HUMAN HEALTH RISK ASSESSMENT OF HEAVY METALS IN DUST SAMPLES OF QUARRY CLUSTERS IN UMUOGHARA QUARRY INDUSTRY, EBONYI STATE, NIGERIA

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Abstract

Background: Heavy metals exert toxic effects on body systems with the degree of toxicity directly dependent on the daily intake. The safety of workers from heavy metal exposure has not been adequately evaluated despite the presence of many quarry industries. **Objective:** This study seeks to determine the inhalational risks of heavy metals in the dusts of Umuoghara quarry industry in Ebonyi state. **Methodology:** Three quarry dust samples from four clusters of the study location were subjected to atomic absorption spectrometer to determine the concentrations of Cadmium (Cd), Zinc (Zn), Lead (Pb), Copper (Cu), and Nickel (Ni). The estimated daily intake (EDI), hazard quotient (HQ), hazard index (HI) and incremental lifetime cancer risks (ILCR) of the heavy metals were calculated. **Result:** The results showed high concentrations of the heavy metals in the dust samples. The EDI of the heavy metals was found in the order of Ni> Pb> Cd for carcinogenic and Zn>Ni>Cu>Cd>Pb for non-carcinogenic. The HQ and HI of the heavy metals were normal (<1). The ILCR was also normal ($\leq 10^{-5}$). There was no significant difference ($P>0.05$) in the concentration of the heavy metals in the dusts of the four clusters. **Conclusion:** The result showed permissible limits of the heavy metals in the quarry dust which may not pose any non-carcinogenic or carcinogenic risk to the quarry workers. However, as toxicity is dependent on dose, duration and type of heavy metal exposure, there is a need for adherent use of personal protective measures and periodic medical check-ups by the workers with close monitoring by relevant authorities.

Key words: Health risk assessment, Health effects of heavy metals, quarry dusts, Umuoghara quarry industry

Introduction

A quarry is an open pit mine from which rock minerals are extracted through various processes that comprise of removal of the topsoil, drilling, blasting with explosives and use of machinery to crush and grade rock materials for transportation.[1] These Industrial activities result in release of dust pollutants and particles and influx of metals into the atmosphere, which can be transported by wind and water into the biotic targets. [2] Sources of heavy metals include coal combustion, pesticides, cements, large scale industrial operations such as oil refineries, foundries, chemical industries, including quarrying, among others.[1] These heavy metals attain higher concentrations and accumulate in dangerous quantities and finally pose danger to the ecosystem including human, plants and other animals [3,4]. The quarry dust particles very often contain heavy metals whose toxic effects can be divided into carcinogenic and non-carcinogenic.[5] The factors associated with the health risks include the particle size, concentration, composition, and extent of exposure and these are usually considered in evaluating the health risks. Health risk assessment involves evaluating the risk of exposure to certain chemical agent(s) to a population, taking into consideration the characteristics of the agent and the target system(s) it affects. The model for health risk assessment begins with formulation of a problem, followed by identification of hazard, characterization of hazard, assessment of exposure and then risk characterization.[6]

Quarrying raises various environmental concerns such as land pollution, emission of dust, noise and ground vibrations which pose danger to the workers and occupants of quarry sites. Quarry dust particles contain many harmful substances in their chemical structure which can be associated with many negative effects on human health. The toxic effects which may be neurotoxic, carcinogenic, mutagenic, or teratogenic can be implicated in a wide range of health disorders in acute, chronic ,or sub-chronic forms. The inhalation of the dust causes severe health problems such as respiratory, pulmonary, ocular and dermal.[7,8]

In Nigeria, quarrying and extraction of limestone by opencast methods for construction activities have intensified in the last few decades. Yet, there is dearth in information on the impact of lime-stone and other mineral explorations on the surrounding environment in terms of heavy metals pollution in Nigeria. There is need to investigate the baseline concentrations of toxic heavy metals within the vicinity of quarry sites. This will form a database on pollution status of the toxic heavy metals within the surrounding environment of quarries and serve as reference point for future studies and health risk assessment. Such assessment is of utmost importance especially in areas rich in solid materials like Ebonyi state which lies within the lead-zinc field of the Eastern cretaceous (chalky) belt of Nigeria.

