UMYU Scientifica, Vol. 1 NO. 2, December 2022, Pp 115 – 122
https://doi.org/10.56919/usci.1222.015
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Assessment of Nickel and Arsenic poisoning and estimation of cancer risk from kaolin mining sites in Dutsin-man and Kankara, Katsina State

Aliyu Sani[1]*, Ahmed Rufai Usman[1] and Mustapha Sani[2]

[1]Department of Physics, Umaru Musa Yar'adua University, Katsina State, Nigeria
[2]Department of Physics, Al-Qalam University, Katsina State, Nigeria

ABSTRACT

The research was carried out to assess how poisonous are Nickel and Arsenic as heavy metals contaminated around Kankara and Dutsinma Kaolin mining sites. Nine (09) samples were collected randomly from the mining sites for the study. The analysis of such elements was done using Energy Dispersive X-ray Fluorescence {EDXRF} at Central Laboratory, Umaru Musa Yar'adua University, Katsina, and the health hazards were evaluated using numerous Statistical and USEPA models. The result obtained was used to calculate the risk assessment of Nickel and Arsenic in the body via inhalation, ingestion, and body contact. In which the most associated environmental and health risk of priority have their average concentrations as 20.02, 12.59, 54.03, 1344.4, 21.94, 140.00, and NA which is not identified element in the studied area. All results were below the USEPA threshold limit for non-carcinogenic risks of 1.0 indicating that the exposed population ages are unlikely to experience any adverse non-carcinogenic risks. The overall total excess lifetime cancer risk for heavy metals was 8.5555E-06 (a maximum of 9 people/1 million may be affected) for children and 7.5773E-05 (a maximum of 8 people /1 million may be affected) for adults. These values were within the USEPA threshold of 1E-04.

ARTICLE HISTORY

Received November 1, 2022
Accepted December 12, 2022
Published December 30, 2022

KEYWORDS

Annual Daily Intake (ADI); Exposure Assessment; Hazard Identification; Toxicity (Dose-Response) Assessment and Not Identified Element (NA).

INTRODUCTION

Human health is continuously affected by the sweeping distribution of heavy metals in our environment, emanating from natural sources or as a result of artificial human activities. These activities contaminate the surrounding air, drinking water, and the food we eat, and in turn affect overall human health. Although mining as a business is lucrative in nature, mining of mineral resources is a major source of exposure to toxic metals and a concern for radiation dose to the surrounding populace, especially to the immediate miners. In several countries, despite the availability of adequate protection policies on exposure to radiation and heavy metals, these policies are not strictly adhered to by miners, thus endangering their overall health status. Significant exposure to heavy metals is a threat to the well-being of miners, workers in the processing plants, and end users. Furthermore, bio-accumulation of heavy metals in the human system occurs through gradual exposure to heavy metals as a result of food consumption, drinking of water, and breathing air. While heavy metals are a natural part of the geologic formation of most mining sites, there are two main contributors to natural radiation exposure, namely; high-energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides originating from the earth's crust which are present everywhere in the environment, including the human body (UNSCEAR, 2000).

To protect miners and the immediate populace, several researchers have studied toxic metals as well as possible background radiations emanating from different mining sites around the world for assessment of potential health hazards of the mining sites for the enlightenment and policy making. For example, China considered the pollution of water and thus studied the effect of the release of heavy metals in typical mountain headwater regions in China (Wei *et al.*, 2018). Similarly, an investigation and health risk assessment of heavy metals in soils from partial areas of Daye city, china

Correspondence: Sani, A. Department of Physics, Umaru Musa Yar'adua University, Katsina State, Nigeria.
✉ aliyu.saniatiku@umyu.edu.ng
How to cite: Aliyu Sani Ahmed Rufai Usman and Mustapha Sani. (2022). Assessment of Nickel and Arsenic poisoning and estimation of cancer risk from kaolin mining sites in Dutsin-man and Kankara, Katsina State. UMYU Scientifica, 1(2), 115 – 122. https://doi.org/10.56919/usci.1222.015

