±1.41^a	2,829.50±12.02^a	45.17±0.37^a	37.10±1.27^e
Walk-way to pit	17.00±2.83^{bc}	68.00±2.83^f	38.13±1.80^{cd}	49.05±0.21^a
Pit	17.50±3.54^{bc}	86.00±5.66^e	40.96±0.35^{bc}	43.50±0.42^b
Control	12.00±1.41^{cd}	60.00±2.83^f	37.03±2.87^d	48.60±0.85^a
WHO Standard	*25 μg/m^3	*50 μg/m^3	NA	NA
USEPA 1996	*35 μg/m^3	NA	NA	NA

*WHO (2005), NA = Not available.

Further studies by Puett *et al*. (2011), Turner *et al*. (2011), and Hoek *et al*. (2013) concluded that increased $PM_{2.5}$ concentrations result in higher mortality rates due to cardiovascular, respiratory, and lung cancer causes based on epidemiological analysis. The prevalence of respiratory diseases among quarrying communities has been attributed to presence of suspended particulate matter in air (Omosanya and Ajibade, 2011). Thus, dust emission is one of the major effects of quarrying activities (Nartey *et al*., 2012) since pollution of water, soil, or air by particulate matter of the wider inhabited area around a quarry or mine can affect the local food sources and hence diet, with immediate and long-term effects (Abdullah *et al*., 2016).

In comparison with similar studies, the concentration of $PM_{2.5}$ (13.00±2.83 to 69.00±1.41 μg/m^3) in this study is well above <0.01±0.00 to 0.130±0.010 mg/m^3 reported for FW SAN HE CONCEPTS LTD quarry site in Ogun State, Nigeria (Bada *et al*., 2013) and 0.0045 to 0.1960 mg/m^3 recorded for quarry site in Southern part of Nablus district in the West bank, Palestine (Sayara, 2016) (Table 5). Similarly, the concentration of PM_{10} (56.50±6.35 to 2,829.50±12.02 μg/m3) in this study is well above 0.030±0.021 to 0.231±0.018 mg/m^3 observed at FW SAN HE CONCEPTS LTD quarry site in Ogun State, Nigeria (Bada *et al*., 2013) and 0.0580 to 3.1853 mg/m^3 recorded for quarry site in Southern part of Nablus district in the West bank, Palestine (Sayara, 2016). The differences in the results obtained in this study with these other studies may be attributed to the fact that chemical composition of particulate matter (PM) can vary widely as a function of emission source and the subsequent chemical reactions which take place in the atmosphere (Mishra and Tripathi, 2008; Engelbrecht *et al.*, 2009; Olatunji *et al*., 2018), fluctuations in time of the year or seasons (Ibe *et al*., 2016), difference in the ambient temperature, relative humidity and wind speed including wind direction could also vary the concentration of atmospheric pollutants over the seasons (Kim *et al*., 2015) and possibly locational difference. The order of abundance of $PM_{2.5}$ in air sampled from the various sections of the China quarry site is as follows: chipping deposition cum collection point > first dust heaps > truck park/pit > walk way to the pits > close to conveyor belt > quarry entrance > $^3/_7$ chipping heaps > before change room while the order of abundance of PM_{10} is as follows: chipping deposition cum collection point > close to conveyor belt > truck park > first dust heaps > $^3/_7$ chipping heaps > pits > walk away to pit > before change room >quarry entrance.

Table 4: Overall changes in number of deaths and mortality rates under different standards for $PM_{2.5}$ for some countries

Country	Deaths/person	Morality rates/‰	Control Standards	Release time	Character of Standard
China	1,670,200	1.22	35 μg/m³	2012	Mandatory
European Union	1,098,100	0.80	25 μg/m³	2010	Mandatory
Japan	526,200	0.38	15 μg/m³	2009	Mandatory
America	354,500	0.26	12 μg/m³	2012	Mandatory
Australia	125,800	0.09	8 μg/m³	2003	Mandatory

Source: Xie et al. (2018.

