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Preliminary Assessment of the Trace Element Composition of Dust from Two Granite Quarries from Jos Plateau and Their Possible Health Implications.

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Abstract
Quarrying of rocks has contributed to the development of many developed and developing nations. However, the entire process generates particulate pollution in the environment. The high level of particulates generated at the drilling and crushing areas depicts them as hazard zones. Moreover, quarry workers and communities living in proximity to these hazard zones are exposed to various health risks. In view of this fact, this research was carried out to determine the trace element concentration in the dust from Ric Rock and Satzen quarries, to establish their extent of contamination and deduce their possible human health implications. The results of As, Cd, Cr, Co, Cu Ni, Pb, Zn and Mo were interpreted based on their Pollution index (anthropogenic factor), enrichment index and index of geo-accumulation. The interpretation revealed that the Rick Rock dust is practically unpolluted with As, Cr, Co Cu, and Ni with deficiency to minimal enrichment, unpolluted to moderately polluted and enriched with Zn. The dust is also extremely polluted and severely enriched by Mo. On the other hand, Satzen dust is practically unpolluted by As, Cd Cr, Co, Cu , Ni, Pb and Zn with deficiency to minimal enrichment. It is practically unpolluted to moderately polluted and enriched by Mo. With respect to the selected elements and their contamination status, Rick rock dust has been contaminated with Cd, Pb, Mo, and Zn and Satzen dust has been contaminated with Mo. The elemental enrichment in the dust samples collected from Rick Rock quarry is higher than those from Satzen quarry and can be attributed to oil spillage and emission from trucks and diesel powered generator which is the only source of power supply to the quarry and work throughout the period of quarry operations. This enriched the elemental concentration in the dust. Satzen quarry, on the other hand, uses electricity from Power Generation Company which eliminated such enrichment contribution in the dust. However the enrichment of Mo in the dust may be attributed to oil spillage and combustion of fossil fuel from heavy duty trucks used for the quarry operation. Geochemical analysis of quarry dust from Ric Rock and Satzen quarries showed that the concentration of trace elements in the dust exceeds the permissible limit set by WHO. Some of which are very harmful to human health even at very low concentration exposure. It is certain that long exposure of quarry workers and those living in close proximity via Inhalation, ingestion and percutaneous absorption can result to various health challenges. The release of these trace elements in high concentration by quarry companies enriching their concentration in the environment, polluting air, soil and both surface and ground water which variably affects human, animal and plants through the chain causes diseases and eventual death of man.

Key words: Quarry Dust, Trace Elements, Pollution index, enrichment Factor and index of geo-accumulation.

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1. Introduction

Quarrying is associated with dust particles which constitute one of the most invasive and potentially irritating air pollutants. Atmospheric dust occurs in various forms including as fugitive dust from excavation, from road hauls and stone blasting or from point sources such as drilling, crushing and screening. Dust reduces visibility which poses potent threat to both human health and the environment (Plumlee, 2004; Sudhere, et al. 2012).
The complex mixture of gases that makes up the earth atmosphere has been altered much more significantly in the recent time by human activities that range from domestic energy utilization to large scale industrial operations which are largely responsible for atmospheric pollution.

Air pollution is a major environmental problem affecting both the developing and developed countries of the world. The effects of air pollution on human health are very complex as there are different sources; there by producing varying effects (Sudhere, 2012; Plumlee, 2004).

Although there are various air pollutants, the emission of particulates is quite outstanding from quarries which have both micro and regional effect. Air pollution and ground vibration arising from blasting, crushing and emission of noxious gasses have negative impacts on human health and well-being (Oguntoke et al, 2009).

Solid materials in the form of smoke, dust and water vapor generated during quarrying operations are usually suspended over a long period in the air. Moreover, particulate matters in the air are capable of being transported from the point of generation to areas far removed. Once particles of varying chemical composition are inhaled, they lodge in human lungs; thereby causing lungs impairments and respiratory problems (Last, 1998; Dockery & Pope, 1994). According to Deborah (1996) and National Industrial Sand Association (1997), dust generated from granite quarrying contains 71 percent silica and inhaling such a dust results in silicosis which is capable of disabling an exposed person and subsequently leads to death. A report by the Environmental Group in California showed that respiratory illness caused by particulate matter are responsible for more than ten thousand deaths and sixteen thousand hospital admissions. The health care cost of this illnesses was put at $132 million, in addition to millions of missed work days and school absence each year (www.angelfire.com; Deborah, 1996; Douglas, 1996; Bart, 1993).

It is established that particulate concentration constitute hazards to humans that either work at quarry sites or live in proximity to quarry sites are exposed to respiratory and other disease caused by exposure to particulate matter. Due to the dilution and spread of particulate matter to other locations, workers at the quarry sites are expected to experience multiple episodes of respiratory ailments than people who live at distance away from the quarry (Dockery, 1994; Plumlee, et al, 2004; Qamar, et al. 2001).

Inspite of the known effects of inhaled quarry dust to human health, there is paucity of research on the trace element composition of these dusts and their possible effect on human health. This research work is therefore aimed at determining the chemical composition of the dust particulates from two different granite quarry sites in the Jos Plateau area with particular reference to determination of the potentially harmful elements (PHEs) in the dust and their possible health implications.

No related work has been carried out in the study area. This is the first detailed work on the study area and even in the entire Plateau State. However, related works have been carried out in the Western and Eastern part of Nigeria, other parts of the world and documented for example Aribigbola, et al (2012), Omosanya, K.O., and Ajibade, O.M (2001), Oguntoke, et al, (2009), Nwibo, et al; (2012), Lar, et. al, (2013); Deborah (1996) and National Sand Association (1997, Natural Resources Defense Council (NDRC, 1996) and Enger and Smith (2002); Olufemi, et al (2014); Chiemeka, (2011); Aremu et al (2010) and Amaka, et al (2014).