(Xiao *et al*., 2017). A study also reported the findings on the risk assessment of heavy metal pollution in soils of Gejiu Tin Ore and other metal deposits of Yunnan Province, China (Yang *et al*., 2017). Other similar studies in same China are those reported by (Bifeng *et al*., 2017; Huang *et al*., 2017; Qing-Long *et al*., 2014; Qingjie and Jun 2008). A study was reported on human health risk assessment of heavy metal pollution in soils around the Kapan mining area (Gevorgyan *et al*., 2017). An Environmental impact assessment of uranium ore mining and radioactive waste around a storage center (Gaso *et al*., 2005). Similarly, heavy metals contamination in groundwater and soils of the Thane Region of Maharashtra, India (Bhagure and Mirgane 2010). In Nigeria, there are also a number of studies on heavy metals from mining sites. Such as health risk assessment of heavy metals in soil from the iron mines of Itakpe and Agbaja, Kogi State (Aluko *et al*., 2018). Additional information on studies of heavy metals reported in Nigeria is available in the literature (Bello *et al*., 20015; Usman *et al*., 2017; Ademola, 2005).

There is also very vast literature on the effect of heavy metals on the health of humans. Such analysis on the concentration of arsenic in the environment in relation to human health (Singh *et al*., 2007). Additional details can be found in a study that reported a rich review of kaolin and other relevant information (Yanguatin *et al*., 2017). Similarly, during the manufacture of colored substances which contain kaolin, such as eye shadow, a popular cosmetic used on eyelids by women, toxic metals such as nickel are retained in pigments. Some toxic elements and their compounds are water-soluble and moist skin can therefore promote the percutaneous absorption of elements occurring as impurities in pigments (Sainio *et al*., 2000). Although dermal absorption for heavy metals is fairly minimal, the poisonous ones could have an effect on the skin. Dermal exposure is the most possible route for cosmetic products to get to the body since the majority of cosmetics are applied topically. Oral exposure could occur for cosmetics used around the mouth, while inhalation exposure is typically considered to be negligible. Nickel is one of the commonest causes of allergic contact dermatitis, and there has been an observed increase in its allergy prevalence (Sainio *et al*., 2000). A small number of heavy metals, as low as 1 ppm of nickel, could generate a preexistent allergy. Therefore, cosmetic products have been recommended not to contain more than 5 ppm of heavy or poisonous metals as impurities (Sainio *et al*., 2000).

The aim of the present work is to assess the level of exposure to nickel and Arsenic metals from the activities of miners of kaolin mineral in some selected locations in Katsina State in order to estimate cancer and other hazard indices. The objectives of the research are to determine the toxicity level of the associated soil as well as the background radiation effect of the mining sites. To evaluate the level of potential exposures from mining sites as well as the health risk posed to the miners, and residents of communities around mining sites.

MATERIALS AND METHODS

Sampling, Study Area, And Depth

The selections of the sampling locations (mining areas) were based on accessibility as well as proximity to the public.

Method

The sampling strategy adopted for the sample collection was however random in line with (ASTM 1983, 1986; IAEA 2004 and USEPA 1989).

Figure 1: Sample collection in one of the mining sites

Nine (09) soil samples were collected from within the mining areas. The Nine Kaolin samples were collected from three different locations with three samples collected from each depth of 5, 15, and 25 meters in the mine wells. The specific sample locations as indicated in Table 1, are Sambisa-Danmarke and DajinGwamna-Yar'goje in Kankara Local Government Area and FararKasarBoto - Garhi/Haukan Zama in Dutsinma Local Government Area of Katsina State. All samples were labeled at the point of the collection while their coordinates are read and recorded respectively using Global Positioning System (GPS).