Heavy metals exist naturally but are introduced in the environment through anthropogenic activities. They accumulate in the environment and can easily penetrate the body system through various pathways and especially the respiratory route. Heavy metals are bio-accumulative, and at toxic levels are hazardous to health, hence, the necessity for close monitoring of heavy metal concentration in quarry dusts to limit the risks. The expected findings will serve as tool for adopting strategies needed for prevention and to save the population from metal toxicity. This study aimed to identify the levels of five common heavy metals in the quarry dusts of different site clusters and establish the risks associated with the exposure.

MATERIALS AND METHODS

Study site: The study was conducted in Ebonyi state, one of the south eastern states in Nigeria. The state is richly endowed with numerous mineral resources such as zinc, lead, limestone, and granite.[9] The study took place at the quarrying industry located at Umuoghara, a densely populated Community in Ezza North Local Government Area (LGA) of the Ebonyi State. The quarry industry has about 300 crushers unevenly arranged in four clusters with about 250 workers found at the sites daily. These figures are dynamic, but has remained as the average for more than ten years.[10] The stones commonly quarried at the Umuoghara quarry industrial site are mainly the granites (igneous), limestones (sedimentary), baked shales (sedimentary), slaty shales (metamorphic) and the pyroclastics.[1] The major occupations of the inhabitants of Umuoghara are farming, trading, and stone quarrying. Although pockets of mining have been going on within the area, it was only recently that quarrying activities assumed prominence to compliment the State Government’s drive for more revenue. [10] Stone quarrying is currently the most notable economic activity going on in the area.

Sampling method: To ensure that the dust samples were true representation of the Umuoghara quarry dust, the four clusters served as the stone crushing sample collection points. The first two clusters- left and right from the quarry road were labelled A and B, while the two clusters behind, left and right were labelled C and D. Clusters A, B, C and D had 77, 76, 73 and 74 crushers respectively. A simple random sampling by balloting (drawing without replacement) was used to select three crushers per cluster from where the dust samples were obtained.

Sample collection, preparation, and analysis: Three quarry dust samples were collected from each of the four clusters using clean sampling sheets of paper. Test locations were mildly excavated around the selected crushing plants. Clean sampling papers were placed on those locations to ensure quality dust deposit during crushing operation and samples were obtained from the deposits in the test locations. The samples were placed in clean polythene bags and transferred to the laboratory.

Samples were dried using oven dry method at 75°C for 2 days and then ground to fine powder. From the powdered Sample, 0.5g was digested in a mixture of 5 ml of HCl and 0.5 ml of conc. HNO_3 in a conical flask under a fume hood. The content was continuously heated gently at 70 – 90°C for 2 hours on a hot plate until dense white fume appeared. It was then heated strongly for 30 minutes and thereafter cooled, filtered, and diluted with 25 ml of distilled water. Using the American Society for Testing and Materials (ASTM) method, the final solution was however analyzed with the Varian AA240 atomic absorption spectrometer. [11]

Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator and onto the detector that measures the amount of light absorbed by the atomized element in the flame.[12] The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample which reflects the standards of known concentration. [12]

Ethical consideration: Ethical approval was obtained from the ethics committee of the Ministry of Health, Ebonyi State, Nigeria, and permission was gotten from the quarry site owners.