1.2 Methodology

1.2.1 Location, Sampling and Laboratory Analysis

The study areas are located in Fobur and Corner Mista Ali in Jos East and Bassa Local Government area respectively (Fig 1). Ric Rock lies within Latitude 9°50'19'' and 9°53' 30'' and Longitude 8°50' 30'' and 9°10'30'' and Satzen lies within latitude 10°1' 0'' and 10°4'0'' and longitude 8°50'30'' and 8°52'17' (Fig 1)

Dust samples from the Ric Rock and Satzen quarries were sampled. The suspended rock dust produced by crushing the rocks into aggregates were sampled by gravity settling on paper placed at specific distances in the direction of the prevailing wind. The dust collected on the paper were placed in sample bags, sealed and clearly labeled.

Geochemical analysis of the dusts was carried at ACME laboratory, Canada using the ultra trace Inductively Coupled Plasma-Mass Spectrometry (ultra-trace ICP-MS) to determine their trace elements composition. It is a multi-acid digestion method which combines a strong multi-acid digestion that dissolves most metals with a choice of ultra-trace ICP-MS analysis to give near total value for all elements. In this method, a 0.25g split is heated by HNO_3-$HClO_4$-HF to fuming and taken to dryness. The residue is dissolved in HCl. Although the method is considered near total, it only enables only partial digestion for some Cr and Ba minerals and oxides of Al, Fe, Hf, Mn, Sn, Ta and Zr. In addition, volatilization during fuming may result in the loss of As, S and Sb.

1.2.2 Calculation of Index of Geo-accumulation, Enrichment Factor, Pollution (anthropogenic) and Integrated Pollution Index.

The assessment of soil or sediment enrichment, contamination or toxicity can be carried out in many ways. The most common ones are the index of geoaccumulation and enrichment factors (Lu et al, 2009). In this work, the index of geoaccumulation (Igeo), enrichment factor (EF) and pollution index (anthropogenic factor) have been applied to assess heavy metals (As,Cd, Cr, Co, Ni, Pb, Cu and Zn) distribution and contamination in the dust of the two quarries.

Index of geo-accumulation is a qualitative measure of the extent of metal pollution in the dust. It was calculated using the geo-accumulation index proposed by Muller (1969). This Igeo of heavy metal is calculated by computing the base 2 logarithm of the measured concentration of the metal over its background concentration using the mathematical relations (Muller, 1969).

$I\text{-}geo=\log_2(Cn/1.5Bn)$

$=\log(Cn/1.5Bn)/\log 2$

Where Cn = Measured concentration

Bn= Background concentration

1.5 is the factor compensating the background data (correction factors).

The classification of Index of geo-accumulation (I-geo) according to Lu, et. al, 2009) is given on Table 1.

Enrichment factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers (Loska et al, 2003). It version adapted to assess the contamination of various environmental media is as follows:

EF=[Cx/Cref]Sample/[Bx/Bref]Background

Where

Cx= Concentration of the element of interest

Cref= Concentration of reference element for normalization

Bx= Concentration of reference element in the examined environment

Bref= Concentration of reference element in the reference environment

A reference element is often the one characterized by low occurrence variability, such as the commonly used elements: Al, Fe, Ti, Si, K etc., (Duzgoren-Aydin, 2007; Li, et al., 2001; Sezgin et al., 2003). The classification of Enrichment Factor according to Manno, et al, 2006 is given on Table 2.

Pollution index (PI) and Integrated Pollution Index (IPI) are also commonly used to assess the environment quality (Dose Anjos, et al., 2000). The pollution index was defined as the ratio of the element concentration in the study area to the background content of the abundance of chemical element in the continental crust. The IPI of all measured elements for each sample was defined as the mean value of the element's PI

Pollution (anthropogenic) index is calculated from mathematical relation as shown below:

PI (AF) Index= Cm/Bm

Where Cm=measured concentration in dust

Bm=Background concentration

Dose Anjos et al., 2000 gave a classification of Pollution Index (PI) as follows (Table 3).

2.0 Results.

The result for the trace elements (in ppm) for the dust from Ric Rock and Satzen quarries is given on Table 4. The distribution of the elements in the dust from the two quarries is described below:

Arsenic (As) concentration in Ric Rock dust ranges from 0.4-1.3ppm with average concentration of 0.88 ppm. However, sample RR3 has the highest concentration (Table 1) from 0.5-3.9 ppm with average concentration of 1.62 ppm and Satzen

Cadmium (Cd) concentration is higher in Ric Rock dust relative to those of Satzen. It ranges from 0.25-0.29ppm with average concentration of 0.265ppm and range in Satzen from below detection limit (<0.02)-0.09ppm with average concentration of 0.052ppm. However, very low concentration below detection limit is recorded in sample SQ10 (Table 4)

Chromium (Cr) concentration is high and generally similar in dust of both quarries. It ranges from 4-9ppm with average concentration of 6 and 6.7ppm for Ric Rock and Satzen respectively. The highest and lower concentration is recorded in Satzen samples OE9 and OE6 (Table 4).

Cobalt (Co) concentration ranges from 0.9-1.1ppm in Rick Rock samples with average concentration of 0.95 and from 0.8-1.6 in Satzen samples with average concentration of 1.08ppm. Some samples (SQ1, SQ4 and SQ5) in Satzen displayed higher concentration relative to those of Ric Rock Samples (Table 4)

Nickel (Ni) concentration in Ric Rock samples ranges from 0.6-0.9ppm and has average concentration 0.75ppm and ranges from 0.8-1.6ppm in Satzen samples and has average concentration of 1.13ppm. However, some individual samples showed higher concentration in dust samples (SQ1, SQ4 and SQ5) from Satzen quarry.