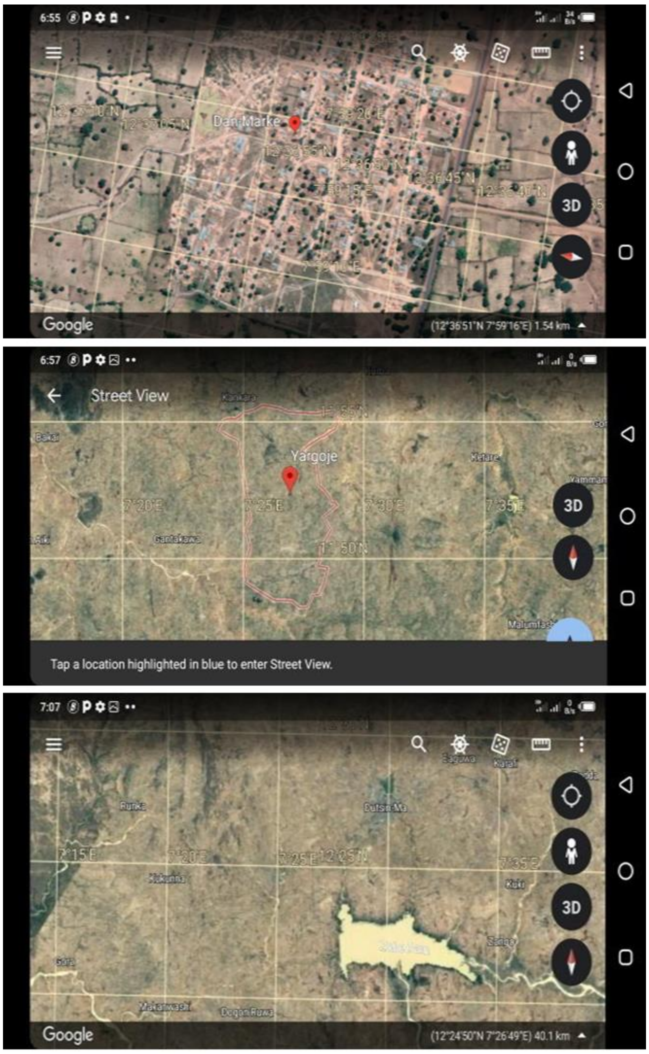

Figure 2: Global positioning system of three different locations of the study

The table also gives the detailed depth at which each sample was collected.

Table 1: Sample ID, collection point, and depth of mines

S/N	ID	Location	Depth (m)
1	Y01	Yar'goje village, Kankara L. G.	5
2	Y02	Yar'goje village, Kankara L. G.	15
3	Y03	Yar'goje village, Kankara L. G.	25
4	S01	Sambisa village, Kankara L. G.	5
5	S02	Sambisa village, Kankara L. G.	15
6	S03	Sambisa village, Kankara L. G.	25
7	G01	Garfi village, Dutsinma, L. G.	5
8	G02	Garfi village, Dutsinma, L. G.	15
9	G03	Garfi village, Dutsinma, L. G.	25

The nine samples were bagged and labeled for elemental analysis using EDXRF. Each sample was sealed in a polyethylene bag, firmly tied to avoid cross-contamination before labeling. Samples were carried to the Advanced Research Section, University Central Laboratory, Umaru Musa Yar'adua University Katsina for EDXRF analysis.

Similarly, the three (3) samples per location were collected by stratified random sampling with the first sample at a depth of 5 m from the surface, the second sample at a depth of 15 m, and lastly from a depth of 25 m considering the possibility of different weathering processes at different depth for minerals. Fig 1; shows the sample collection activities at the mining site.

An overview of the materials, equipment, and methods used for the research study is presented in table 2 below, with emphasis placed on the technically required ingredients and processes to achieve the different objectives set for the study.

MATERIALS

Table 2: the materials used for the different stages of the study and their function with respect to the different stages of the research effort.

Stage	Material	Details/ Function
Sample Collection from Mines	Hoe	Digging Kaolin Sample from the earth crust
	Global Positioning System (GPS)	Locating point and taking coordinate at the sampling location
	Shovel	Collection of dug samples
	Polythene bag	Packaging collected the sample at the collection point
	Plastic bucket	Packaging the whole sample at one point for easy movement
	Measuring Tape up-to 50ft (15m)	Measuring the depth of each sampling point
	Touch light	Providing illumination inside the dug mining well

Other non-technical materials of no significant scientific consequence used in the research include; PC laptop computer, printer and paper for word processing and production of hard copies of the study reports.

Sample Preparation and Analysis

EDXRF has been known to require minimal sample preparation processes. The process proceeded by grinding the samples into fine powder to a grain size of <75μm with the aid of a mortar and pestle as shown in table 3 below.

Table 3: Sample Preparation for the Analysis

Stage	Material	Details/ Function
Sample preparation for edxrf	Electronic balance/Digital Scale	Sample weighing for accurate measurement
	Crusher	Grinding of sample into smaller particles
	Mesh (2mm)	Measuring the sample to ensure right size

2g of homogeneous sample pellet of the mixed samples were weighed and then poured into a sample holder and covered with cotton wool to prevent it from spraying. The samples were then loaded into a 09-position sample changer for analysis.

The sample holder used for these studies features removable types that accommodate samples between 32 and 47 mm in size. The filters provided were 47 mm in diameter and therefore fit perfectly into the sample holder. The bottom of the sample holder is made of polypropylene.–For the quantitative analysis using the Standard Method however, the fundamental parameters have been adopted instead of the coefficient models so that the calibration will be varied over a whole range of elements of interest in both cases. However, the calibration determines the relation between the concentration of a compound and the intensity of an element.