Measurements and definition of variables: Variables measured/determined were the intake rate (estimated daily intake (EDI); hazard quotient (HO); non-carcinogenic index - hazard index (HI); carcinogenic index in the form of incremental lifetime cancer risk (IRCR)

The intake rate (Estimated Daily Intake, EDI)

Inhalational Exposure Concentration (EDI Inh) = C× InhR × EF × ED (mg/m3)

PEF × BW × AT

(Where:C = Concentration of chemical (mg/m^3); EF = Exposure frequency (days/year, average reference value = 150 for children and adult, soil); ED = Exposure duration (30 years average reference value for adult, soil); Inh= Respiratory Frequency (average reference value = 20 m^3/d, for adults); PEF = Atmospheric dust reduction factor ($m^{3/}kg$) (average reference value=1.36×10^9 m^3/kg, for adults); Body Weight (BW) =70kg(average reference value for adults, soil); Average time (AT) a) For carcinogens = 365 × 70 days(average reference value for adults/children, soil), b) For non-carcinogens =365 × ED (average reference value for adults/children, soil). [6,13]

ii) Hazard quotient (HQ): This is the ratio of the estimated exposure to a substance (EDI) and the level at which no adverse effects are expected which is the reference concentration. A hazard quotient less than or equal to ***1*** indicates that adverse effects are not likely to occur, and thus can be considered to have negligible hazard. HQs greater than1 may be said to be unsafe.[14]

$$HQ = \frac{\text{Exposure Concentration (EDI)}}{\text{Reference concentration (RFD)}}$$

HQ < 1 safe; HQ > 1 unsafe

iii) Hazard index (HI): This isa measure of the potential risk of adverse health effects from a mixture of chemical constituents in various quarry dust samples. It is the summation of HQs for multiple substances and/or multiple exposure pathways. Non-carcinogenic impacts may be said to occur when HI > 1(Antoine et al, 2017)

$HI = HQPb+HQCd+HQZn+HQCu+HQNi.$

HI < 1 safe; HI > 1 unsafe

iv) Incremental lifetime cancer risk (ILCR)*:* This is used to identify probable cancer risks due to exposure to a specified dose of heavy metal. Cancer risks will be considered highly negligible when the estimated ILCR is $\leq 10^{-5}$; however, if the ILCR is greater than 10^{-5}, the risk assessment should either be repeated in a refined manner or risk management measures taken.[13]

$ILCR=EDI\times CSF$

where, CSF is the cancer slope factor and is defined as the risk generated by a lifetime average amount of one mg/kg/day of carcinogenic substance

Statistical analysis: Data collected were analyzed using Kruscal-Walis test to compare the means at 5% level of significance.

RESULT

Metal concentration in quarry dusts

Table 1 shows mean concentration of heavy metals in the quarry dust. The result shows that across the four clusters, zinc has the highest mean concentration (3.224mg/L) while lead has the lowest mean concentration (0.045 mg/L).There was no significant difference in the mean concentration of the heavy metals of the four clusters of the quarry site.

Table 4.1: Mean concentration heavy metals in quarry dust

	Cluster A Mean±SD	Cluster B Mean±SD	Cluster C Mean±SD	Cluster D Mean±SD	k-w	p-value
Lead	0.045±0.022	0.056±0.023	0.057±0.020	0.056±0.020	1.05	0.789
Nickel	1.436±0.709	0.769±0.165	0.956±0.130	1.902±1.270	3.51	0.319
Copper	0.715±0.410	0.427±0.53	0.317±0.14	0.592±0.429	3.21	0.361
Zinc	2.447±1.461	1.625±0.297	1.081±0.090	3.224±3.327	4.13	0.248
Cadmium	0.261±0.150	0.080±0.059	0.011±0.006	0.014±0.012	5.59	0.133

Estimated daily intake (EDI)

Table 2 shows the mean values of the inhalational carcinogenic and non-carcinogenic estimated daily intake (EDI) of heavy metals concentration. The average daily exposure of metals via inhalation of quarry dust ranges from 4.7484747E-13 (for cd) to 1.0888396E-10 mg/kg/day (for Zn).The daily average exposures were estimated for both non-carcinogenic and carcinogenic effects.

The mean values of inhalational carcinogenic EDI of heavy metal concentrations in the dust samples were found in the order of Ni> Pb> Cd. The mean values of the inhalational non-carcinogenic EDI of heavy metal concentrations in the dust samples were found in the order of Zn>Ni>Cu>Cd>Pb.