Lead (Pb) concentration is very high; it ranges from 38.23-44.64ppm in Ric Rock dust samples and from 20.59-29.93ppm in Satzen with average concentration of 41.03 and 20.58ppm respectively. The highest concentrations are recorded in dust samples from Ric Rock quarry.

Copper (Cu) concentration in Ric Rock samples ranges from 2.26-3.08ppm with average concentration of 4.00ppm. In dust samples from Satzen, it ranges from 0.86-1.95ppm with average concentration of 1.345ppm.it can be seen that the concentration of Cu in samples from Rick Rock quarry is high relative to those from Satzen quarry. However, sample SQ1, SQ4 and SQ5 from Satzen showed slight distinct concentration among the other samples.

Zinc (Zn) concentration is very high and maintained almost the same concentration in all the dust samples from Ric Rock. The concentration ranges from 154.1-157.6ppm and has average concentration of 154.93ppm. However, the concentration of Zn in dust samples collected from Satzen are far less than that of Ric Rock; it concentration ranges from 47.4-78.7ppm with average concentration of 62.75ppm.

Mo concentration in dust samples from Ric Rock ranges from 7.14-15.36ppm and has average concentration of 10.01ppm. It ranges from 1.53-3.93ppm and has average concentration of 2.70ppm in samples from Satzen quarry. It can be noted that Mo concentration in dust samples from Ric Rock is high compared to its concentration in dust samples from Satzen. The highest concentration recorded in Ric Rock in sample RR4 (Table 1)

The Index of Geo-accumulation (I-geo), Pollution Index (Anthropogenic Factor) (PI) and Enrichment Factor (EF) are given on Tables 5 and 6. They are used to interpret the contamination status of some selected heavy metal levels in the dust analysed from the two quarries.

The decreasing trend of average metal level showed that in Ric Rock dust, Zn>Pb>Mo>Cr>Cu>As>Co>Ni>Cd; where as in Satzen dust, Zn>Pb>Cr>Mo>Cu>Ni>Co>As>Cd (Tables 5 and 6)

In Ric Rock dust, the Enrichment Factor (EF) of As, Cr, Co, Cu and Ni are 1.62, 0.45, 0.48, 0.50 and 1.4 and their respective calculated Index of Geo-accumulation are -0.45, -2.32, -2.24 -2.17 and -0.68. The I-geo is less than zero (I-geo<0) which indicates that the dust is practically unpolluted with these elements with deficiency to minimal enrichment. Meanwhile, the Enrichment factors (EF) of Cd and Pb are 4.00 and 3.08. Their respective index of geo-accumulation are 0.82 and 0.45, that is less than 1 (I-geo < 1) indicating that the dust is unpolluted to moderately polluted and moderately enriched with respect to Cd and Pb. The enrichment factor (EF) of Mo is 6.66 and its Index of Geo-accumulation is 1.57, (I-geo <2) which is an indication that the dust is moderately polluted and severely enriched with Mo. Zn has an enrichment factor of 4.62 with an Index of Geo-accumulation of 2.27 which showed that the dust is moderately to strongly polluted and moderately enriched by Zn. (Tables 6 and 7, Fig 2).

The pollution index (Anthropogenic factor) of As, Cr, Co, Cu and Ni are less or equal to one (PI≤1).The pollution of the dust by As, Cr, Co, Cu and Ni is of low pollution intensity. Cd and Pb have pollution index less or equal to three (3) and falls within the middle pollution intensity. Mo and Zn are highly polluted in the dust with their PI greater or equal to three (3) (Table 6, Fig.3).This also conform to the other parameters stated above.

In Satzen quarry dust, the enrichment factor (EF) of As, Cd, Cr, Co, Cu, Ni, Pb and Zn are 0.88, 0.78, 0.50, 0.54, 0.17, 2.0, 1.88 and 1.88. Their respective Index of Geo-accumulation is -1.35, -1.53, -2.16, -2.06, -3.4, -0.10, -0.26, 0.36 and -0.26 which is an indication the dust is practically unpolluted by these elements. Meanwhile the enrichment factor of Mo is 2.88 with Index of Geo-accumulation of 0.36. This showed that the dust is unpolluted to moderately polluted and moderately enriched by Mo (Tables 8 and Fig. 3).

The pollution index (Anthropogenic factor) of As, Cd, Cr, co, Cu, Ni, Pb and Zn are less or equal to two (2). This reflects low pollution intensity in dust from Satzen quarry by the stated elements. However, Mo have pollution index less or equal to 3 which depicts middle pollution intensity in the dust (Table 8, Fig. 3). This also conformed to the other two parameters described above.

3.0 Discussion

The results showed that the concentration of the measured trace elements is higher in Ric Rock dust than in Satzen dust. The measured concentration of As, Cd, Cr, Zn, Pb, Ni, Cu, Mo, and Co are high in the dust exceeding the WHO/EPA guideline values as shown in Table 9.

The Index of Geo-accumulation, Pollution Index and Enrichment Factor indicated that the dust sampled from Ric Rock quarry is practically unpolluted by Arsenic, Chromium, Cobalt, Copper and Nickel and deficiency to minimal enrichment by these elements. It is unpolluted to moderately polluted and moderately enriched with Cd, Pb and Zn. The dust is moderately polluted and severely enriched by Mo.

In Satzen dust, the pollution intensity showed the dust is practically unpolluted and is deficient to minimal enrichment by As, Cd, Cr, Co, Cu Ni and Zn. It is unpolluted to moderately polluted and moderately enriched with Molybdenum.