METHOD

Present study employed EDXFR to determine the concentration of Nickel and Arsenic in sampled kaolin extracted from stated mining sites in Katsina.

Table 4: Method Employed of the Analysis

Stage	Material	Details/ Function
Elemental Analysis	Sample Holders	White Plastic container for holding a sample in preparation for analysis
	Polythene Holder Seal	A transparent polythene used for sealing a sample Holder for running the sample
	ARL QUANT'X Machine and Software	Spectrum acquisition machine and software used to read and display the spectrum from EDXRF on the Monitor
	EDXRF Machine	Quantitative and Qualitative elemental analysis of the material.
	Computer System	Host of the AARL QUANT'X software system set for display and acquisition of result

Equation 1 – 7 are employed to make calculations on annual daily intake, health quotation hazard index, and total risk assessment

$$ADI_{ing} = \frac{C \times IR_{ing} \times EF \times ED}{BW \times AT \times 10^6} \quad (1)$$

$$ADI_{inh} = \frac{C_s \times IR_{inh} \times EF \times ED}{BW \times AT \times PEF} \quad (2)$$

$$ADI_{derm} = \frac{C_s \times S_A \times FE \times AF \times ABS \times EF \times ED}{BW \times AT \times 10^6} \quad (3)$$

$$HQ = \frac{ADI}{RFD} \quad (4)$$

$$HI = \sum_{K=1}^{n} HQ_k = \sum_{K=1}^{n} \frac{ADI_K}{RFD_K} \quad (5)$$

$$Risk_{pathway} = \sum_{k=1}^{n} ADI_k CSF_k \quad (6)$$

$$Risk_{total} = Risk_{ing} + Risk_{inh} + Risk_{dermal} \quad (7)$$

RESULTS AND DISCUSSION

The results of the EDXRF spectroscopic measurements to determine the Nickel and Arsenic composition of the Kaolin samples from the different mining sites are presented in Table 5. The depth dependence of heavy metals is determined and discussed while further The results of the studied concentrations are presented in ppm for each element detected

Table 5: Elemental Composition of Mined Kaolin Samples

	Concentration (PPM)								
	YAR'GOJE			SAMBISA			GARFI		
ELE	**Y01**	**Y01**	**Y03**	**S01**	**S02**	**S03**	**G01**	**G02**	**G03**
Ni	24.70	15.20	18.70	18.80	11.60	12.34	44.10	33.60	55.10
As	3.00	NA	NA	NA	NA	NA	NA	NA	NA

Table 6: Statistical Analysis of the Elemental Composition of Mined Kaolin Sample

ELE	MIN	MAX	M	SD	SE
Ni	11.60	55.10	26.02	15.21	5.07
As	-	NA	NA	NA	NA

In Table 6; Statistical Analysis of the obtained data has been presented to include the Minimum (Min) and Maximum (Max) concentration of all elements in PPM. The Mean Concentration (M), the standard Deviation (SD), and the Standard Error (SE) have also been determined for each Element (ELE).

Table 7: Concentration and Statistical Analysis for Ni and As identified in Kaolin Sample

ELE	Concentration (PPM)						M_e+SD_e
Ni	**Y01**	24.70	S01	18.80	G01	44.10	29.20±10.81
	Y02	15.20	S01	11.60	G02	33.60	20.13±9.64
	Y03	18.70	S03	12.34	G03	55.10	28.71±18.84
M_d±SD_d	19.53±3.92		14.25±3.32		44.27±8.78		

Calculation of Health Hazard Indices

Estimation of the health and environmental risk assessment from heavy metal has been carried out including the determination of the effects of exposure to carcinogenic and non-carcinogenic chemicals. The assessments involved Hazard Identification, Exposure Assessment, Toxicity (Dose-Response) Assessment, and Risk Characterization. The indices considered include Ingestion of chosen Heavy Metals through Soil (ADI_{ING}), Inhalation of chosen Heavy Metals via Soil Particulates (ADI_{INH}), Dermal Contact with Soil (ADI_{DERM}) for children and adults and for the different heavy metals of interest using equation 1 - 3. The Non-Carcinogenic Hazards Assessment characterized with Hazard Quotient (HQ) was then determined using equation 4 for these categories of indices. Carcinogenic Risks Assessment characterized by the Excess Lifetime Cancer Risk (ADI_K) Was also determined using equations 5, 6, and 7. The equations for this analysis have been implemented for the study in Microsoft Office Excel.