Table 2: Inhalational carcinogenic and non-carcinogenic estimated daily intake (EDI) of heavy metals from quarry dust

Variables	**EDI of Inhalational route (mg/kg/day**			
	Cluster A	**Cluster B**	**Cluster C**	**Cluster D**
Carcinogenic				
Lead	1.9425578E-12	2.4174053E-12	2.4605732E-12	2.4174053E-12
Nickel	6.1989179E-11	3.3196155E-11	4.1268562E-11	8.2105444E-11
Copper	-	-	-	-
Zinc	-	-	-	-
Cadmium	1.1266835E-11	3.4534361E-12	4.7484747E-13	6.0435132E-13
Non carcinogenic				
Lead	4.5326349E-12	5.6406124E-12	5.7413376E-12	5.6406124E-12
Nickel	1.4464141E-10	7.7457695E-11	9.6293311E-11	1.9157937E-10
Copper	7.2018533E-11	4.3009669E-11	3.1929895E-11	5.9629331E-11
Zinc	2.4647461E-10	1.6367848E-10	1.0888396E-10	3.2473811E-10
Cadmium	2.6289282E-11	8.0580177E-12	1.1079774E-12	1.4101531E-12

Lead- Pb, Nickel- Ni, Copper- Cu, Zinc – Zn, Cadmium- Cu

Estimated hazard quotient(HQ)

Table 3 shows the mean values of the inhalational carcinogenic and non-carcinogenic estimated hazard quotient (HQ)) of heavy metals concentration

The heavy metal inhalational carcinogenic HQ in each of the cluster of the quarry sites is below 1, showing absence of carcinogenic risk from the heavy metal contaminants in the quarry dusts.

The heavy metal inhalational non-carcinogenic HQs in each of the cluster of the quarry sites is below 1, showing absence of non-carcinogenic risk from the heavy metal contaminants in the quarry dusts.

Table 3: Inhalational carcinogenic and non-carcinogenic estimated hazard quotient (HQ) of heavy metals from quarry dust

Variables	**HQ of Inhalational route**			
	Cluster A	**Cluster B**	**Cluster C**	**Cluster D**
Carcinogenic				
Lead	5.5501651E-10	6.9068722E-10	7.0302091E-10	6.9068722E-10
Nickel	2.47956716E-9	1.34478462E-9	1.65074248E-9	3.28421776E-9
Copper	-	-	-	-
Zinc	-	-	-	-
Cadmium	1.97663771E-7	6.05865982E-8	8.33065736E-9	1.06026547E-8
Non carcinogenic				
Lead	1.2950385E-9	1.6116035E-9	1.6403822E-9	1.6116035E-9
Nickel	5.7856564E-9	3.0983078E-9	3.8517324E-9	7.6631748E-8
Copper	1.6004118E-9	9.5577042E-10	7.0955322E-10	1.3250962E-9
Zinc	7.0421317E-10	4.6765280E-10	3.1109702E-10	9.2782317E-10
Cadmium	4.6121547E-7	1.4136873E-7	1.9438200E-8	2.4739528E-8

HQ- Hazard Quotient

Estimated hazard index (for non-carcinogenic analysis) and Incremental Lifetime Cancer Risk of heavy

Table 4 shows the inhalational non-carcinogenic hazard Index (HI) and incremental lifetime cancer risk (ILCR) of heavy metals from quarry dust. The inhalational HQ computed for each metal was summed and expressed as a Hazard Index (HI). The result however shows non-carcinogenic risk to health as each of the values of the HI is below 1.

The estimated inhalational ILCR for carcinogenic analysis for all the cancer prone heavy metals (lead, nickel and cadmium) in all the clusters were less than 10^{-5}which is an indication that there was no cancer risk from the heavy metal contaminants in the quarry dusts.