EF values ranging between 0.5 and 2.0 can be considered in the range of natural variability, whereas ratios greater than 2.0 indicates some enrichment corresponding mainly to anthropogenic input (Shakeri et al, 2009)

From the above statement, dust sampled from Ric Rock is enriched with Cd, Pb and Zn as a result of moderate anthropogenic contribution because their EF is greater than 2.0 and less than 5. On the other hand, the dust is severely enriched by Mo as a result of greater anthropogenic contribution because its EF is greater than 5.However, As, Cr, Co, Cu, Ni have their respective EF less than 2.0 and therefore, their elemental concentration is probably entirely due to crustal or natural origin (Tables 5, 7 and Fig. 2).

Conversely, the enrichment factor (EF) of Mo in dust sampled from Satzen quarry dust is above 2.0 and less than 5 which is an indication that the dust pollution status results from moderate anthropogenic contribution. As, Cd, Cr, Co, Cu, Ni, Pb and Zn on the other hand, have their respective EF less than 2.0 which indicates that their elemental concentration is also probably entirely due to crustal or natural origin (Table 8, and Fig. 3)

The release of these high trace elements concentration into the environment through the activities of quarry companies enriches their concentration in the environment there by polluting the soil, air, surface and ground water. Quarry workers and those in proximity are at high health risk due to long exposure to these high trace elements concentration either through direct ingestion, percutaneous absorption, inhalation or bioaccumulation in the human system through the food chain. The trace elements and their possible health implications associated with deficiency and/or excess are as discussed below:

The Arsenic concentration in the dust ranges from 0.5 to 3.9ppm in Ric Rock and from 0.4 to 1.3 in Satzen exceeding the WHO permissible limit of 0.05ppm (Table 9).

Arsenic is regarded as human carcinogen from extremely low levels of exposure, having no possible beneficial metabolic function for human. Its low level exposure causes nausea and vomiting, decreased production of RBCs and WBCs, abdominal pains. It long term exposure causes darkening of the skin and appearance of small corns in palm soles. Other effects include abnormal ECG, anorexia, fever, fluid loss, goiter, hair loss, headache, herpes, impaired healing, jaundice, keratosis, kidney and liver damage, muscle spasms, pallor, peripheral neuritis, sore throat, weakness and interferes with the uptake of folic acid.

Cadmium is highly toxic non-essential heavy metal and does not have a role in biological process in living organisms. It can be toxic even in low concentrations. Its concentration in the dust ranges from 0.25 to 0.29 in Ric Rock and from less than 0.02 to 0.09ppm in Satzen. It is found to exceed the WHO permissible limit of 0.005ppm (Table 9).

Cadmium is very toxic, its long- term exposure to lower level leads to build up in the kidney and possible kidney disease, lung damage, and fragile bones. Hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility, hypoglycemia, headache and strokes are some it long term effects.

Lead is a toxic metal even at low concentration levels. The concentration of lead in the dust range from 38.23 to 44.64ppm in Ric Rock, and from 20.59 to 29.93ppm in Satzen which both exceeds the WHO permissible limit of 0.015ppm (Table 9).

Diseases associated with deficiency of lead is not recognized but those associated with excess exposure either through ingestion or inhalation can leads to varieties of maladies, including: system hypertension; gastro intestinal pains and bleeding, pulmonary edema; anemia, destruction of red blood cells; liver necrosis, kidney failure encephalopathy and other central and peripheral nervous system disorder. Chronic toxicity can lead to systemic hypertension; skin disorder such as eczema, hyperkeratosis, melanosis, ulceration and skin cancers

Chromium concentration in the dust ranges from 5 to 7ppm in Ric Rock and from 5 to 9ppm in Satzen, both exceeding the WHO permissible limit of 0.1ppm (Table 9).

Chromium (III) is essential to maintain the metabolism of the human body; it is effective in management of diabetes and it is a cofactor with insulin. Itsdeficiencies result in defective glucose metabolism, hyperlipidemia, corneal opacity. Health effects associated with excess exposure causes irritation and generation of lesions in skin, respiratory tract, and gastric and intestine mucosa; contact dermatitis, pulmonary edema, acute kidney failure, Long-term risk for lung cancer, pneumoconiosis from exposure to Chromites dust.

Cobalt is an integral component of vitamin B12 molecules; is an essential element needed in human body for normal physiological function. It concentration in the dust ranges from 0.8 to 1.1ppm in Ric Rock and from 0.8 to 1.6ppm which are above the WHO permissible limit of 0.1ppm (Table 9). Health effects associated with deficiency includes anemia and anorexia. Excess ingestion results to Cardiomyophathy, hypothyroxism, polycythemia (excess RBCs), cancer. Excess inhalation causes respiratory irritation “Hard metal” pneumoconiosis. Percutaneous exposure causes allergic dermatitis.

Copper is an essential element for plant and animal health. Its concentration in the dust ranges from 2.26 to 3.08ppm in Ric Rock exceeding the WHO permissible of limit 1.00ppm and from 0.86 to 2.71ppm in Satzen exceeding WHO permissible limit except for sample E6 and E8 that has Cu concentration which falls below the permissible limit (Table 9). Its deficiencies lead to Anemia and menke’s syndrome. Health effects associated with excess inhalation and ingestion are Wilson’s diseases (associated with Cu buildup in organs), intestinal and liver inflammation, hemolysis (destruction of red blood cells, with diffusion of hemoglobin into surrounding fluids), and hyperglycemia.

Zinc is an element that is also essential for human and animal health. It has an important role in metabolism, growth and general well being. It concentration in the dust ranges from 153.8 to 157.6ppm in Ric Rock and from 47.4 to 78.7ppm in Satzen, both exceeding the WHO permissible limit of 2.0ppm (Table 9).

Diseases associated with Zn deficiency are anorexia, dwarfism, anemia, hypogonadism, hyperkeratosis, acrodermatitis, enteropathica, depressed immune response and teratogenic effects. Health effects associated with excess ingestion is hyperchronic anemia and inhalation is metal fume fever at high doses.