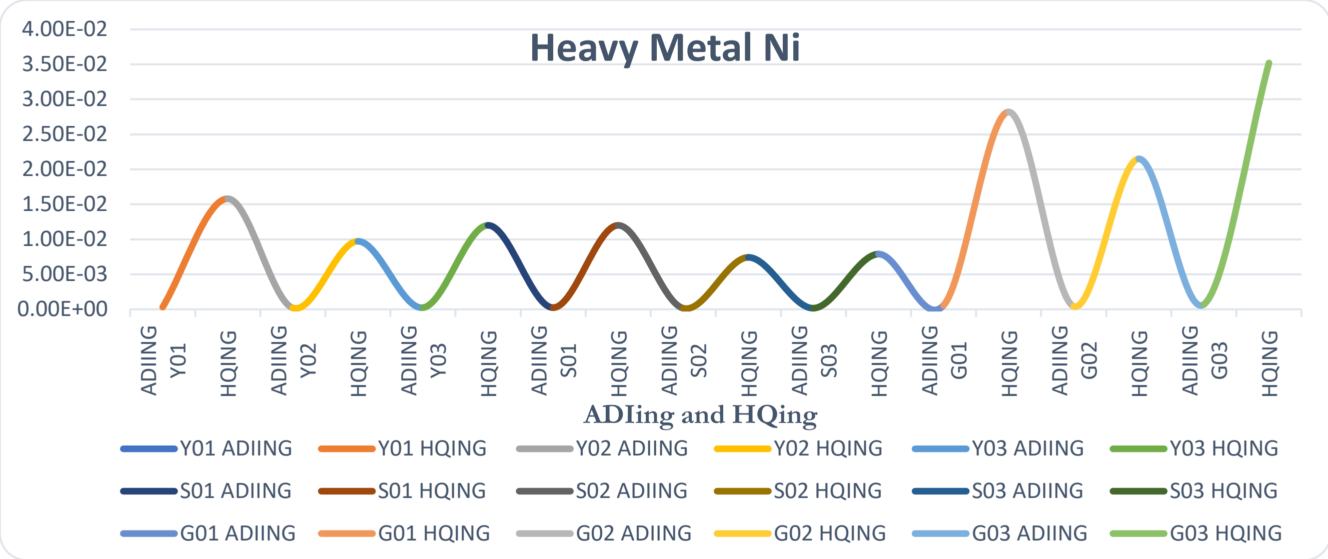

Figure 3 (a): Indices of Ingestion of Heavy Metal through Soil with their Health Quotients for children

Table 8 (a) and (b) to 10 (a) and (b) presents the Indices of Ingestion of Heavy Metal through Soil (ADI_{ING}), of Inhalation of Heavy Metals via Soil Particulate (ADI_{INH}), and of Dermal Contact with Soil (ADI_{DERM}) and their corresponding Non-Carcinogenic Hazard Quotient (HQ_{ING}, HQ_{INH}, and HQ_{DERM}) in children and in adults for Ni which is considered as Non-Carcinogen Heavy Metal. The values of ADI_{ING}, ADI_{INH}, ADI_{DERM}, and HQs were determined respectively using equations 1, 2, 3, 4, 5, 6, and 7 as implemented using Microsoft Office Excel

Table 8: Calculated Result of Indices of Nickel Ingestion (ADI_{ING}) through Soil and Corresponding Hazard Quotient (HQ_{ING}) as a Result of Non-Carcinogenic Nickel

Sample ID	Hazard Quotient	Heavy Metal (Ni)
Y01	**ADI_{ING}**	3.16E-04
	HQ_{ING}	1.58E-02
Y02	**ADI_{ING}**	1.94E-04
	HQ_{ING}	9.72E-03
Y03	**ADI_{ING}**	2.39E-04
	HQ_{ING}	1.20E-02
S01	**ADI_{ING}**	2.40E-04
	HQ_{ING}	1.20E-02
S02	**ADI_{ING}**	1.48E-04
	HQ_{ING}	7.42E-03
S03	**ADI_{ING}**	1.58E-04
	HQ_{ING}	7.89E-03
G01	**ADI_{ING}**	5.64E-04
	HQ_{ING}	2.82E-02
G02	**ADI_{ING}**	4.30E-04
	HQ_{ING}	2.15E-02
G03	**ADI_{ING}**	7.04E-04
	HQ_{ING}	3.52E-02