At the China quarry site in Ngwogwo, the highest temperature value (45.88±0.53 °C) was recorded close to the conveyor belt but the value is statistically the same with values obtained at the chippings deposition/collection point (45.17±0.37 °C), before change room (43.12±0.16 °C), quarry entrance (42.97±0.54 °C), truck park (42.69±1.36 °C) and $^3/_8$ chippings heaps (42.63±1.88 °C) but significantly

(P < 0.05) higher than temperature values recorded at the dust heaps (41.32±0.43 °C), at the pit (40.96±0.35 °C), walk way to pit (38.13±1.80 °C) and control (37.03±2.87 °C) (Table 3). The different levels of temperature at the quarry site may pose a serious health risk to the quarry workers since temperature is a modifier for particulate matter (PM) such as $PM_{2.5}$, PM_{10}. Temperature is an important modifier for particulate matter, which has a great impact on mortality (Sun *et al*., 2015). Thus, Sun *et al*. (2015) reported greater mortality effects of $PM_{2.5}$ in low temperature than that in high temperature for all natural and respiratory mortality and their findings is in conformity with the results of a study conducted in Shanghai, which found higher PM_{10} effects in low temperature for all natural, cardiovascular, and respiratory diseases. However, some authors have observed that adverse effects of particulate matter may be more apparent at higher temperatures. For instance, Ren and Tong (2006) reported high mortality from cardiovascular disease related to PM_{10} on days with temperature above 27°C in Brisbane, Australia while Meng *et al*. (2012) observed high mortality from cardiovascular disease related to PM_{10} on days with temperature above 30°C in China. There is significant interaction between PM and temperature (P < 0.05), with stronger health effects of PM in high temperature days for cardiovascular mortality (Li *et al*., 2011). In contrast, Cheng and Kan (2012) found significant interaction (P < 0.05) with higher PM effects in low temperature days for all natural and respiratory mortality. The temperature values obtained at the China quarry ranged from 38.13±1.80 °C (pit) to 45.88±0.53 °C (conveyor belt) and the values are higher than 21 to 37.2 °C (Jayamurugan *et al*., 2013), -0.10 to 26.8 °C (Tecer *et al*., 2008), -10.1 to 32.1 °C (Guo *et al*., 2013), and 13.3 to 42.3 °C (Rodrigues *et al*., 2017) in related studies. The order of increase of temperature at the China quarry site is in the order: walk way to the pit < pit < dust heaps < 3/8 chippings heaps < truck park < quarry entrance < before change room < chippings deposition/collection point < close to the conveyor belt.

Table 5: Comparison between results of this study ($PM_{2.5}$, PM_{10}) and other studies

Reference	$PM_{2.5}$	PM_{10}	Temperature	Relative humidity	Study area
This study	13 – 69	56.50 – 2,829.50	38.13 – 45.88	36.90 – 49.05	Ngwogwo in Ivo LGA, Ebonyi State, Nigeria
Sayara (2016)	0.0045 – 0.1960	0.0580 – 3.1853	–	–	Quarry site in Jammain, Palestine
Sun *et al*. (2015)	5.4 – 179.7	7.9 – 573.0	8.2 – 31.8	27.5 – 98.1	Hong Kong
Bada *et al*. (2013)	<0.01 – 0.130	0.030 – 0.231	–	–	Quarry site in Odeda LGA in Ogun State, Nigeria
Nartey *et al*. (2012)	–	54.6 – 125.0	–	–	Limestone quarry in ManyaKrobo District of the Eastern Region of Ghana
Wang *et al*. (2020)	125.9	–	–	–	Beijing, China
Rodrigues *et al*. (2017)	0.10 – 172.3	–	13.30 – 42.30	35.0 – 97.0	Municipalities of Cuiabá and Várzea Grande, State of Mato Grosso, Brazil
Tecer *et al*. (2008)	4.55 – 95.65	12.0 – 200	-0.10 – 26.80	29.0 – 95.0	Coal-mining area in Zonguldak, Turkey
Enotoriuwa *et al*. (2016)	3.1 – 75.7	10.8 – 211.9	29.8 – 33.9	57.8 – 82.8	Oil operating areas in Obigbo and its environs in River State, Nigeria
Choi *et al*. (2012)	41.9	–	–	–	Korea
Akinfolarin *et al*. (2017)	2.9 – 300.35	5.65 – 1926.30	–	–	Three emerging industrial sites in Port Harcourt, Rivers State, Nigeria
Yu *et al*. (2019)	50-53 53-55 54-56	67-71 93-102 87-94	–	–	Shanghai Nanjing Hangzhou
Xu *et al*. (2012)	44.3	–	–	–	Fuzhou
Ubong *et al*. (2015)	2.2 – 59.7	10.3 – 367.5	–	–	Port Hacourt in River State, Nigeria
Ukpong (2012)	–	–	–	56.9 – 91.3	Stone quarrying in Akamkpa, Cross River State, Nigeria
Li and Bai (2009)	117	–	–	–	Tianjin
Opara *et al*. (2016)					Air pollution in Orlu city, Owerri municipality and a quarry site in Okigwe, Imo State, Nigeria
Zhang *et al*. (2009)	63.9	–	–	–	Beijing, China
Oguntoke *et al*. (2009)		3.67 – 26.03	–	–	Quarry site in Abeokuta, Ogun State, Nigeria
Jayamurugan *et al*. (2013)	–	–	21 – 37.2	44 – 98	Coastal urban area in North Chennai, India
Li *et al*. (2010)	38.8	–	–	–	Changbai mountain Nature Reserve
Guo *et al*. (2013)	0.7 – 517.7	10.0 – 600.0	-10.1 – 32.1	8.0 – 97.0	Main campus of Peking University in Beijing, China
Onwe (2015)	–	138.71 – 176.29	–	–	Quarry site in Umuoghara in Abakiliki, Ebonyi State, Nigeria
Li *et al*. (2010)	89.2	–	–	–	Shanghai
Kalu (2018)	–	20.0 – 860	–	–	Stone quarrying activities in Akpoha and Ishiagu in Ebonyi State, Nigeria
Peter *et al*. (2018)	–	15 – 860	–	–	Quarry site in Akpoha and Ishiagu in Ebonyi State, Nigeria
Tanner *et al*. (2004)	19	–	–	–	Tennessee