Molybdenum is an essential element necessary for human and animal body to perform it normal physiological function. The concentration of Mo in the dust ranges from 7.14 to15.36ppm in Ric Rock and from 1.53 to 3.93ppm in Satzen and all exceeds the permissible limit of 0.15ppm (Table 9).

Health effects associated with Mo deficiencies are growth depression, keratinization effects and hyperurinemia. Exposure to excess of Mo causes high uric acid in serum and urine, loss of appetite, diarrhea, slow growth, anemia, "gout-like lesions and molebdenosis.

Nickel plays some roles in body functions including enzyme function. In very trace amount, it may be beneficial to activate some systems. It ranges in the dust from 0.7 to 0.9ppm in Ric Rock and from 0.8 to1.6ppm in Satzen. This concentration is found to exceed the permissible limit of 0.02ppm(Table 9).

Health effect associated deficiency is not recognized but exposure to Ni inhalation results to chronic bronchitis, emphysema, reduced lung capacity, cancers of the lung and nasal sinus. Ingestion of Ni can result to death (due to cardiac arrest), gastrointestinal effects (nausea, cramps, diarrhea, vomiting), effect on blood, liver, kidney. Also, it can leads to neurological effects (giddiness weariness).

4.0 Summary and Conclusions.

Quarrying of rocks have shown to have contributed to the development of many developed and developing nations. However, it generates and releases particulate pollution in the environment. The high level of particulates generated at the drilling and crushing areas depicts them as hazard zones. Moreover, quarry workers and those communities living in proximity to these hazard zones are exposed to various health risks.

The study investigated the trace elements concentration in the dust of Ric Rock and Satzen quarries to determine the concentration of trace elements in the dust and also to deduce their possible health implications. The results of the geochemical analysis were interpreted based on the Pollution index (anthropogenic factor), enrichment index and index of geoaccumulation using some selected trace elements (As, Cd, Cr, Co, Cu Ni, Pb, Zn and Mo). The interpretation revealed that:

i. The Rick Rock dust is practically unpolluted with As, Cr, Co Cu, and Ni with deficiency to minimal enrichment, unpolluted to moderately polluted and enriched with Zn. The dust is also extremely polluted and severely enriched with respect to Mo. On the other hand, Satzen dust is practically unpolluted by As, Cd Cr, Co, Cu , Ni, Pb and Zn with deficiency to minimal enrichment. It is practically unpolluted to moderately polluted and enriched by Mo.

ii. Even though biotite Granite is the rock been quarried in both areas, the dust from the Ric Rock quarry have higher concentration of the trace elements compared to the dust from the Satzen quarry. This is as result of moderate to severe anthropogenic activities considering their enrichment factors relative to those in Satzen quarry dust. With respect to the selected elements and their contamination status, Rick rock is not contaminated with Cd, Pb, Mo, and Zn and Satzen dust has been contaminated with Mo.

iii. The elemental enrichment in the dust samples collected from Rick Rock quarry is higher than those from Satzen quarry and can be attributed to oil spillage and emission from trucks and diesel powered generator which is the only source of power supply to the quarry. This enriched the elemental concentration in the dust. Satzen quarry, on the other hand, uses electricity from Power Generation Company which reduced such enrichment contribution in the dust. However the enrichment of Mo in the dust may be attributed to oil spillage and combustion of fossil fuel from heavy duty trucks used for the quarry operation.

Geochemical analysis of quarry dust from Ric Rock and Satzen quarries showed that the concentration of trace elements in the dust exceeds the permissible limit set by WHO. Some of which are very harmful to human health even at very low concentration. It is certain that long exposure of quarry worker and those living in close proximity via inhalation, ingestion and percutaneous absorption can result to various health challenges. Ric Rock quarry workers are at high potential risk than Satzen quarry worker because the trace element concentrations are much higher and extensively contaminated in Ric Rock dust relative to Satzen quarry dust. The release of these trace elements in high concentration by quarries can enrich their concentration in the environment thereby polluting the air, soil and both surface and ground water which variably affects human, animal and plant lives through food chain which may cause diseases and eventual death of man.

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Table 1: Classification of Index of Geo-accumulation (I-geo) (Lu et al, 2009)

I-geo	Class	Pollution Intensity
Igeo<0	0	Practically unpolluted
0<Igeo<1	1	Unpolluted to moderately polluted
1<Igeo<2	2	Moderately polluted
2<Igeo<3	3	Moderately to strongly polluted
3<Igeo<4	4	Strongly polluted
4<Igeo<5	5	Strongly to extremely polluted
Igeo>5	6	Extremely polluted

Table 2: Classification of Enrichment Factor (EF) (Manno et al, 2006)

Enrichment factors (EF)	Degree of enrichment
<2	Deficiency to minimal enrichment
2-5	Moderate enrichment
5-20	Severe enrichment
20-40	Very high enrichment
>40	Extremely high enrichment

Table 3: Classification of Pollution Index (PI) (Dose Anjos et al., 2000)

Pollution (Anthropogenic) Index (PI)	Intensity of pollution
IP≤1	Low
1<IP≤3	Middle
IP>3	High

Table 4: Results of Geochemical analysis of dust samples for the Ric Rock (RR1-RR4) and the Satzen Quarries (SQ1-SQ6) in parts per million (ppm) for trace elements.