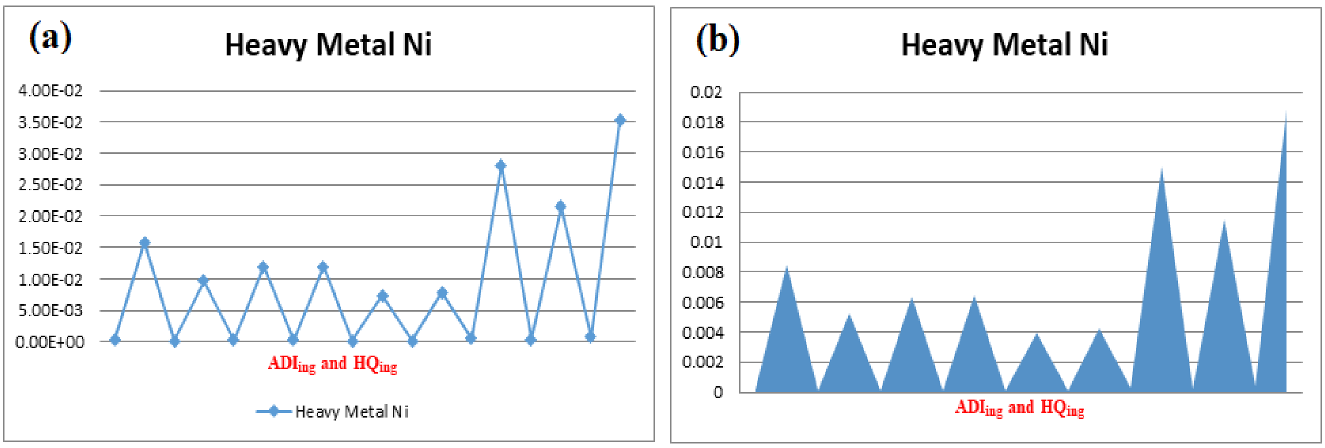

Figure 3: Indices of Ingestion of Heavy Metal through Soil with their Health quotients for (a) children and (b) Adult

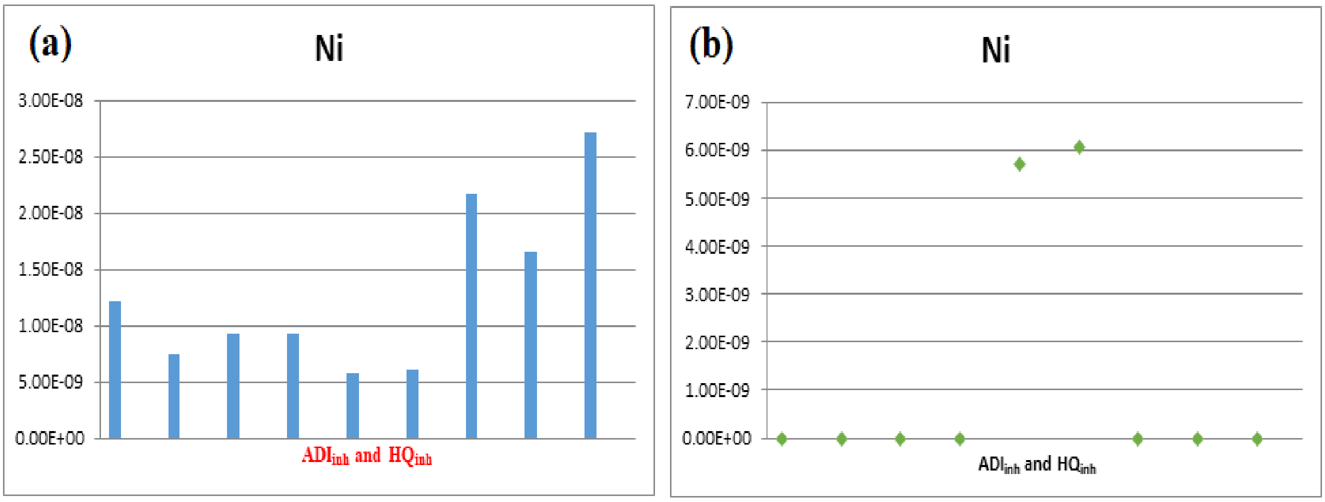

Figure 4: Inhalation of Heavy Metals via Soil Particulate with their Health quotients for (a) children and (b) adults