In this study, the highest value of relative humidity (49.05±0.21 %) was obtained at the walk way to pit but the value was not different (P < 0.05) from the values obtained at the control site (48.60±0.85 %) but significantly (P < 0.05) higher than values of relative humidity recorded at the pit (43.50±0.42 %), quarry entrance (41.30±0.14 %), dust heaps (40.85±1.34 %), $^{3}/_{7}$ chippings heaps (39.95±0.64 %), before change room (39.80±0.57 %), truck park (38.60±0.71 %), chippings deposition/collection point (37.10±1.27 %), and close to the conveyor belt (36.90±1.27 %) (Table 3). The levels of relative humidity at the China quarry site may expose quarry workers to respiratory and cardiovascular diseases since the values of relative humidity in this study are below 54.5 % and 80 %. The findings of Rodrigues *et al*. (2017) noted that the action of $PM_{2.5}$ on hospitalizations and mortality from cardiovascular disease can be exacerbated on days of low relative humidity below 54.5 % while Qiu *et al*. (2013) observed an increase in emergency hospitalizations for ischemic heart diseases related to PM_{10} on days when relative humidity was below 80 % in China. The values of relative humidity in this study ranged from 36.90±1.27 to 49.05±0.21, which are lower than 56.9 to 91.3 % at stone quarrying site in Akamkpa, Cross River State, Nigeria (Ukpong, 2012), 29.0 to 95.0 % (Tecer *et al*., 2008), 35.0 to 97.0 % (Rodrigues *et al*., 2017), 8.0 to 97.0 % (Guo *et al*., 2013), and 44.0 to 98.0 % (Jayamurugan *et al*., 2013) in a related study. The order of increase of relative humidity at the China quarry site is in the order: close to conveyor belt < chippings deposition/collection point < truck park < before change room < 3/8 chippings heaps < dust heaps < quarry entrance < pit < walk way to the pit.

4.0. Conclusion

The highest concentrations of Pb, Zn, Mn, Fe, Ca, K, and Na in granites were recorded in dust particles at China quarry site in Ngwogwo in Ishiagu, Ebonyi State. The order of abundance of the elemental composition in granites is: Fe > Mn > Zn > Ca > Mg > Pb > Co > As > Na > K. The highest concentration of $PM_{2.5}$ and PM_{10} were detected at the chippings deposition cum collection point. The concentration of $PM_{2.5}$ is higher than the permissible limit set by United States Environmental Protection Agency (USEPA), World Health Organization (WHO) as well as the Control Standards set by the People Republic of China, European Union, Japan, United States of America and Australia. The concentration of PM_{10} are substantially well above the permissible limit set by World Health Organization (WHO).

Acknowledgement

The authors acknowledge the Manager of China quarry for given us access to the various sampling positions in this study. The services of Mr. Emebu, Prosper Kome (statistical analysis of the data) are also appreciated.

Conflict of interest

There is no conflict of interest associated with this work.

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Cite this article as:
Ogbonna P. C., Ukpai N. P. and Ubuoh E. A., 2020. Assessment of particulate matter ($PM_{2.5}$, PM_{10}) in air, elemental composition of granite and weather parameters at a quarry site in Ngwogwo, Ebonyi State, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 4(1), pp. 182-196. https://doi.org/10.36263/nijest.2020.01.0199