Samples No.	RR1	RR2	RR3	RR4	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	Average
Mo	7.57	9.95	7.14	15.36	2.67	3.65	3.93	1.53	2.82	2.69	2.88
Cu	2.54	3.08	2.26	2.71	1.95	0.86	1.15	0.97	1.57	1.57	1.35
Pb	42.04	44.64	39.21	38.23	29.23	20.59	22.11	21.22	28.64	27.96	24.96
Zn	154.2	157.6	153.8	154.1	78.7	52.1	47.4	54	71.6	72.7	62.75
Ni	0.8	0.7	0.6	0.9	1.2	1	0.8	0.8	1.4	1.6	1.13
Co	1.1	0.8	1.1	0.9	1.4	0.8	0.8	0.8	1.4	1.6	1.13
Mn	411	379	378	362	184	134	127	157	180	175	159.50
As	0.8	1.3	3.9	0.5	1.3	0.4	0.4	1	0.9	1.3	0.88
U	13.6	14.7	12.9	15.1	13.8	8.8	9.1	11.2	11.8	12	11.12
Th	57.2	59.3	62.8	59.8	48.1	29.1	33.2	34.3	48.9	48	40.27
Sr	40	41	42	37	10	8	9	8	10	10	9.17
Cd	0.27	0.25	0.25	0.29	0.09	0.07	0.04	0.07	0.04	<0.02	0.06
Sb	0.24	0.31	0.18	0.23	0.32	0.16	0.16	0.21	0.24	0.24	0.22
Bi	0.11	0.14	0.08	0.09	0.09	0.04	0.05	0.07	0.09	0.07	0.07
V	2	1	2	2	2	2	2	2	3	3	2.33
Cr	7	5	5	7	8	4	5	6	9	8	6.67
Ba	291	287	290	243	50	32	29	36	44	41	38.67
Cs	4.3	3.6	3.7	3.6	1.8	1.9	1.9	1.9	1.9	1.8	1.87
W	4	3.6	3.5	3.6	3.1	1.9	2.2	2.2	2.6	2.9	2.48
Zr	97	108.1	101.5	142.7	182.4	121	112.6	170.5	136.2	145.4	144.68
Sn	8	7.3	7.6	6.8	6.1	6.8	6.3	6.7	4.8	4.9	5.93
Be	12	11	13	13	14	9	10	16	12	10	11.83
Sc	1.9	1.7	1.6	1.7	0.9	0.6	0.6	0.7	0.8	0.9	0.75
Y	117.9	113.4	106.1	152.7	267.2	159.8	162.7	183	201.5	202.1	196.05

Table 5: Summary of the mean concentration, Index of Geo-accumulation (I geo), Pollution Index (PI) and Enrichment Factor (EF) of some selected heavy metal contents of dust from Ric Rock Quarry, Fobur.

Elements	**Conc (ppm)**		**I-geo**		**Pollution (PI)**		**Enrichment Factor EF)**	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
As	0.50-3.90	1.625	-2.17-0.79	-0.45	0.33-2.6	1.08	0.33-3.90	1.62
Cd	0.265-0.29	0.265	0.82- -0.95	0.82	2.65-2.90	2.65	3.97-4.30	4.00
Cr	5-7	6.0	2.59- -2.10	-2.23	0.25-0.35	0.30	0.38-0.53	0.45
Co	0.8-1.1	0.95	2.50- -1.97	-2.24	0.26-0.37	0.32	0.40-0.55	0.45
Cu	2.62-3.078	4.00	-2.70- -2.55	-2.17	0.21-0.26	0.33	0.33-0.39	1.50
Ni	0.6-0.9	0.75	-1.00- -0.42	-0.68	0.75-0.30	0.94	1.12-1.69	1.40
Pb	38.23-44.64	41.03	0.35-0.57	0.45	1.91-2.23	2.05	2.88-3.35	3.08
Mo	7.14-15.36	6.67	1.66-2.77	1.57	4.76-10.24	4.5	7.14-15.36	6.70
Zn	153.8-157.6	154.93	1.04-1.07	1.05	3.08-3.15	3.10	4.61-4.73	4.62

Table 6: Summary of the Mean Concentration, Index of Geo-accumulation (I-geo), Pollution Index (PI) and Enrichment Factor (EF) of some selected Heavy Metal Contents of Dust from Satzen Quarry, Corner Mista Ali

Elements	**Conc (ppm)**		**I-geo**		**Pollution (PI)**		**Enrichment Factor EF)**	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
As	0.40-1.30	0.883	-2.00 - -0.79	-1.35	0.27-0.87	0.59	0.33 – 1.06	0.88
Cd	<0.02-0.90	0.052	<0001 - -3.12	-1.53	<0.2-9.00	0.52	<0.20 – 8.81	0.78
Cr	4-9	6.7	-5.22 - -1.74	-2.16	0.2-0.45	0.34	0.06 – 0.13	0.50
Co	0.8-1.6	1.08	-2.50- -1.50	-2.06	0.27-0.53	0.36	0.05 – 0.11	0.54
Cu	2.26-3.08	1.345	-2.99 - -2.55	-3.4	0.19-2.57	0.11	0.07 – 0.090	0.17
Ni	0.8-1.6	1.13	-0.58 - -0.42	-0.10	1.00-2.00	1.41	0.02 – 0.03	2.00
Pb	20.59-29.93	25.02	-0.54 - -0.003	-0.26	1.03-1.50	1.25	2.43 – 3.5	1.88
Mo	1.53-3.93	2.88	-0.56 - 0.81	0.36	1.02-2.62	1.92	1.5 – 3.85	2.88
Zn	47.48-78.70	62.75	-0.66 – -0.07	-0.26	0.68 – 1.12	1.26	0.99 – 1.65	1.88

Table 7: Summary of Quantitative Indices with respect to Trace Elements in Quarry Dust from Ric Rock Quarry