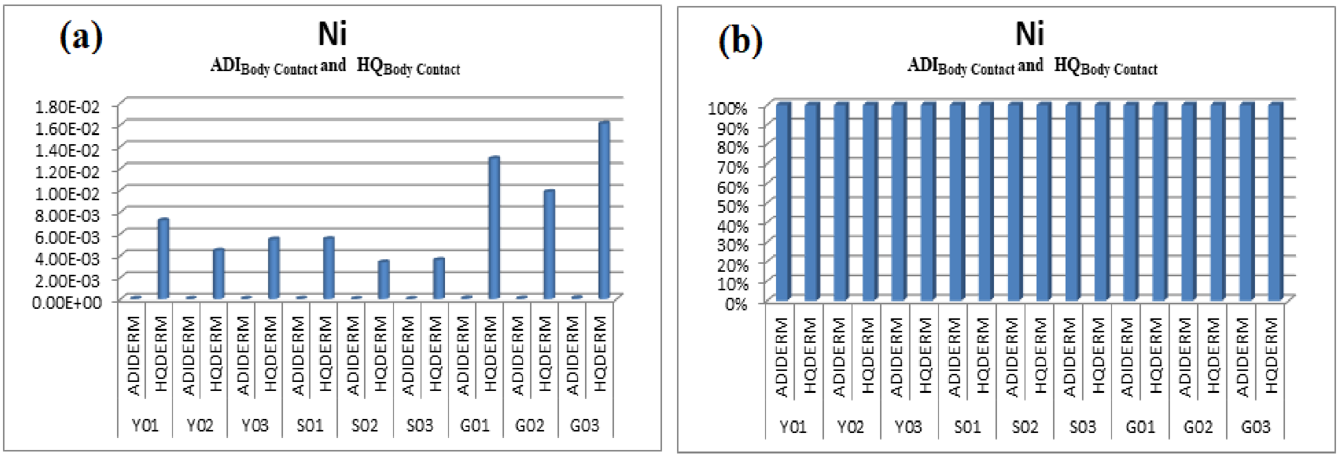

Figure 5: Dermal Contact with Soil with their Health quotient for (a) Children (b) Adult

Furthermore, consideration has been made to determine the carcinogenic impact of the As metal concentration from the different samples for both children and adults. Those elements As, Cd, Cr, and Pb have been classified as Group 1 carcinogens by the International Agency for Research on Cancer (Hyun *et al*., 2015). However, the calculated carcinogenic risk value obtained for As in this study is very low and hence, was not reported due to the absence of element values which leads to a record of Arsenic as NA which is not identified.

CONCLUSION

We have determined the concentration of Nickel and Arsenic from some mining sites of kaolin in some selected locations in Katsina and Dutsin-ma. The obtained data were used to calculate the no-carcinogenic risk of Ni to our body via inhalation, ingestion, and dermal contact. The overall calculated results show that the effect of these heavy metals is within the acceptable limit. On the other hand, the carcinogenic risk of As was also analyzed and the calculated result shows a very low level, and contributes insignificantly and hence was not reported. Present calculated risks can serve as important data for policymakers as there are no adequate studies in the chosen area.

ACKNOWLEDGMENT

The authors wish to thank the management of Umaru Musa Yar-adua University, Katsina-Nigeria, and the Director, Central Research Laboratory-UMYUK for their support and cooperation.

REFERENCES

Ademola J.A. (2005) *Radionuclide content of concrete building blocks and radiation dose rates in some dwellings in Ibadan, Nigeria, (J. Environ. Radioact.*81, 107-113). **[Crossref]**

Ali H. and Khan E. (2017) *What are heavy metals? Long-standing controversy over the scientific use of the term 'heavy metals'—proposal of a comprehensive definition,* (Toxicological & Environmental Chemistry, pp. 1–25). **[Crossref]**

Aluko, T.S., Njoku, K.L., Adesuyi, A.A. and Akinola, M.O (2018). *Health Risk Assessment of Heavy Metals in Soil from the Iron Mines of Itakpe and Agbaja, Kogi State, Nigeria*. (*Pollution*, 4(3): 527-538). **[Crossref]**.

Bello, S. Zakari, Y.I. Ibeanu, I.G.E and Muhammad, B.G (2015). *Evaluation of heavy metal pollution in soils of Dana steel limited dumpsite, Katsina state Nigeria using pollution load and degree of contamination indices*. (American journal of engineering research). 4(12):161-169.