Table 4: Inhalational Non-carcinogenic Hazard Index and Incremental Lifetime Cancer Risk of heavy metals from quarry dust

Variables	Cluster A	Cluster B	Cluster C	Cluster D
		Inhalational HI		
Non-Carcinogenic	4.70600789E-7	1.47502064E-7	2.59509648E-8	1.05235798E-7
Carcinogenic		**Inhalational ILCR**		
Lead	2.9138367E-11	3.6261079E-11	3.6908598E-11	3.6261079E-11
Nickel	5.6410152E-11	3.0208501E-11	3.7554391E-11	7.4715954E-11
Copper	-	-	-	-
Zinc	-	-	-	-
Cadmium	4.2813973E-12	1.3123057E-12	1.8044203E-13	2.2965350E-13

HI - Hazard Index, ILCR- incremental lifetime cancer risk

DISCUSSION

Quarrying exposes workers to increased quantities of suspended dust particles. The quarry site in Umuoghara, Ebonyi state hosts about 250 quarry workers daily creating a beehive of activity in the four clusters of the quarry site.[10] In this study, the risks of heavy metal contamination in the quarry dusts of Umuoghara quarry sites were assessed to determine the non-carcinogenic and carcinogenic health risks caused by inhalation. This is crucial as health risk assessment is one of the most widely used screening tools in the field of health promotion and is often the first step in multi-component health promotion program. [16,17] The result revealed that quarry dust contains heavy metals - lead, zinc, cadmium, nickel, similar to findings of earlier studies. [14]

A wide variation in mean values of heavy metals were seen in the four clusters of the quarry site where the maximum metal concentration was for Zn with a mean of 3.224mg/L and the minimum metal concentration was for Pb with a mean concentration of 0.045 mg/L. The order of the heavy metals according to mean concentrations measured in the quarry dusts was Zn>Ni>Cu>Cd>Pb. Although there was higher concentration of zinc in the dust samples followed by nickel, copper, cadmium, and lead, the comparative analysis of the mean values in the four clusters of the quarry site showed no significant difference (*P>0.05*) in the heavy metal concentrations.

The estimated hazard quotients (HQ) and hazard index (HI) were below 1 for all the metals in the samples. The result indicated that the highest values of carcinogenic and non-carcinogenic HQ values were 1.97663771E-7 and 4.6121547E-7, both for cadmium. The least carcinogenic and non-carcinogenic HQ values were 5.5501651E-10 and 3.1109702E-10 for lead and Zinc respectively. The estimated Incremental Lifetime Cancer Risk (ILCR) for Carcinogenic analysis for all the cancer prone heavy metals in all the clusters was less than 10^{-5}. The human health risk assessment in the dust samples of the four clusters of the quarry site shows obvious absence of carcinogenic and non-carcinogenic health risk through the inhalational route as each of the values of the HQ and HI were below 1, and the estimated Incremental Lifetime Cancer Risk (ILCR) for Carcinogenic analysis for all the cancer prone heavy metals in all the clusters were less than 10^{-5}.These findings are consistent with earlier studies. [14,15]

A hazard quotient less than or equal to **1** indicates that adverse effects are not likely to occur, and thus can be considered to have negligible hazard. HQs greater than 1 may be said to be unsafe but this is a mere hypothetical statement which depends on whether the exposure concentration (EDI) exceeds the reference concentration (RfD).[14] The hazard index is a measure of the potential risk of adverse health effects from a mixture of chemical constituents in various quarry dust samples and non-carcinogenic impacts may be said to occur when HI > 1(Antoine et al, 2017). Incremental lifetime cancer risk is used to identify probable cancer risks due to exposure to a specified dose of heavy metal. Cancer risks will be considered highly negligible when the estimated ILCR is ≤ 10^{-5}; however, if the ILCR is greater than 10^{-5}, the risk assessment should either be repeated in a refined manner or risk management measures taken.[13]

The risk assessment in this study can be related to a study in Ogbere town, Ijebu-North Local Government Area of Ogun State which shows that the population of the biodiversity (flora and fauna) around the quarry community was greatly decreased by the negative impact of the quarry dust particles; aquatic and terrestrial animals are all at risk.[18,19] In Lagos, a report from a study pointed out that lead from most classrooms dusts was above the reference limit which revealed significantly high concentration of lead from classroom dusts.[20] Evaluation of some heavy metals in the dusts of three university motor parks in Western Nigeria (University of Ibadan, University of Ilorin and Kwara State University) showed the presence of Mn, Zn, Pb, Ni, Cu and Cd in different concentrations.[21] The above expositions are indications that the dusts in our environments may not be free from heavy metal.