Elements (ppm)	**Mean I-geo**	**Mean PI**	**Mean EF**	**Summary of contamination**
As	-0.45	1.08	1.62	Practically unpolluted with deficiency to minimal enrichment
Cd	0.82	2.65	4.00	Practically unpolluted to moderately polluted with moderate enrichment
Cr	-2.32	0.30	0.45	Practically unpolluted with deficiency to minimal enrichment
Co	-2.24	0.32	0.45	Practically unpolluted with deficiency to minimal enrichment
Cu	-2.17	0.33	1.50	Practically unpolluted with deficiency to minimal enrichment
Ni	-0.68	0.94	1.40	Practically unpolluted with deficiency to minimal enrichment
Pb	0.45	2.05	3.08	Unpolluted to moderately polluted and moderately enrichment.
Mo	1.57	4.5	6.60	Moderately polluted with and severe enrichment
Zn	2.27	3.10	4.62	Unpolluted to Moderately polluted with moderate enrichment

Table 8: Summary of Quantitative Indices with respect to Trace Elements in Quarry Dust from Satzen Quarry.

Elements (ppm)	Mean I-geo	Mean PI	Mean EF	Summary of contamination
As	-1.35	0.59	0.88	Practically unpolluted with deficiency to minimal enrichment
Cd	-1.53	0.05	0.78	Practically unpolluted and deficiency to minimal enrichment
Cr	-2.16	0.34	0.50	Unpolluted with deficiency to minimal enrichment
Co	-2.06	0.36	0.54	Unpolluted with deficiency to minimal enrichment
Cu	-3.4	0.11	0.17	Unpolluted with deficiency to minimal enrichment
Ni	-0.10	1.41	2.00	Unpolluted and moderate enrichment
Pb	-0.26	1.25	1.88	Unpolluted with deficiency to minimal enrichment
Mo	0.36	1.92	2.88	Unpolluted to moderately polluted with moderate enrichment
Zn	-0.26	1.26	1.88	Practically unpolluted with deficiency to minimal enrichment

Table 9: Measured Concentration of some selected Heavy Metals in Dust from Ric Rock and Satzen Quarries and WHO (2000) maximum permissible limit in water.

Heavy metals (ppm)	Measured concentration range in Ric Rock dust (ppm)	Measured concentration range in Satzen dust (ppm)	WHO/EPA permissible limit (ppm)
As	0.5-3.9	0.4-1.3	0.01
Cd	0.25-0.29	<0.02-0.07	0.01
Cr	5-7	4-9	0.1
Cu	2.26-3.08	0.86-1.57	2.00
Ni	0.8-1.6	0.6-0.9	0.02
Mo	7.57-15.36	1.53-3.93	0.15
Pb	38.23-44.64	20.59-29.93	0.05
Zn	153.8-157.6	47.4-78.7	5.00

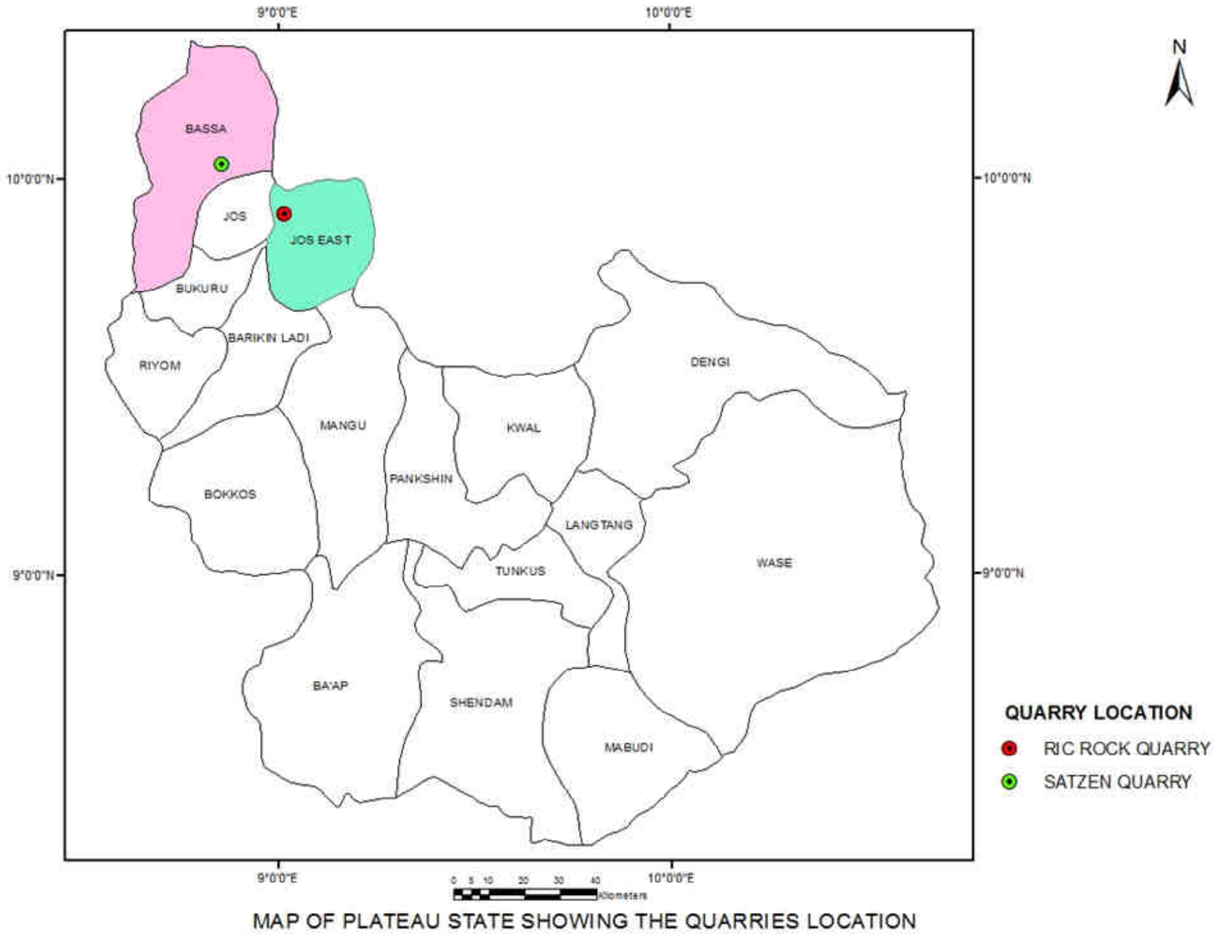

FIGURE 1: MAP OF PLATEAU STATE SHOWING THE LOCATION OF THE STUDY AREAS.