Bhagure, G. R. and Mirgane, S. R. (2010). *Heavy metals Contamination in groundwater and soils of Thane Region of Maharashtra, India*. (Environmental Monitoring and Assessment 1(4): 1-10). **[Crossref]**

Bifeng, H., Xiaolin, J., Jie, H., Dongyun, X., Fang, X and Yan, L. (2017). *Assessment of Heavy Metal Pollution and Health Risks in the Soil-Plant-Human System in the Yangtze River Delta, China*. (International Journal of Environmental Research and Public Health. 14:1042). **[Crossref]** https://doi.org/10.3390/ijerph14091042; Sep. 2017.

Cember, H., and Johnson, T. E., (2009). *Introduction to Health Physics* 4th Ed. (The McGraw-Hill Companies New York, USA).

Cember. H (2009). *Introduction to Health Physics. Fourth edition*. (Mc Graw Hill. Health Professional. Davis).

Gaso, M.I., Segovia, N., Morton, O. (2005). *Environmental impact assessment of uranium ore mining and radioactive waste around a storage centre from Mexico*. (Radioprotection, Suppl. 1, Vol. 40: S739-S745). **[Crossref]**

Gevorgyan, G. A., Ghazaryan, K. A., Movsesyan, H.S., Zhamharyan, H.G (2017). *Human health risk assessment of heavy metal pollution in soils around Kapan mining area, Armenia*. (Electronic journal of natural sciences. 2(29): 29-33). **[Crossref]** .

Huang, S. H., Li, Q., Yang, Y., Yuan, Y., Ouyang, K and You, P (2017). *Risk Assessment of Heavy Metals in Soils of a Lead-Zinc Mining Area in Hunan Province China*. (Kemija u Industriji. 66 (3-4): 173−178) **[Crossref]**.

Paul, B. T., Clement, G. Y., Anita, K. P., and Dwayne, J. S. (2014). *Heavy Metals Toxicity and the Environment, NIH-RCMI Center for Environmental Health, College of Science, Engineering, and Technology*, (pp 1-30). **[Crossref]**

Morgan, J. W. & Anders, E. (1980). *Chemical composition of Earth, Venus, and Mercury*. (Proc. Natl. Acad. Sci. 77 (12): 6973–77. Bibcode:1980PNAS...77.6973M). **[Crossref]**

Pourret, O. (2018). *On the Necessity of Banning the Term Heavy Metal from the Scientific Literature*. (Sustainability. 10 (8): 2879). **[Crossref]** .

Qingjie, G. and Jun, D. (2008). *Calculating pollution indices by heavy metals in ecological geochemistry assessment; a case study in parks of Beijing*. (Journal of China the University of Geosciences. 19(3): 23–41). **[Crossref]**

Qing-Long. F., Lanhai, L., Varenyam, A., An-Ying, J., Yonglin, L. (2014). *Concentrations of Heavy Metals and Arsenic in Market Rice Grain and Their Potential Health Risks to the Population of Fuzhou, China*. (Human and Ecological Risk Assessment: An International Journal, 21 (1): 117-128). **[Crossref]**

Sainio, E. L., Jolanki, R., Hakala, E., Kanerva, L. (2000). *Metals and arsenic in eye shadows*. (Contact Dermatitis 42(1):5-10). **[Crossref]**

Wei, W., Ma, R. M., Sun Z., Zhou, A., Bu, J., Long, X. and Liu, Y. (2018) *Effects of Mining Activities on the Release of Heavy Metals (HMs) in a Typical Mountain Headwater*. (International Journal of Environmental Research and Public Health, Vol 15:1987 pp 1-9). **[Crossref]**

Xiao, M.S., Li, F., Zhang, J.D., Lin, S.Y., Zhuang, Z.Y. and Wu, Z.X. (2017). *Investigation and health risk assessment of heavy metals in soils from partial areas of Daye city, china*. (IOP Conference Series: Earth and Environmental Science. 64 (012066)): 1-7, Sci. **64** 012066; Apil 2017.

Yang, S., Tomas, D., Xianfeng, C., Qianrui, H. (2017). *Risk Assessment of Heavy Metal Pollution in Soils of Gejiu Tin Ore and Other Metal Deposits of Yunnan Province*. (IOP Conference Series. Earth and Environmental Science). **[Crossref]**

Yanguatin, H., Tobon, J., Ramirez, J. (2017). *Pozzolanic reactivity of kaolin clays, a review, RevistaIngeniería de Construcción*, (Vol 32 No 2, pp 13-24); August 2017.