Despite the safety level of the heavy metals noted in this study, there is the need to understand that heavy metal dusts can adversely affect human health at toxic level which depends on the degree of the dosage, duration, and dust type.[22] The effects of heavy metal dusts had been established to cause necrosis, interstitial fibrosis, and degenerative changes in the lungs when they bypass the natural respiratory self-defence.[23]The respiratory system has protective barriers and other mechanisms of self-defence; while the bigger particles are captured by nasal mucosa, the remaining particles are discarded by mucociliary mechanisms in the respiratory tract and also by macrophages in the alveolar parenchyma. [23] Dusts of only 1-5 µm diameter can reach the lung parenchyma but dust particles smaller than 1 mm are discarded by expiration.[23]

LIMITATION OF THE STUDY

The study was only carried out in a rural quarry industry in Ebonyi State; this may limit the extent to which the study can be generalised.

Research laboratories, where heavy metals are analyzed, are not as common as conventional medical laboratories. This makes the cost of heavy metal analyses to be on the high side.

CONCLUSION

This study has provided data on heavy metal content in the quarry dusts commonly seen in Umu-Oghara quarry site in Ebonyi state, Nigeria. The level of heavy metals in the studied dusts were used to estimate the risk posed by these heavy metal content in different clusters of the quarry site and has been established through the comparative assessment of the means of exposed concentration as well as the estimated hazard quotient, hazard index and incremental lifetime cancer risk that the quarry dust in Umu-Oghara quarry site currently pose no risk. However, universal precautions should be adhered since the risk is dose dependent.

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CONFLICTS OF INTEREST

There are no conflicts of interest

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APPENDIX

REFERENCE DOSES (RFD) FOR HEAVY METAL CONCENTRATION

Reference doses (RFD) (mg/kg/day) of heavy metals via ingestion, inhalation and dermal exposure routes used for the non-carcinogenic health risk assessment.

Table showing reference doses (rfd) for heavy metal concentration

Heavy metals	Pb	Cd	Cr	Ni	Cu	Fe	Zn
RFD Ingestion	3.5 E -3	1.0 E -3	1.5 E +0	2.0 E -2	4.0 E -2	7.0 E -1	3.0 E -1
RFD Dermal	5.3 E -4	1.0 E -3	3.0 E -3	2.0 E -2	4.0 E -2	7.0 E -1	3.0 E -1
RFD Inhalation	3.5 E -3	5.7 E -5	3.0 E -5	2.5 E -2	4.5 E -2	8.0 E -1	3.5 E -1

US EPA, 2001

B. INCREMENTAL LIFE TIME CANCER RISK (ILCR) =EDI×CSF

Table showing cancer slope factors for heavy metals (mg/kg per day)$^{-1}$

Lead	15.00
Nickel	0.91
Copper	--
Zinc	--
Cadmium	0.38

CHHRA, 2010

C. MEAN RANK

Table showing K-W mean rankings

	area	N	Mean Rank
Lead	Cluster A	3	5.00
	Cluster B	3	6.67
	Cluster C	3	6.33
	Cluster D	3	8.00
	Total	12	
Nickel	Cluster A	3	7.33
	Cluster B	3	3.67
	Cluster C	3	6.00
	Cluster D	3	9.00
	Total	12	
Copper	Cluster A	3	8.00
	Cluster B	3	8.67
	Cluster C	3	5.00
	Cluster D	3	4.33
	Total	12	
zinc	Cluster A	3	7.33
	Cluster B	3	7.00
	Cluster C	3	3.00
	Cluster D	3	8.67
	Total	12	
cadmium	Cluster A	3	10.33
	Cluster B	3	6.83
	Cluster C	3	5.00
	Cluster D	3	3.83
	Total	12	