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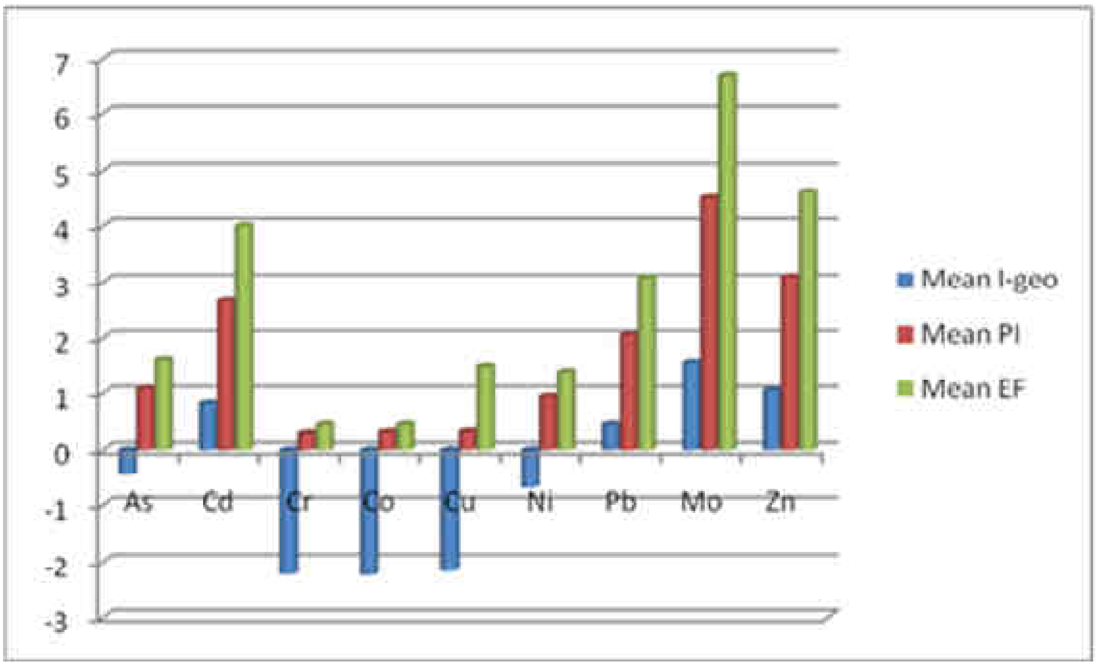

Fig. 2: Chart showing mean values of I-geo, PI and EF against elements for dust from Ric Rock quarry.

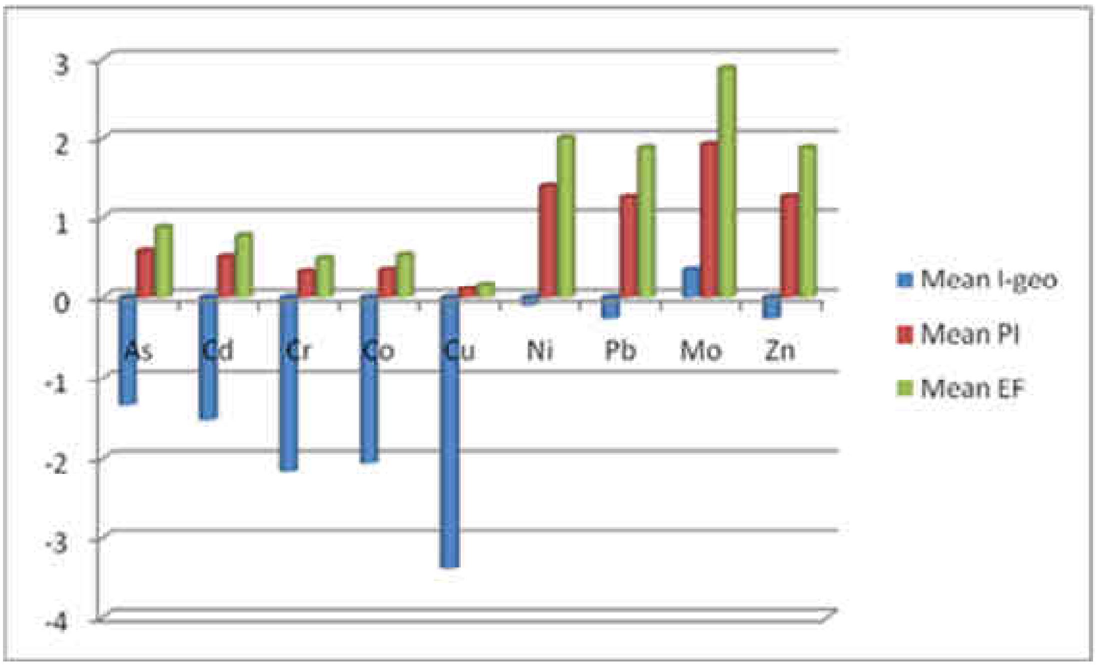

Fig. 3: Chart showing mean value ofI-geo, PI and EF against elements of dust from Satzen quarry.